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Stella Boess, Ming Cheung y Rebecca Cain.

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Ming Cheung
Rebecca Cain

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Editors

Stella Boess, Ming Cheung, Rebecca Cain

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Table of Contents

President's Foreword	xxiv
Rachel COOPER	
DRS2020 Editorial: Synergy	xxvi
Stella BOESS, Ming CHEUNG, Rebecca CAIN	

Volume 1: Situations

Editorial: Theme Situations	1
Stella BOESS, Rebecca CAIN	
SECTION: LANGUAGE AND VALUES	
148. Design Languages in the Design Space: Silicon Valley	4
Tarja PÄÄKKÖNEN, Melanie SARANTOU, Satu MIETTINEN	
177. Mutuality and reciprocity: foregrounding relationships in Design and Social Innovation.	23
Viola PETRELLA, Joyce YEE, Rachel E CLARKE	
374. A framework for designing for divergent values.	39
Marina BOS-DE VOS	
SECTION: LOCALITIES AND DATA	
183. Design considerations for the transformative reuse of a Japanese temple.	54
Guy KEULEMANS, Josh HARLE, Kyoko HASHIMOTO, Liam MUGAVIN	
218. What's it like to be Alexa? An exploration of Artificial Intelligence as a Material for Design.	73
Franziska Louise PILLING, Paul COULTON	
293. Edge of Tomorrow: Designing Sustainable Edge Computing	88
Michael STEAD, Adrian GRADINAR, Paul COULTON, Joseph LINDLEY	
SECTION: RESEARCH THROUGH DESIGN	
108. 3D Printing Craft: weaving and oozing	111
Rina BERNABEL, Jacqueline POWER	
220. "Where is your other half?": A Wedding shaped by the Profile, Politics and Potential of the Indo-China Border	125
Karthikeya Satish ACHARYA, Yiyi WU	
362. Grappling with Diversity in Research Through Design	139
Boudewijn BOON, Ehsan BAHA, Abhigyan SINGH, Frithjof E. WEGENER, Marco C. ROZENDAAL, Pieter Jan STAPPERS	

SECTION: DESIGN FOR BELONGING

278. Building a Sense of Identity Belonging and Culture Through Place-Making and Creative Co-Design: Practices within New Zealand’s Educational Context 152
 Rumen RACHEV, Yvonne CHAN, Talia PUA

318. Design Meets Death: Emergent Issues in a Research Study on Reimagining ‘Legacy’ in the Context of Paediatric Palliative Care 169
 Farnaz NICKPOUR, Lynda BROOK, Ming LIM, Scott GAULE

324. Understanding Dynamics of Identity Navigation in Social Design 186
 Eva KNUTZ, Thomas MARKUSSEN, Valentijn VISCH, Ed TAN

SECTION: EXPERIENTIAL KNOWLEDGE

187. Thinking while drawing and drawing to think: Exploring the critical reflective practice of ‘reflective doodling’. 204
 Niki WALLACE

258. The space between us: how designers and the general population see typographic emphasis. 223
 Claire Louise TIMPANY

350. Toward Deeper Understandings of the Cognitive Role of Visual Metaphors in Emerging Media Art Practices 240
 Kyungho LEE

HIGHLIGHTS: PLURIVERSAL DESIGN SIG

Editorial 257
 Renata M. LEITÃO, Lesley-Ann NOEL

161. The context and experience of mobility among urban marginalized women in New Delhi, India 259
 Kritiy GERA, Peter HASDELL

165. Putting the trans* into design for transition: reflections on gender, technology and natureculture 275
 Sarah Elsie BAKER

228. Whiteness in design practice: the need to prioritize process over artefact. 288
 Meghan KELLY

277. Anti-Oppression Mindsets for Collaborative Design 299
 Hillary CAREY

387. Coffee Farms as Design Labs: Manifesting Equity x Design Principles in Practice. 310
 Pedro REYNOLDS-CUÉLLAR, Rubez CHONG LU MING

HIGHLIGHTS: INCLUSIVE DESIGN SIG

Editorial 329
Hua DONG

275. 50 Years of Inclusive Design for Childhood Mobility; Insights from an Illustrative Mapping Review 332
Cara O’SULLIVAN, Farnaz NICKPOUR

239. Designing an Integrated Public Transportation System for the Accessible Needs of Long-Term Care in Taiwan Using Service Design 358
Jing-Ting YU, Chih-Yun LI, Yi-Jie LI, Yi-Sin YANG, Hsien-Hui TANG, Shu-Yi CHEN

268. Inclusive Design Museums and Social Design 376
Qi WEN, Sandy NG

133. The role of participatory design activities in supporting sense-making in the smart city 389
Julieta MATOS-CASTAÑO, Anouk GEENEN, Mascha VAN DER VOORT

340. To empathize or perceive? Towards a ‘perceptive design’ approach. 406
Prithi YADAV

325. Fixperts: models, learning and social contexts 423
Paul MICKLETHWAITE, Daniel CHARNY, Maya ALVARADO, Julia CASSIM, Yumei DONG, Ian DE VERE

Volume 2: Impacts

Editorial: Theme Impact	445
Rebecca CAIN, Stella BOESS	
SECTION: REACHING IN	
198. Monsters in the borderlands: Designer-academics in action	447
Philip ELY, Qassim SAAD, Dianne SMITH	
313. Catcall: Card Game to Trigger Conversations about Sexism and Gender Stereotypes	463
Tania Ananta HIDAYAT, Keiko OKAWA	
178. Incorporating behavioral theory in design ideation for changing sustainability behaviors	479
Aysha ALWAZZAN, G. Mauricio MEJÍA, Yumeng XIE, Daniel FISCHER	
SECTION: GRAPHICS AND PEOPLE	
135. Processes that cause invisibility for women in Australian graphic design	494
Jane CONNORY	
192. Enhancing Interactivity: How has design exploration of physically and intellectually interactive picturebooks enhanced shared reading?	513
Nicholas VANDERSCHANTZ, Claire TIMPANY, Kristy WRIGHT	
365. Navigating contemporary complexities in the design of sexuality education materials	535
Louise Moana KOLFF	
SECTION: TRANSLATIONS	
167. Process matters: from car owner experiences to automotive design proposals	554
Jiayu WU, Dale HARROW, Katrine HESSELD AHL, Samuel JOHNSON, Sheila CLARK, Daniel QUINLAN	
363. Instructional Design for Non-specialist Beginners to Learn Chinese Semantic Radicals	572
Tian TIAN, Maria dos Santos LONSDALE, Vien CHEUNG	
372. Graphic design studies: what can it be? Following in Victor Margolin's footsteps for possible answers	586
Robert George HARLAND	
SECTION: TECHNOLOGY FOR WELLBEING	
208. The Social Aspects of Companion Robots	601
Parisa MORADI, Ricardo SOSA, Amabel HUNTING	
266. Supporting people with dementia - Understanding their interactions with Mixed Reality Technologies	615
Shital DESAI, Alethea BLACKLER, Deborah FELS, Arlene ASTELL	
351. A Health Care Platform Design: Applying Novel Machine Learning Methods to Predict Chronic Cardiac Disease	638
Chien-Hsiang CHANG, You-Hsun WU, Chih-Chun YANG, Meng-Ting WU, Ting-Yi WU, Yi-Fan LIU, Chien-Hsu CHEN, Yang-Cheng LIN	

HIGHLIGHTS: OBJECTS, PRACTICES, EXPERIENCES, AND NETWORKS SIG	
Editorial	652
Tom FISHER	
222. Identifying and addressing unintended values when designing (with) Artificial Intelligence	654
Niya STOIMENOVA, Maaïke KLEINSMANN	
271. Design prototyping for policymaking	667
Diana Pamela VILLA ALVAREZ, Valentina AURICCHIO, Marzia MORTATI	
265. Social Media Research and the Impact of Graphic Design: a case study examining an Indonesian political campaign	686
Fanny SUHENDRA, Nicole WRAGG, Carolyn BARNES	
 HIGHLIGHTS: SUSTAINABILITY SIG	
Editorial	710
Emma DEWBERRY	
116. Setting the Stage for Responsible Design	713
Wouter EGGINK, Deger OZKARAMANLI, Cristina ZAGA, Nicola LIBERATI	
402. Multispecies Cohabitation and Future Design	731
Stanislav ROUDAVSKI	
186. The HfG Ulm and Sustainable Design: a comparative analysis	751
Carolina SHORT, Tomas GARCIA FERRARI	
285. Over the Rainbow: Sharing a cross-disciplinary philosophy of waste through spectrum visualisation	768
Manuela TABOADA, Alice PAYNE	
307. Designerly Living Labs: Early-stage exploration of future sustainable concepts	787
Martin SJÖMAN, Mia HESSELGREN	
401. When behaviour change is about hot air: home systems should change behaviour to fit practices	803
Elise WABEKE, Stella BOESS, Froukje SLEESWIJK-VISSER, Sacha SILVESTER	
 HIGHLIGHTS: DESIGN INNOVATION MANAGEMENT SIG	
Editorial	822
Erik BOHEMIA, Blair KUYS	
185. Expanding industrial design's contribution to manufacturing SME's in Hong Kong by introducing a Balanced Scorecard for industrial design management	824
Sonny Yip Hong CHOY, Blair KUYS, Gianni RENDA	
251. Product standards as a barrier to innovation: the case of jockey's safety vests	838
Lisa GIUSTI GESTRI, Carolyn BARNES	
286. Research on the value of CMF design in industrial products	853
Ying LIU	
204. The inherent value of design research for industry: An impact case study using low-cost 3D printing for high-value commercial products	866
Blair KUYS, Mark STRACHAN	
272. A pilot study used to better construct a research direction to understand where industrial design fits within the 4th industrial revolution (Industry 4.0)	887
Christoph KOCH, Blair KUYS, Gianni RENDA	
358. Sharpening Critical Thinking in Problem Identification in Design and Technology Education	899
Wei Leong LOH	

Volume 3: Co-creation

Editorial: Theme Co-creation	926
Rebecca CAIN, Stella BOESS	
SECTION: PARTICIPATION	
246. The Politics of Materiality: Exploring Participatory Design Methods, Tools & Practices	929
Awais Hameed KHAN, Stephen SNOW, Scott HEINER, Robert HARDGROVE, Sarah MATTHEWS, Ben MATTHEWS	
296. Preserving Sequential Context: Developing Participatory Video Analysis Practice	947
Sarah MATTHEWS, Awais Hameed KHAN, Marie BODEN, Stephen VILLER	
302. Invisible Impact: Revaluating data in design research	963
Leigh-Anne HEPBURN	
SECTION: EMPOWERMENT	
231. Healthcare design sprints: what can be changed and achieved in five days?	975
Mira ALHONSUO, Samantha HOOKWAY, Melanie SARANTOU, Satu MIETTINEN, Maarja MOTUS	
247. Co-designing tools to empower further, independent co-design: collaborating with diverse individuals with lived experience of food poverty	992
Gemma COUPE, Whitham ROGER, Cruickshank LEON, Perez DAVID, Pearson BEN	
367. Under construction: Reimagining health and safety communication for multilingual workers in Qatar	1009
Denielle Janine EMANS	
SECTION: TEAM WORK	
378. Critical and Collaborative Making with augmented technical tools	1025
Catherine NORMOYLE, Rebecca TEGTMEYER	
330. Behaviours in design collaborations: Insights from a team learning perspective	1045
Linus TAN	
398. Designing Six Dimensions of Intercultural Teamwork: A next-gen challenge in co-creation processes	1062
Kelly MURDOCH-KITT	
SECTION: DESIGNERS AND SCIENTISTS	
126. Treasure Hunting: an exploratory study of how designers and scientists identify potential collaborative projects	1082
Nolwenn MAUDET, Sion ASADA, Miles PENNINGTON	
154. The Role of Narrative Thinking in Design: Taking the Mathematical Hall of the London Science Museum as an Example	1097
He XIUCHUAN	
182. Design and Science: A workshop-based approach for identifying commercial opportunities in universities	1116
David MESA, Christine THONG, Charles RANSCOMBE, Blair KUYS	

SECTION: SOCIAL AND SERVICE DESIGN

- 173. Optimizing the Adoption Process in Public Animal Shelters through Service Design Thinking** 1132
Danyang WANG, Chin-Wei CHEN, Yen-Ya YOU, Shin-Chih TSAI, Shih-Min HONG, Shu-Yi CHEN, Hsien-Hui TANG
- 259. Auckland Plan 2050: A narrative experience of a Social Design project in Aotearoa New Zealand** 1150
Tatiana TAVARES, Marcos MORTENSEN STEAGALL
- 273. Synergy through Making: Co-designing with Educational Stakeholders in Northeastern Nigeria** 1168
Gretchen Caldwell RINNERT, Kathleen CAMPANA, Marianne MARTENS,
Davison MUPINGA, Joanne CANIGLIA, Grace MALGWI, Tsukuru KAMIYAMA, Allyson FILIPPI

SECTION: MOBILITY AND PUBLIC SPACE

- 308. Collecting People’s Preferences in Immersive Virtual Reality: A Case Study on Public Spaces in Singapore, Germany, and France** 1185
Sebastian STADLER, Henriette CORNET, Fritz FRENKLER
- 364. SEAMLESS JOURNEYS TO WORK: A multifaceted approach to exploring daily journey to work experiences of young people with disabilities** 1201
Marianella CHAMORRO-KOC, Amanda BEATSON, Carla SARTORI DO AMARAL,
Sven TUZOVIC, Stafford LISA, Marston GREGORY
- 396. An exploration on influencing factors for personalized music selection in recreational fitness running activities** 1216
Jiawei HUANG, Ding Bang LUH, Chi Hua WU

HIGHLIGHTS: WELLBEING, HAPPINESS AND HEALTH SIG

- Editorial** 1229
Ann PETERMANS, Rebecca CAIN, Pieter DESMET, Leandro TONETTO,
Deger OZKARAMANLI, Marc HASSENZAHL, Tiuu POLDMA, Anna E. POHLMEYER, Matthias LASCHKE
- 287. Tuning into the Sound: Discovering Motivational Enablers for Self-Therapy Design** 1232
Eujeen HWANG, Youn-kyung LIM
- 152. When theory meets users in co-design: four strategies towards synergy between bottom-up and top-down input** 1246
Judith AUSTIN, Jelle VAN DIJK, Constance DROSSAERT
- 281. Designing for Helpers: Identifying new design opportunities for digital volunteerism** 1262
Khushnood Z. NAQSHBANDI, Naseem AHMADPOUR, Ajit PILLAI, Silas TAYLOR
- 117. Artful Design for Positive Design: A Case Study in VR** 1278
Jack ATHERTON
- 274. Integral Living Research: Synergies in Research, Advocacy, and Healthy Living** 1297
Diana S. NICHOLAS, Yvonne MICHAEL, Shivanthi ANANDAN
- 282. Human-centered AI: Different Human-Centered Design practices in the design and research of ethical AI** 1315
Jan AUERNHAMMER

HIGHLIGHTS: GLOBAL HEALTH SIG

Editorial	1334
Emmanuel TSEKLEVES	

145. Challenges and Opportunities in Conducting and Applying Design Research beyond Global North to the Global South	1336
Emmanuel TSEKLEVES, Andy DARBY, Collins AHORLU, Roger PICKUP, Dziejdom DE SOUZA, Daniel BOAKYE	

118. The sum is the realisation of the parts: interdisciplinary perspectives on care	1354
Laurene VAUGHAN, Sarah PINK, Melisa DUQUE, Shanti SUMARTOJO	

127. A holistic outcome-based approach to co-create healthcare systems.	1366
Irma Cecilia LANDA-AVILA, Carolina ESCOBAR-TELLO, Gyuchan Thomas JUN, Rebecca CAIN	

142. Photo Narrative: Co-Designing a Built Environment with Seniors with Mild Cognitive Impairments	1392
Leila AFLATOONY, Leandro Miletto TONETTO, Gabrielle Conrad CAMPIGLIA, Jennifer R. DUBOSE	

292. Understanding interactivity for the needs of the elderly's strength training at nursing home in Indonesia.	1408
Elizabeth WIAN TO, Chien-Hsu CHEN, Irma Ruslina DEFI, Erwani Merry SARTIKA, Aan Darmawan HANGKAWIDJAJA, Yang-Cheng LIN	

370. Designing Novel and Engaging Interactions with and for Residents Living with Dementia and their Visitors	1426
Andrew MURPHY, Stu FAVILLA, Sonja PEDELL, Jeanie BEH, Tanya PETROVICH	

HIGHLIGHTS: BEHAVIOUR CHANGE SIG

Editorial	1440
Kristina NIEDDERER	

252. Strange bedfellows: Design research and behavioral design	1443
Ruth SCHMIDT	

129. Designing Cross-Disciplinary Relationships for Improving Safety	1458
Laura Filippa FERRARELLO, Ashley HALL, Paul ANDERSON, Rachel COOPER, Chris ROSS	

329. A Diary Study on the Exercise Intention-Behaviour Gap: Implications for the Design of Interactive Products	1474
Daphne MENHEERE, Mathias FUNK, Erik VAN DER SPEK, Carine LALLEMAND, Steven VOS	

262. Meeting Afoot – A Step Towards Transforming Work Practice By Design Of Technical Support	1492
Helena TOBIASSON, Fredrik NILBRINK, Jan GULLIKSEN, Pernilla ERIKSSON	

Volume 4: Education

Editorial: Theme Education	1508
Rebecca CAIN, Stella BOESS	

SECTION: DESIGN THINKING

334. Teaching Design Strategy for Social Impact: A Synergistic Pedagogical Framework	1512
Brooke BRANDEWIE, Neha MANN, Claudia REBOLA	

166. Designing by frontline tobacco-prevention practitioners: How can Design Thinking workshop affect the development of public health strategies?	1531
Eric Chen-F HSIEH, Min-yuan MA, Fu-Yu LIN	

294. Designing game-inspired narratives for learning	1551
Miranda VERSWIJVELEN, Ricardo SOSA, Nataly MARTINI	

SECTION: DESIGN TECHNIQUES

280. Reframing in Design: When and how do teams frame and reframe in design projects	1563
Jan AUERNHAMMER, Max LENZEN, Larry LEIFER	

109. Nominal Groups? Ok Boomer! A future-oriented agenda for brainstorming studies	1583
Ricardo SOSA	

256. New Design Heuristics Compared with Existing Ones	1597
Xiaoneng JIN, Hua DONG, Mark EVANS	

SECTION: DESIGN INSPIRATION

203. Leveraging Empathic Strategies: Prototyping for Commercial Space Vehicle Design	1611
Justin LUND, Jason O'Neill GERMANY	

284. Designing in virtual environments: The integration of virtual reality tools into industrial design research and education	1628
Sarah ROBERTS, Rowan PAGE, Mark RICHARDSON	

298. Optimizing sources of inspiration for innovation: a case study in concept generation process	1644
Jeff FENG	

SECTION: RESEARCHING THE MATERIAL

229. Studying Material Interactions to Facilitate a Sense of Being with the World	1659
Bilge Merve AKTAS, Camilla GROTH	

335. Unfolding passion: Autoethnography on the emergence and impact of teacher's passion in the design studio ...	1677
Miikka J. LEHTONEN, Gionata GATTO	

337. Philosophy at work: Postphenomenology as a generative lens in design research and practice	1691
Sander VAN DER ZWAN, Maarten SMITH, Jelle BRUINEBERG, Pierre LÉVY, Caroline HUMMELS	

SECTION: ETHICS AND HEALTH

107. Co-Evolving Towards Evil Design Outcomes: Mapping Problem and Solution Process Moves	1707
Shruthi Sai CHIVUKULA, Colin M. GRAY	

110. Attuning Contraception Choice and Patient Values	1727
Michael ARNOLD MAGES, Janice LIN, Anni XU	

376. Improving access to psychotherapy in a digital age: an exploratory design study based on five studio classes. ...	1743
Stéphane VIAL, Sana BOUDHRAË	

SECTION: COMMUNITY AND COMMUNICATION

276. Enhancing the Student Learning Experience through Engagement with Community: A Transdisciplinary and Collaborative Approach to WIL	1767
Petra PEROLINI, Naomi HAY	
291. Transforming a Public School: A Case Study of Tongji-Huangpu School of Design and Innovation and Its Search for Synergy	1788
Yubei GONG, Yongqi LOU	
317. The Graduate Professional Portfolio as “synergy tool”: navigating the complex role of portfolios in future-focused design education	1803
Deanna METH, Melanie FINGER, Dean BROUGH	

SECTION: TRANSDISCIPLINARITY

143. Exploring transdisciplinary learning and lifelong training in visual communication design education	1817
Jesvin Puay-Hwa YEO, Chua-Tee TEO	
243. The Practice of Design Innovation in the Academic Context: The Project Portfolio by Brunel Design	1828
Giulia COSCO, Vanja GARAJ	
344. Towards Design-Driven Transdisciplinary Education: Navigating the Challenges and Envisioning the Role of Design as a Facilitator	1847
JiaYing CHEW, Jung-Joo LEE, Miikka J. LEHTONEN	

HIGHLIGHTS: DESIGN PEDAGOGY SIG

Editorial	1867
Derek JONES, Liv Meret NIELSON, Ingvild DIGRANES, Nicole LOTZ, Lesley-Ann NOEL, Naz A G Z BÖREKÇİ	
120. Educating for design character in higher education: Challenges in studio pedagogy	1870
Elizabeth BOLING, Colin M. GRAY, Kennon M. SMITH	
193. Design Education for the Knowledge Society: An Action Research Study of Implementing a Liberal Arts Approach to Industrial Design Education	1883
Luke FEAST	
386. Why am I Studying Design?	1898
Ehsan BAHA, Maartje KOCH, Nick STURKENBOOM, Rebecca PRICE, Dirk SNELDERS	
157. Partnerships in an industrial design studio: augmenting the master-apprentice model to inspire collaboration	1916
Karen Tamara YEVENES, Jean PAYETTE, Sasha ALEXANDER, James Henry BERRY	
194. From Engagement to Empowerment: Exploring the Potential for Pedagogical Partnerships in Design	1933
James Robert THOMPSON	
315. Novice to Expert Real-time Knowledge Transition in the Context of X-ray Airport Security	1946
Shahab HOGHOOGHI, Vesna POPOVIC, Levi SWANN	

Volume 5: Processes

Editorial: Theme Processes	1962
Stella BOESS, Rebecca CAIN	
SECTION: FRAMING CHANGE	
130. Reframing and Strategic Transformation	1964
Kees DORST, Rodger WATSON	
132. The Future of Design Process Research? Exploring Process Theory and Methodology	1977
Frithjof E. WEGENER, Philip CASH	
355. Expanding innovation capacity in public sector by design projects	1993
Francesca RIZZO, Felicitas SCHMITTINGER, Alessandro DESERTI	
SECTION: INNOVATION	
155. Reinterpreting Tradition to Digitalize: Framing the Design DNA of LEGO House	2010
Linda Nhu LAURSEN, Louise Møller HAASE	
260. Mapping the Organisational Landscape of the UK FMCG Industry: A Review of Packaging Design & Development Professionals	2023
Nicholas Samuel JOHNSON, Awais Hameed KHAN, Abbie LAWRENCE, George Edward TORRENS, Ian STORER	
332. Multidisciplinary design collaboration in the lenses of CSCW and current technology enablement	2048
Mimi NGUYEN, Céline MOUGENOT	
SECTION: EXPERIENCE	
158. Swipe, Scroll, Add-To-Cart: a case study of e-commerce gallery designs for small screen devices	2065
Nicholas VANDERSCHANTZ, Nicole SIJNJA	
205. Exploring wearable technology for supporting couples in long-distance relationships	2083
Hong LI, Pradthana JARUSRIBOONCHAI, Jonna HÄKKILÄ	
234. Mapping Interactive Experience Over Time	2098
Chung-Ching HUANG, Erik STOLTERMAN	
SECTION: BEHAVIOUR	
223. Activity Scenario Modelling: an emerging method for examining human-artefact interaction	2116
Miguel MONTIEL, Ricardo SOSA, Darryl HOCKING	
232. The method of Immersive Behavioural Observation (IBO) — a conversation between theory and practice	2133
Shalini SAHOO, Stefan W. SCHMIDT	
255. Phantom Volume: A spatial explanation for domestic clutter	2151
Heidi OVERHILL	
SECTION: SPATIAL MOVEMENT	
174. Design Guidance for Location-based Play: a review of research frameworks	2166
Lorna MACDONALD, Ben MATTHEWS, Stephen VILLER	
400. Humanities discourse in games classroom: research through design with Games4Impact	2184
Sam YANG, Aslihan TECE BAYRAK	
224. Improving the Spectator Experience of AR Sports Events from a Service Design Perspective – Using HADO as an Example	2203
Pei-Ling SHIH, Hsien-Hui TANG, Shu-Yi CHEN	

SECTION: PERCEPTION

- 162. Visual Representations of Taiwanese Endemic Bird Species on Digital Media** 2221
Chia-yin YU
- 311. The effect of digital design representation on designers' visual attention** 2234
Rongrong YU, John GERO
- 395. A Theoretical Model of Similarity Judgment based on Ideas of Form and Spirit** 2245
Yifeng WEN, Ding-Bang LUH, Chi-Hua WU

SECTION: FORM

- 164. Using FCE and FAHP to Explore the multirotor drone appearance preference** 2267
Shih Wen HSIAO, Po Hsiang PENG
- 382. Morphological Exploration of the Turkish Tea Glass for Engaging Design Solutions** 2284
Naz Ayşe Güzide Zehra BÖREKÇİ, Fatma KORKUT
- 383. Design Science Approach to Nature Inspired Product Forms: Studies on Processes and Products** 2303
Shiv Kumar VERMA, Ravi Mokashi PUNEKAR

HIGHLIGHTS: EXPERIENTIAL KNOWLEDGE SIG

- Editorial** 2323
Nithikul NIMKULRAT
- 216. Material Connections in Craft Making: The case of felting** 2326
Bilge Merve AKTAŞ, Maarit MÄKELÄ, Tarja-Kaarina LAAMANEN
- 113. Empowering artisans through design: a case study on the dynamics of collaborative projects** 2344
Estelle BERGER
- 354. Materialising weaving: embedding a narrative of construction time within experimental woven textiles** 2358
Jessica Lynne PRIEMUS

HIGHLIGHTS: TANGIBLE, EMBEDDED, NETWORKED TECHNOLOGIES SIG

- Editorial** 2373
Sarah KETTLEY
- 188. A Tarot of Things: a supernatural approach to designing for IoT** 2377
Haider Ali AKMAL, Paul COULTON
- 139. Designing for the Internet of Things: a critical interrogation of IoT processes and principles** 2392
Boyeun LEE, Rachel COOPER, David HANDS, Paul COULTON
- 195. Open-Source Philosophy in Fashion Design: Contesting Authorship Conventions and Professionalism** 2410
Natalia SÄRMÄKARI, Annamari VÄNSKÄ
- 377. A Curated Chronology: Traits of Electro-Energy from Research-through-Design Practices** 2427
Karthikeya Satish ACHARYA, Matteo CAMPINOTI, Mirko PRESSER
- 237. Signs of the Time: Making AI Legible** 2442
Joseph Galen LINDLEY, Paul COULTON, Haider Ali AKMAL, Franziska Louise PILLING
- 331. Data Science for Service Design: An exploration of methods** 2460
Youetta KUNNEMAN, Mauricy ALVES DA MOTTA FILHO

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DRS2020
BRISBANE, 11–14 AUG
SYNERGY



DRS President's Foreword

Rachel COOPER

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The Design Research Society is a unique organisation comprised of people dedicated to the value of design and design research and its value to our people and our planet. Without a dedicated group of volunteers, we would not exist; people who offer their services to the management of the organisation, people who host conferences and people who submit papers and their combined intelligence to further knowledge of design and its contribution to the world. This year the fragile nature of the planet, of human relationships and the basis of our economy and society has been illuminated (fires, floods and a virus). We have seen the effect of radical changes in patterns of behaviour; both positive influences on the environment and negative influences on health and wellbeing and livelihoods. There are many design challenges and design researchers have come to the fore. This conference is a triumph of that creativity and fortitude, embracing the virtual world and bringing together all those people who so want to exchange ideas. Many of the papers are pre-Covid, and whilst we should not forget the conversations and research directions before this pandemic, it will, of course, shape our future and our conversations. People make the DRS and whether online or in person the conversations will continue. Let us together build a wider, deeper and stronger global design research community.

As a foot note I would like to say that 2020 marks a turning point for DRS in so many ways, we have a new structure of the organisation, that is a new International Advisory Council and executive who are eager to continue to move forward. We have a new virtual conference and I would like to thank the conference team for such a triumph in changing format and delivery mode, and also to you the members and delegates who are embracing this with your attendance. Enjoy the conference and the future DRS.

Rachel Cooper
DRS President 2020



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DRS2020
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DRS2020 Editorial

Stella BOESS, Ming CHEUNG and Rebecca CAIN

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Never before has a Design Research Society Conference happened in such uncertain and changing times. When we embarked on planning the DRS2020 Conference in Brisbane, Australia, we were in a different time, when unrestricted travel and meeting-up face-to-face at academic conferences was the norm. Then the COVID-19 global pandemic happened, which prompted us to rethink and reimagine DRS2020 in a new format.

In recent times, the debate around the sustainability of physical conferences has been starting to surface. This was an issue the DRS was starting to grapple with, but the practicalities of a blended or entirely virtual conference were still uncharted territory. Even before the pandemic was born, the devastating Australian bushfires were causing people to consider whether it would be safe to travel to Australia. Ultimately, the pandemic made a physical conference impossible, and the conference host Griffith University made a joint decision with DRS to convene DRS2020 as a virtual conference. DRS2020 marks an important turning point in the history of DRS conferences, being the first conference to go entirely virtual. We are very grateful to Griffith University for embracing this challenge, and for their leadership and management of the virtual conference in such complex and difficult times.

DRS conferences are international biennial events, held to further and promote design research. They are inclusive conferences, bringing together a wide range of disciplines and communities related to design research, with the aim of fostering new debates on the important issues of the time. Historically, DRS conferences have always taken place through gatherings of delegates in physical venues at a host organisation, with face-to-face presentations and discussions, accompanied by written conference proceedings. New collaborative formats have been added over time – for example, Conversations which were introduced in 2014. DRS2020 took on the challenge of transforming these formats into a virtual experience. Also worth mentioning, the DRS2020 Postgraduate Research Day is pioneering in that it is inclusive of both PhD and MPhil students and of their theory-driven and/or practice-led research projects. In this sense, DRS2020 becomes a prototype for a new type of virtual and inclusive conference experience and continues to build on the legacy of innovation from the previous conferences.



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The 144 papers in these proceedings were conceived of and written in our pre-COVID world. Just three authors were able to make late additions to their papers addressing the current situation (165, 398 and 402). These proceedings therefore provide an interesting juxtaposition, whereby what is written represents design research in the world as we knew it, whereas the discussion that these papers will promote during and beyond the conference will almost certainly be viewed through the lens of the complexities and challenges we now face. The discussions and reflections in the proceedings are a timely barometer for what the international design research community is thinking about and working on, and they will surely prove inspiring and thought-provoking for design researchers worldwide. We hope that you enjoy reading them as much as we have enjoyed curating them.

Themes

The overall theme for DRS2020 is Synergy – the coming together of people and disciplines in design research to create a positive impact. On the one hand, design research champions the uniqueness of disciplinary knowledge and creativity, yet on the other hand, the complex world we now live in demands a more synergistic approach to creativity and problem-solving whereby different mindsets, backgrounds and perspectives come together to realise transformative visions of the future. DRS2020 celebrates these emerging synergistic approaches to design research and seeks to explore their exciting possibilities for addressing multi-faceted problems, supporting participation, and transforming problematic situations into desirable ones.

For DRS2020, we used an emergent approach to the development of the conference programme, with a general call for papers around five themes – Situations, Impacts, Co-Creation, Education and Processes. These themes emerged in discussions between the Organising and Programme Committees at an early stage of the conference planning and were felt to capture a broad spectrum of current design research topics from which we would be able to build more focused themed sections. Continuing the collaborative approach to theme building, we asked the international reviewers to indicate to which of these themes (or others) each paper contributed. Following the acceptance of papers, the reviewers' indications helped us to cluster the papers into the rich programme we have here, with the main conference theme of Synergy being an interwoven thread throughout.

Impacts and Co-creation are the biggest theme categories, reflecting the design research community's commitment to applied research. Situations are an emerging theme reflecting the community's increasing awareness of diverse circumstances and contexts. With Australia as the host country for DRS2020, it is worth noting that 12 out of the 144 papers mention Indigenous communities (108, 135, 165, 166, 177, 187, 198, 228, 277, 278, 387, 402). 32% of the accepted papers are from Oceania, 18% from Asia and 33% from Europe, compared with 5% each from Oceania and Asia and 64% from Europe at DRS2018. Themes such as pluriversal design and diversity, design for global health and wellbeing, collaboration, sustainability and education continue to attract new directions in research and illustrate the

potential of design research to change the world for the better. The theoretical foundation of research into (design) Processes continues to be an enduring theme, the development of which can be traced back through all previous DRS conferences. Some sections were additionally clustered by domain, such as graphics, mobility, experience design or data. A point to note is that the paper clustering differs somewhat between conference programme and these proceedings, as the former also needed optimising by time zones to allow presenters from around the world to interact in their session discussion.

A further way we grouped the papers was around existing themes of interest within the DRS: those of the DRS special interest groups (SIGs). These open and dynamic groups of DRS members form around current and emergent issues in design research, and they welcome participation. The DRS SIGs are one of the main ways that the DRS drives forward debates and keeps a pulse on ongoing topics as well as emergent topics of the day. The DRS currently supports eleven SIGs, all of whom have contributed to these proceedings by selecting and grouping just over a third (55) of the submitted papers into SIG themed sections. Some of these sections are chaired as sessions by SIG members at the conference. This way, the SIGs hope to give authors the opportunity to get to know the SIGs and their members and to get involved. The eleven SIGs are Health, Wellbeing and Happiness, Global Health, Design Pedagogy, Pluriversal Design, Design for Behaviour Change, Experiential Knowledge, Human-Object Interactions, Inclusive Design, Sustainability, Networked and Embedded Technologies and Design Innovation Management. While the SIGs selected their set of papers because the papers speak to current and future themes of the existing DRS SIGs, many more of the accepted papers also relate to the SIG themes and all authors are welcome to engage with a SIG. DRS members are also free to propose new SIGs. One of the aspirations of the DRS conferences is to catalyse the creation of new SIGs, through the collective community building and knowledge sharing which takes place.

Review

Despite moving to a virtual conference format, what stays a predictable constant is the academic quality of the work presented at DRS conferences. Our standards remain high, through the excellent work of the authors, our Programme Committee and the community of reviewers. The Programme Committee is appointed by the DRS and chaired by a member of the DRS International Advisory Council. We are privileged to have many eminent scholars in the design research community within our reviewer pool, but also early career academics who are supported in writing peer reviews, a core part of their academic development, and who form our reviewer pipeline for future conferences. We endeavoured to match reviewers' expertise with papers through topic selection and automation, with some manual adjustments. The reviewers provided feedback to authors on how to improve their papers.

In total we received 280 full paper submissions in a one-stage submission procedure, of which 269 were viable to go to review. In total the 192 reviewers wrote 553 reviews, using reviewer guidelines. The reviews averaged 350 words. Each paper received two, sometimes

three reviews. 87 papers (32%) were accepted with minor revision and a further 57 (20%) accepted following (major) revision. This represents a 52% acceptance rate. As in previous conferences, we used the ConfTool system to manage the submission process. The ability of authors to rate and comment on their reviewers as in previous years, helps to drive up the quality of the review process. The authors rated 237 (43%) of the reviews with an average of 4.4 on a scale of 1-5 on the criteria *justified, constructive, encouraging, fair and convincing*.

Words of thanks

DRS2020 would not have been possible without the contributions of many excellent people who have devoted their insight and experience to the conference. We would sincerely like to thank the Local Organising Team at Griffith University for their remarkable work in transforming the conference into a virtual experience, and the extra time, effort and resources that this has involved. In particular, undertaking this transformation 4.5 months before the conference launch has entailed a significant level of creativity, courage and perseverance. We also thank the DRS for their expertise and guidance in the programme and review aspects of the conference. The authors, the Programme Committee and all the reviewers all deserve thanks for their valuable time and expertise in ensuring the high academic quality of this conference, as well as the SIG convenors for their role in curating themed tracks. Finally, we thank Griffith University and the Design Research Society for supporting the conference.

We hope that you enjoy these proceedings, and that they provide a thought-provoking and inspiring read.

Stella Boess, DRS2020 Programme Chair

Ming Cheung, DRS2020 Conference Chair

Rebecca Cain, DRS2020 Conference Co-Chair

About the Authors:

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Volume 2
Theme Impact



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Editorial: theme Impact

Rebecca CAIN, Stella BOESS

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Ultimately, design research has the power to have a positive impact on people and the world. At the more applied end of design research, there are explorations into the value, significance and dimensions of design research as well as the discussion on how to assess and measure these impacts. The Impacts theme for DRS2020 called for papers which related to the responsibility among stakeholders and users of design research, and examples of types of impact such as sustainability or economic impact.

When submitting papers, authors were able to pick appropriate keywords for their papers which allowed the emergence of four sub-themes within the Impacts theme – Reaching-in, Graphics and People, Translations, and Health and Wellbeing. This is in addition to three DRS SIGs which also have themed Impacts sessions on Objects and Practices, Sustainability and Design Management. The SIG Impact sessions are discussed within the SIGs editorials within these proceedings.

The exploration of the Impact theme starts with the Reaching-in sub-theme, which is concerned with the ways designers come to engage and influence domains of concern. Paper 198 explores how a new type of ‘designer-academic’ comes to communicate in different ways depending on the domain in which they are engaged. Paper 313 describes how design can address sexism and gender stereotyping through the creation of a card game. Paper 178 presents a reverse process: it studies how novice designers come to incorporate concerns from another domain, behavioural theory, in their design process.

Impact in design research is considered further through the Graphics and People sub-theme, which explores design research into the graphic and visual aspects of design. Paper 135 investigates the key processes that cause gendered inequity in graphic design, including the representation and understanding of the name ‘graphic design’, the biases in historical narratives, and the disparate understandings of ‘success’ and ‘significant contributions’. There are two further papers exploring graphic design for children. Paper 192 reinterprets the design of childrens’ books by taking the book and the interaction with it as a holistic design task to promote greater interaction and engagement from parent and child. Paper 365 explores how attitudes to sexuality education, including birthing, are changing to become



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more cognisant of the role of women, and how the complexities involved are reflected in the design of books on this topic aimed at younger children.

Continuing in a related vein, the Translations sub-theme speaks to the information design, instructional design and graphic design aspects of design research. Paper 167 reports on research to optimise a process supporting designers continually switching between gathering user experiences and industry contexts when generating automotive design proposals. Paper 363 investigates the effectiveness of instructional design for non-specialist beginners to learn Chinese characters, to inform future instructional design for teaching Chinese characters to beginners. Then taking a more broader view of the field, Paper 372 looks at graphic design and proposes graphic design studies as a new field to differentiate between practice in graphic design from reflection on that practice, to inform future interdisciplinary research agendas.

Health and wellbeing applications continue to be a field of design research with strong impact. In particular, the technology aspects of health and wellbeing and the effect of these technologies on users' emotions, and the support of ageing are drawn together in the Technology for Wellbeing theme. Paper 208 investigates the social context of older users interacting with emergent smart products, paper 266 considers how mixed reality technologies could support people with dementia and paper 351 looks at the design of detection systems for cardiac disease. Further papers relating to health and wellbeing are also presented within the SIGWELL and Global Health SIG themes.

Overall, the papers within the Impacts theme point towards the wide-reaching scope of the theme, both in terms of impacting on particular domain areas, as diverse as health and wellbeing, automotive design and graphic design aimed at children, while also describing the tools with which to support and reflect upon the creation of impact. Central to the theme of impact is the idea of collaboration. Many of the papers in this theme involve real users and wider stakeholders in the research, reinforcing the conference theme of Synergy.



DRS2020
BRISBANE, 11–14 AUG
SYNERGY



Monsters in the borderlands: Designer-academics in action

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Abstract: Much attention has been paid to how design – as an activity and a discipline – takes shape, with a focus on the professional designer. This paper explores a different kind of design practitioner - the ‘designer-academic’ - who holds a unique position at the border of pedagogy, practice and research in the creation not only of new ‘things’, but also processes and ways of working. Taking a reflective look at two projects over a emergent over a thirty-six month period we provide a glimpse into the everyday complexities of design research-in-action. We argue that we should look at designer-academics alongside the ‘outstanding’ professional designers, for they stand proudly at the borders of knowledge domains and epistemological traditions and are worthy of more attention in the annals of design theory and history.

Keywords: design academics; borderlands; case studies; knowledge creation

1. Introduction

In 2007, Nigel Cross contributed an essay to the volume *Design Research Now* (Edelmann et al, 2007) in which he suggested that:

“...Outstanding designers can be expected to work and operate in ways that are at the boundaries of normal practice. Studying such ‘boundary conditions’ may provide more significant results and an extension of understanding that is not available from studying average designers” (ibid, p.50).

In a later paragraph, Cross argued that studying “average and novice designers” may limit our understanding of design and “hold back design methodology...leading to weak or even inappropriate models for design cognition” (ibid). An immediate response to this approach to the research of design is what is termed ‘outstanding’ and by who’s definition? In *Designerly Ways of Knowing*, Cross provides us with his example of outstanding designers, including engineering designer Victor Scheinman, product designer Kenneth Grange and the Formula One racing car designer Gordon Murray (Cross, 2006, pp.64-75). Cross’ interest in



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'outstanding' aligns with the tendency amongst design historians to focus on the canonical professional figures in design (for example, Meggs, 2010) yet as Goldschmidt (2014, 2016) and Christenson, Ball & Lavkov (2017) have shown us, design activity is conducted in multiple settings with many actors and is a collaborative, generative and social process.

'Design' – as both discipline and process - is shaped by a heterogenous network of ideas, artefacts, projects, people and places. This is perhaps better conceptualised (drawing on Susan Leigh Star's studies of scientific and technical knowledge) as an 'ecology' (Star & Griesemer, 1989). Star suggests that an ecological standpoint of a particular professional domain is "anti-reductionist in that the unit of analysis is the whole enterprise, not simply the point of view of the university administration or of the professional scientist" (ibid: 389). We may view the field of design as a mixed ecology of the mundane to the exceptional; from the 'average' to the outstanding and in such an ecology we find what we term 'designer-academics'. These are designers who have hybrid roles inhabiting the spaces between design practice, theory, history and research. In these liminal space, knowledge and information flows between individuals and institutions whilst authorship and person-making are performed (Nickelsen & Binder, 2010, p.40).

Drawing on Anzaldúa (1987), Bowker & Star (1999) have conceptualised these spaces between communities of practice as 'borderlands' (1999, pp 302-305) and the people who refuse to be naturalized into any one particular professional membership as equivalents to Haraway's 'monsters' (Haraway, 1992). These monsters may not be the highly esteemed designers sought after by Cross, but are they deserving of our attention? Do they not shed light on contemporary design practice?

2. Approach

The world of design discourse - exploring a predominantly action-oriented practice - relies heavily on auto-biographical, biographical and sometimes polemical approaches (Foster, 2003) to explain design-in-action and it is often written by individuals who themselves are practicing designers (e.g. Rand, 1947, 1983; Heller, 2017; Bierut, 2017). The advantages of these forms of design discourse is that they reveal the innermost thought processes and subsequent design actions of professional designers at a level of intimacy and intricacy that cannot be gleaned from a solitary theoretical or historical analysis of artefacts. The disadvantages are that such perspectives provide only a limited view of design-in-action with obvious personal biases that can allow for a 'selective memory' of how design projects have come about. As a result, the successes are often lauded over the failures; aesthetic concerns dominate strategic intent; and personalities outshine collective acts of creativity and innovation.

To counter this criticism, we take a reflective approach to the thick description (Geertz, 1973) of design activities as forms of action research. Such a reflective approach differs from a memoir or autobiography (which are usually self-narrations) in that we participate in a form of "halfway-house case of thinking" which is between the "disengaged thinking" of Rodin's

le Penseur (The Thinker) and the deliberate thinking in-the-moment of a particular action (Ryle, 2009, p.481). We conceptualise design research here as action research because of its focus on producing pragmatic knowledge “developed in the service of action” (Romme, 2004, p.496).

In this paper, we present two design projects as case study samples drawn from a wider portfolio of ten projects which the lead author (Ely) has acted as lead design researcher over a thirty-six-month period in a university setting. Case studies are widely used in sociological, business and design research where the focus of inquiry is on the action of the researcher and not on controlling variables to measure their effects as we find in empiricist studies (Hammersley & Gomm, 2000, p.4).

The ten projects are the subject of a separate analysis of their ‘design value’ (Ely & Geneste, 2020); the two projects we present below are an in-depth look at demand-led design research in action, selected on the basis of their contrasting origins and outcomes. The first project, *Social Design in Action* was initiated on the back of an external approach for design expertise. The second project, *Humanities Research*, was initiated within the Faculty of Humanities on the back of a growing interest in adapting new working methodologies in the management of university research. As we suggested earlier, accounts of professional designers’ work tend to focus on the canonical work that has been launched, published or celebrated and we have sampled projects which provide a messier, incomplete – yet realistic – perspective on design initiatives.

All of the projects that Ely has been involved with over the course of thirty-six months, (including these two), are against a backdrop of teaching in undergraduate and postgraduate courses, PhD supervisions, journal article writing, continuous professional development delivery for industry, research leadership activities and curriculum development amongst many other common tasks and duties in higher education.

The two projects explored here cross the boundaries between design pedagogy, research and practice and draw upon knowledge from at least two design disciplines as outlined in *Table 1* below:

Table 1

Case Number	Project Name	Design Disciplines	Description	Status
1	Social Design in Action	Social Design/ Communication Design	The co-design of integrated health, education and community services	Terminated
2	Humanities Research	Design-Led Innovation/ Communication Design	Collaborative development of research narratives for public dissemination	Ongoing

In the following cases, we have changed the names of companies, projects or individuals to protect their anonymity and client confidentiality.

3. Case Studies

3.1 Case Study #1: Social Design in Action

PROJECT INITIATION

In April 2017, author 1 (Ely) was approached by the coordinator (“Mindy”) of *Zero-to-Eighteen*, a project involving primary schools in the delivery of integrated health, education and welfare services to families. The intention of *Zero-to-Eighteen* was to support families from a baby’s antenatal stage of development right the way through to the child entering the workplace or higher education, in an attempt to enable children to break the poverty cycle and reach their full potential. The project mirrors a similar initiative in New York – the Harlem Children’s Zone (HCZ, 2020).

Mindy contacted Ely requesting the student-led design of a brand identity for the project and, during a lengthy telephone conversation in which Ely explained the scope of both design research and pedagogy, it seemed that the project team not only required a name and brand identity for the project but also support in designing a complex, inter-agency framework for collaborative working. The school (on the geographical fringes of metropolitan Perth, Western Australia) in which Mindy was based had already garnered varying degrees of financial and logistical support from local government, not-for-profits, state-level departments and federal agencies but a complex, multi-agency and stakeholder project of this scale required a planning and coordination knowledge hitherto lacking in the project team.

An exploratory meeting between Ely, author 2 (Saad), Mindy and the primary school Principal (“Deborah”), we were able to agree collaborative steps forward: an initial visit to the School and local community to understand the context of the wider problem and a developmental framework built upon our own synthesis of design thinking methodologies (Brown, 2009, Liedtka, 2006) and the open-endedness of the project (Figure 1).

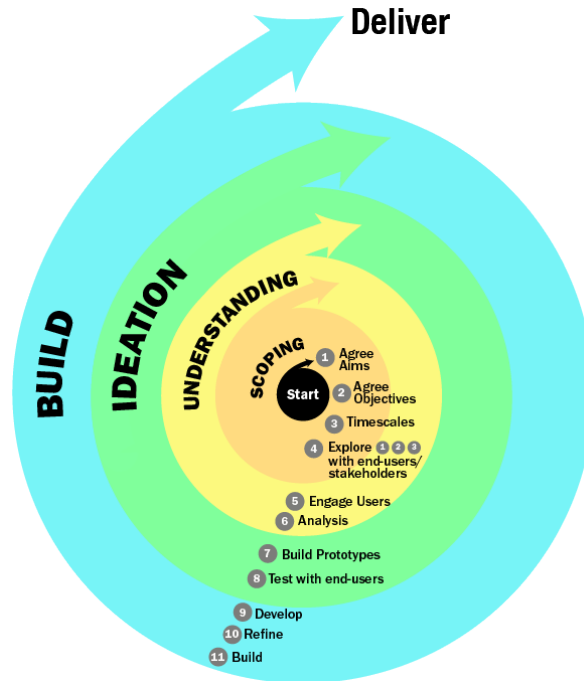


Figure 1 *Zero-to-Eighteen Design Engagement Model, showing 11 distinct stages in a four-phase model. The diagram and process model were developed to show both iteration and a focus on building prototypes to test with the community. We simplified the design process for client groups unfamiliar with the plethora of design process models. [Image: Ely]*

There are a couple of important characteristics of the project that we should highlight here, which became immediately evident to us as design researchers after our first meeting with a charismatic and motivational school Principal (Deborah). Firstly, our involvement with the project had extended after the initial enquiry from Mindy on branding into a broader processual or systems design project because of the compelling human stories that Deborah and Mindy were able to share on children and families who were facing extremes of domestic violence, destitution or ill health. We could not fail to want to be involved in positively supporting the school and wider Department of Education in realising their ambitions towards a local version of the Harlem Children's Zone; our empathic values as designers engaged us fully in this social problem. Secondly, our involvement in an ever-changing problem situation relied on us securing the necessary funding to drive the project forward. Unlike professional design commissions, this project would rely on all of the partners (school, state department, local agencies and not-for-profits) to work together to secure the in-kind and direct funding necessary to be able to take affective action through the project.

DESIGNING FOR ACTION

Given the scale and scope of the *Zero-to-Eighteen*, a number of experts and community leaders with expertise across educational psychology, family health, law enforcement, social care, health care, childcare, pre-School, high-school *and* design we felt the need to draw attention to our contribution directly as a social design project. To this end, Ely designed a

project identity - *Social Design in Action* (Figure 2) – which would act as an internal identifier between us as design researchers in the university but also to the wider cohort of experts contributing to the *Zero-to-Eighteen* project.



Figure 2 *Project identity for Social Design in Action. This designed artefact, used as a rhetorical device demonstrates how designer-academics operate across epistemological and ontological boundaries. In this project, we both construct and interpret knowledge for community use. [Image: Ely]*

Early-stage prototypes help build coalitions (Cottam, 2019) and signify the intent of project teams. Here we used *Social Design in Action* as an explicit rhetorical device to garner support for our well-intentioned involvement for *Zero-to-Eighteen*. We were able to secure internal funding, under the *Social Design in Action* identifier, to conduct a literature review of developments in social design, design thinking, health and education services (conducted by Author 3, Smith).

Uncertainties over future funding and the sheer complexity of multi-agency working meant that our first collaborative workshop with project partners in the school (n.9) did not take place until June 2018. We positioned the workshop as a ‘Team Studio’ with a series of co-design exercises conducted over three and a half hours with the express aim of understanding the individual and collective difficulties that the school and wider community were facing. Given that we were inviting participants from the student services team in the school to share their (in some cases harrowing) personal stories of interactions with pupils and their families, the workshop required prior ethical approval (approval HRE2018-0341) and the production of participant consent forms and participant information sheets.

The studio session was structured in five sections, as outlined in Table 2.

Table 2 *Team Studio collaborative workshop for ‘Zero-to-Eighteen’*

Section	Exercise	Purpose	Duration
1	Introduction	Welcome to country, personal introductions and purpose of Studio	15 minutes
2	Storytelling	Provide insights into the lived experience of children and parents in the local community – using customer journey maps	60 minutes
3	Needs Analysis	Identifying the service and support that address problems identified by the customer journey maps	50 minutes
4	Service Blueprinting	Here, we map (1) common issues experienced by families/children; (2) what we currently offer; and (3) what is missing	30 minutes

5	Next Steps	Through the use of 'Pledge Cards' individuals identify what they see as key priorities for the project and commit to a task of their own	15 minutes
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We (Ely, Saad, Smith) photographed each exercise during the Team Studio, capturing outputs from each participant. The narratives explaining the journey of children and their parents provided all (researchers and participants) with key insights into lives in trouble from the perspective of the support worker or educator (for example Figure 3). The process of re-telling of these interactions with children and their families reinvigorated the collective desire to improve the systems and relationships that create these problems in the first place; the exercise focussed attention on prevention and support services (see Figure 4).

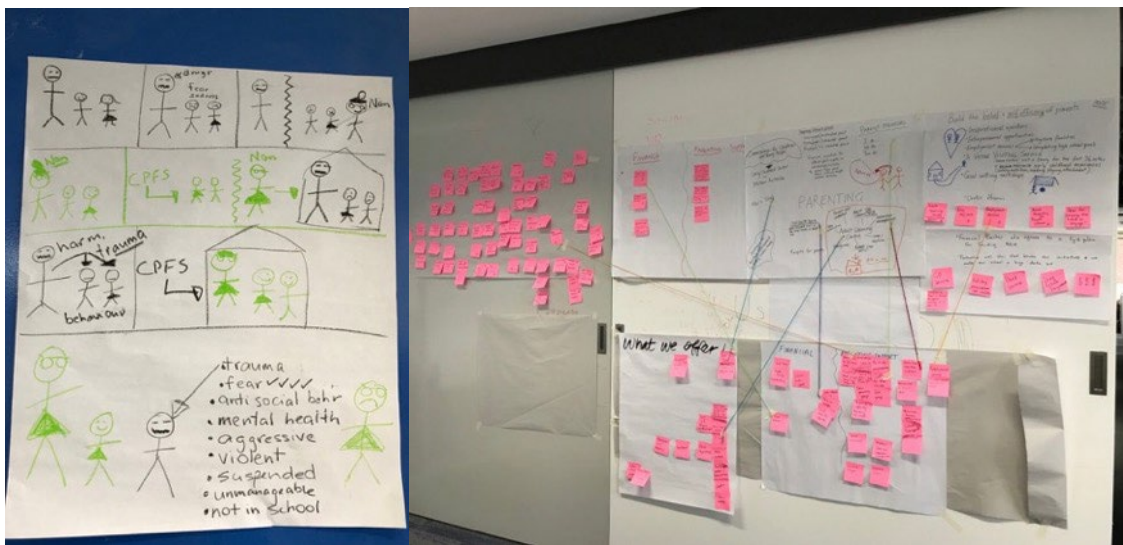


Figure 3 (left) Customer journey map telling the story of one support worker’s involvement with a child and their family [Photo: Saad]

Figure 4 (right) Service Blueprinting exercise mapping needs to existing services, using coloured string. This allowed the participants to understand how the work they undertook already had value to the overall project aims. [Photo: Saad]

A week following the workshop, we synthesised the outcomes from the Service Blueprinting exercise (and the complex web of services and needs featured in Figure 4), clustering issues into service domains (Figure 5).

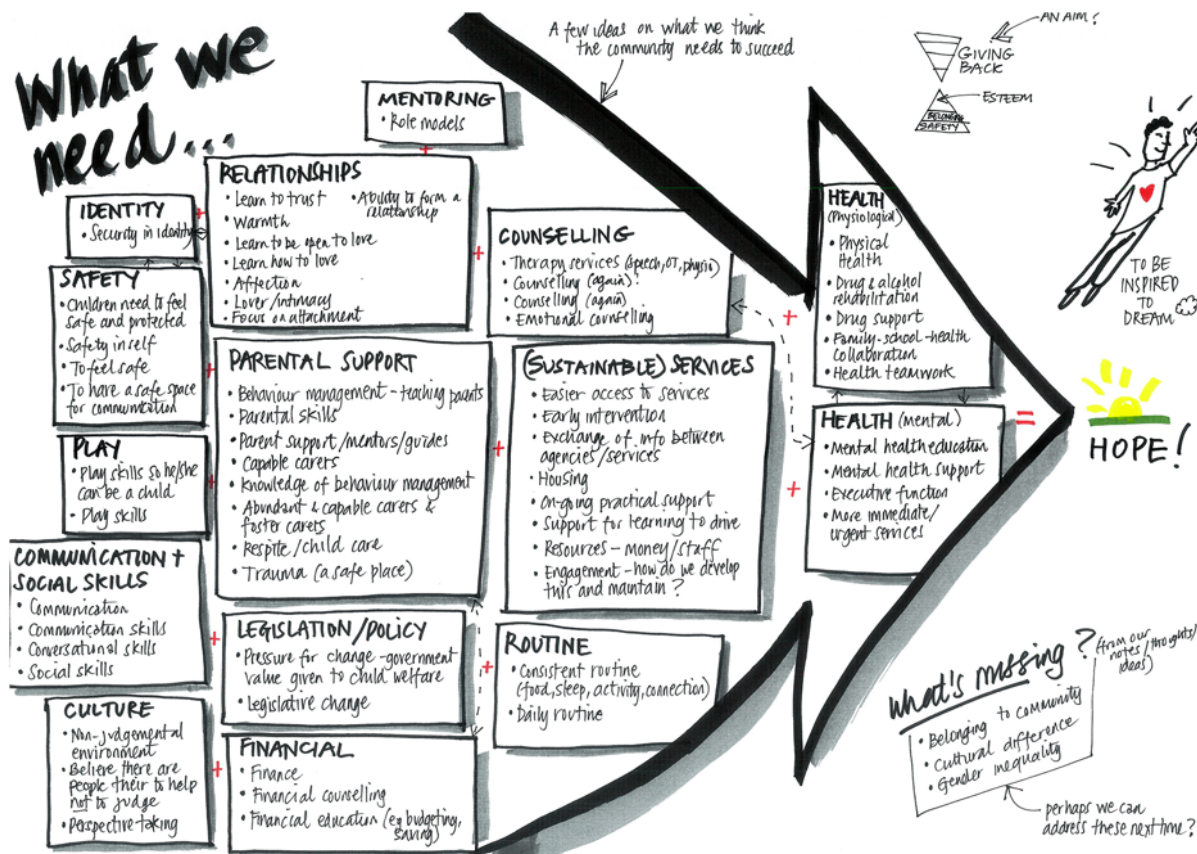


Figure 5 This sketched summary of the mapping exercise identifies service needs and project aims. By visualising concepts and ideas in this way, we were able to communicate (and inspire) the project team towards shared goals and mapped the problem terrain [Image: Ely]

THE PROJECT LOSES IMPETUS

Following the Team Studio workshop, the *Social Design in Action* researchers highlighted to the *Zero-to-Eighteen* project team that our work to date had largely been altruistic and speculative and that to enable us to continue working on the project it was important that we secured funding. To that end, we were invited into a funding bid with a number of key stakeholders, including a local government, state government, international charity, local not-for-profit and a charitable foundation in the hope of securing a substantial grant to develop some of the services that we had identified in the *Team Studio*. Specifically, we outlined and costed a project to re-design the local built environment to create more accessible, user-friendly (family and child friendly) services. A key aspect of designing user-friendliness was the design of an environment that would acknowledge local, indigenous cultures whilst recognising the complexities of a community that included a larger immigrant population whose cultural norms (particularly in relation to gender, government services and schooling) had so far inhibited common goals around supporting children from birth to workplace. Unfortunately, two key events ground the project to a halt.

Firstly, our short-term bid for funding as a collective was distracted by a regional state-wide initiative supporting early childhood and this subsequently pulled the potential funder's

attention away from our project (and this community) towards another metropolitan area. As a result, the international charity, not-for-profit and charitable foundation turned their attention elsewhere. The bid – led by the School – was not submitted. Secondly, our key advocate and sponsor of a design-led approach, Mindy, announced her resignation as she was offered a lucrative position elsewhere in the sector. The complexities of redesigning multi-agency services had taken its toll on the school and attention was, perhaps understandably, focussed on education services only. The *Zero-to-Eighteen* initiative stopped. *Social Design in Action* no longer had a project to drive forward. Our design initiative had come to an end.

ANALYSIS

When we were first approached to design a mere logo for a project, first author (Ely) attempted to open lines of inquiry by offering wider strategic human-centred design expertise. Following Ely and Saad's meeting with the principal of the school and the project co-ordinator, it was clear that *Zero-to-Eighteen* needed more than a brand identity to deliver an integrated health, education and community service to support life outcomes for children in the locality. As Shea (2011) has noted, graphic design expertise is often leveraged to, later, tackle more complex social problems through holistic, social or service design methods. Graphic designers are initially called upon to work on what appear to be simple communication issues around projects and initiatives and they are later involved with more strategic use of design (ibid: 152), changing behaviour, systems or processes (cf. Boehnert, 2018). Like professional design studios who are approached by clients for logos or brand identities, these projects invite interrogation by the design researchers to understand the underlying reasons for such a request and to offer alternative framings of problems (Dorst, 2015).

Unlike professional design studios where projects are unlikely to come to fruition unless clients are prepared to pay for them immediately, designer-academics remained engaged in this project for long periods of time, driven by a combination of empathy, curiosity, action-orientation and - initially at least - not by financial constraints. By staying engaged with a problem situation for longer and through their rich interactions with stakeholders, we were able to understand the sheer enormity of the task of designing multi-agency services whilst understanding the limits of design. In our particular setting, social capital (Lin, 2001) alone is not enough to sustain a project, however well-intentioned and ultimately life-affirming it may be.

3.2 Case Study #2: Humanities Research

PROJECT INITIATION

In the case study above, designer-academics are shown to traverse modes of design knowledge, starting out working on 'everyday' forms of design (Dorst, 2011) where we make 'things' – logos – and then applying our strategic thinking to much more complex (and in many cases still unresolved) design or innovation problems. This boundary spanning

(Schaminée, 2018, pp.89, 112) becomes more evident in the next project: *Research in the Humanities*. This project originated from a senior academic in the Faculty of Humanities (a Faculty of which we belong) looking for new ways of working amongst research leaders. Author 1 (Ely) initially designed and delivered a part-day workshop looking at how we might develop working practices which were to be more generative (collaborative) than discursive (committee). The starting point was Jeanne Liedtka’s ideas towards taking more design-centric approaches to managing:

“Most of us have learned to talk as if we are in a debate advocating for a position. But within a diverse group, debate is more likely to lead us to a stalemate rather than breakthroughs: breakthroughs come from asking new questions, not debating existing solutions; they come from re-examining what we take as given.”

(Liedtka, 2006, p.17)

Ely applied Liedtka’s process model for design - the Design4Growth model of ‘*What Is? What If? What Works? What Wows?*’ (Liedtka & Ogilvie, 2013) – to frame the development of research ‘narratives’ that could explain the diverse forms of research in the faculty and to present Humanities research to a broader science/technology-oriented academy. The workshop was structured as outlined in Table 3:

Table 3

Section	Exercise	Purpose	Duration
1	Part One Introduction	Exploring the problems; introducing design thinking and introducing Problem 1: Our focus topics are not yet motivating our stakeholders	20 minutes
2	What is...research in the discipline?	Sharing of conceptual, theoretical, philosophical, methodological and practical interests	30 minutes
3	What is...the common ground? What are the outliers?	Summary of (2) above and share with wider team, followed by whole team synthesis	35 minutes
4	What If? What stimulates? What might challenge us?	Identify salient topics that discipline areas can coalesce. What themes matter to the outside world? What stands out?	30 minutes
5	Part Two: Introduction: Smarter, lean ways of working	Exploring other models of organising (e.g. tribes, squads, agile)	20 minutes
6	Get Organised	Agreement on nature of squads; appoint squad leaders	20 minutes
7.	Decision Making	Using design-centred thinking: Why? Why? Why? Why?; Make a Pledge	15 minutes

The aim of the workshop was to bring research leaders (n.23) from across the Faculty together to find new ways of working and to commit, through the formation of teams and a

pledge (similar to the Team Studio in Case Study #2) to take action. For the sake of brevity in this paper, rather than describe each stage in detail here in the following section we take a closer look at the outcomes.

DESIGNING BEYOND THE WORKSHOP

At the end of the workshop, a summary of key research themes within the Faculty emerged (Figure 6).

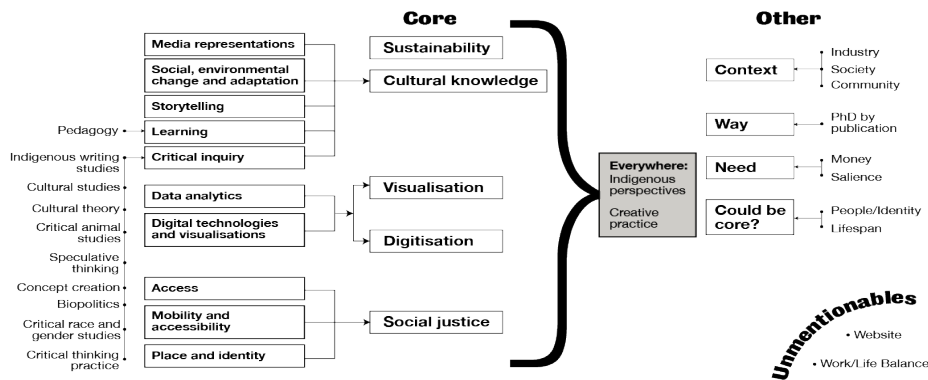


Figure 6 Concept map of key themes emergent from clustering of research themes in the workshop (Image: Ely)

Using the qualitative data analysis tool, NVivo, Ely also coded each of the sticky-notes from the first collaborative workshop to produce both a Word Cloud (Figure 7) and Coded Tree Map (Figure 8) below.



Figure 7 Word Cloud showing prominence of key terms on sticky notes from the first collaborative session

Social justice	memory making	PhD by publication	urban planning transitions	relational economics (left movement)	places	place - location-identity																la...	la...
	illfspan Identity	Literacy	topic diversity	quantitative methods	interviewing media consumers		div...	di...	di...	dig...													
Sustainability	humanities collaboration	Environmental criminology	theoretical diversity	quantitative (content analysis)	interviewing academics	integrated STEM	conflict narratives	Vis...	VI...	VI...	VR												Te...
	digital heritage	Digitisation	textual analysis	quantitative and qualitative	information databases		Teach...																
Pedagogy	digital accessibility	Digital Engineering	social sciences approach	quantitative (textual analysis)	industry grants and research grants	collaborations	Story-t...																
visual social media	data analytics	social cultural theory	project funded	Industry funded	careers & wellbeing	Specul...	Mobility	K-1...	In...	In...	In...	In...	In...	In...									
user experience and technology	cultural theory	Critical Inquiry	social constructivist	processes of change	how to improve income for citizens	Society...	Media...	Forms ...	Dig...	DI...	DI...	DI...	DI...	DI...									
urban design	critical reading studies	Construction Informatics	research evaluation social science	practice-led	practical studies about research with transdisciplinary focus	Society	Meanin...	Fine Art															
sustainable preservation	algorithm changes	work with teachers (format) means/transform	representations of science	genres - particular	forms of art practice	Social...	Mappl...	Everyw...	Datafi...	Cr...	CrI...												
sustainable livelihoods	World Cinemas	visual communication	representation of knowledge	post-humanities	fieldwork, collaborative work	Social ...	Luxury ...	Everyw...	Curric...														
politics of access	Place & Identity	writing data to identify trends and problems	reporting of heritage and people	post-colonial narratives, dark side	fieldwork	Social...	Lingu...	Enviro...	Commu...	CRIC	Art	Ant...											
open access	online identities	using ICT (online discussion)	reporting of education	policy	empirical	Salliance	Lifespan	Educat...	Cultur...	Collabo...	Algorit...	Acc...	Ac...										
						STEM	Learning	Disaste...	Cultur...	Classifi...	Adaptiv...	ANT (actor...											
						BOTL	Learners	Disabil...	Critical...	CRCP	Adap	3D models											

Figure 8 Coded Tree Map showing frequency of terms in first collaborative workshop. Reading top to bottom, left to right, we can see Social Justice, Sustainability and Pedagogy as the most mentioned, with Visual Social Media and User Experience & Technology next. This shaped subsequent discussion on research focii.

Acknowledging that key concepts emergent from the workshop were biased towards those researchers in the workshop, one team – led by Ely – focussed on the development of a written articulation of Humanities research intended for a public (popular) audience. The idea of small teams working on discrete work packages in a non-committee structure appeared elusive to the group, yet a quorate of 5-6 academics remained committed to the concept of small, action-oriented teams developing research narratives. Again, rather than simply meeting around a committee table, we synthesised ideas emergent from the workshop to develop (thinking through the question ‘What If...Humanities was articulated as this?’) overarching focus areas – *People, Planet and Technology*.

This focus on people, planet and technology became a way of framing a broad and diverse range of research projects, many of which cross these distinctions. Taking a series of projects from each functional School, Ely edited and designed a *Research for humanity* publication which, rather than reify these thematic distinctions, simply summarised the strength of research in the Humanities (Figure 9).

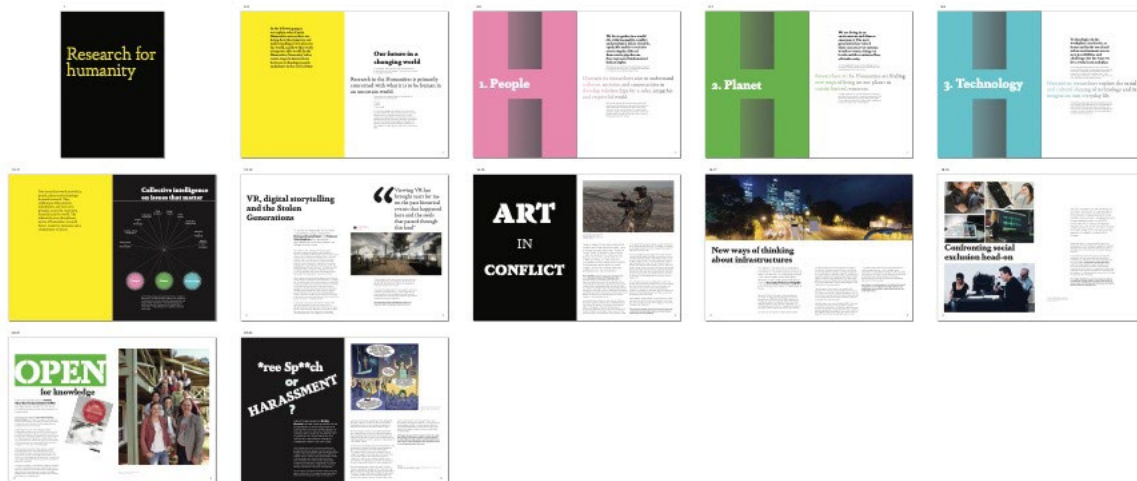


Figure 9 Thumbnails showing cover and double-page spreads from the publication “Research for humanity” designed and edited by Ely. The designed artefact is the result of a research endeavour in which design thinking methods have brought together researchers from diverse fields to develop a coherent narrative description of research activity and practice-based design has then turned these narratives into a discursive (Tharp & Tharp, 2018) artefact.

The resultant publication included contributions on the preservation of sensitive places in Aboriginal history; visual art and culture in times of conflict; Business Information Modelling and critical infrastructures; the deficit in audio description in Australian broadcast television; Open Knowledge initiatives; and online harassment and notions of free speech’.

ANALYSIS

We had taken an action-oriented design approach throughout and we have begun to ‘socialise’ our outcomes across the university (sharing practice and artefacts). Importantly, the idea of *People, Planet and Technology* as underpinning lines of inquiry for researchers in Humanities has allowed many diverse disciplines (for example, human rights and social justice; media, culture and technology; STEM education; creative arts and applied linguistics) to recognise their place and belonging in a research community. Design research has been applied in two important ways: Firstly, in a processual sense to find new ways of working. Our collaborative workshop, with a focus on *What If?* reoriented the academic gaze away from the problems of *now* towards creating a possible future (Binder & Brandt, 2019, p.102). Secondly, the making of ‘things’, here in the form of visualisations and publications is design as knowledge creation through a form of graphesis (Drucker, 2014). The publication is yet to find completion, yet such an artefact is a discursive form of design (Tharp & Tharp, 2018) which stimulates conversation, debate and (sometimes) disagreement.

5. Discussion

As the case studies of *Social Design in Action* and *Humanities Research* show, often the act of designing goes beyond artefacts and into the territory of services, experiences and processes. Indeed, in these instances projects can either begin or end in the creation of 'things'. The projects outlined above provide a glimpse into the varied activities of 'designing' by designer-academics. As we explained, such projects are set against the backdrop of substantial curriculum development and delivery, PhD supervisions, information design projects, article submissions, executive education programmes, research bid-writing and design-led innovation initiatives aimed to improve university processes or services.

Designer-academics are, just like their professional brethren, design entrepreneurs (Hoover & Heltzel, 2013) who respond to the situations they confront and seek out alternative ways of framing problems (Dorst, 2015). Designer-academics are the innovative designers as Bonsiepe described them – 'tinkerers' who, like innovative scientists, try things out experimentally (Bonsiepe, 2007, p.29). As we have seen, not every design project that a designer-academic engages in or initiates ends in a positive outcome (or even *any* outcome other than failure in some instances) but this should not be the reason to ignore them in favour of the professional designer who works in industry. Designer-academics cross not only disciplinary boundaries but the boundaries of research, practice and pedagogy. Just as as Binder and Brandt (2017) have described design research as being homologous with any other design practice, so we must think of these monsters in the borderlands between academia and industry as homologous to the revered 'outstanding' designers that dominate our short history.

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Catcall: Card Game to Trigger Conversations about Sexism and Gender Stereotypes

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Abstract: Sexism has been ingrained as a part of daily life through culture and social values. Often people don't realize that their words or actions are actually fortifying sexism and gender stereotype. On top of that, this issue is not a common conversation topic, even sensitive, especially in Asian countries like Japan. To tackle those issues, a card game about sexism and gender stereotype was proposed. Taking the name "Catcall", which is a form of street harassment, players are encouraged to reflect on their experiences, past actions, and words, by facing themselves with sexist situations that occur in daily life and call out those behaviors through funny, educational, or sarcastic answer cards. Evaluation result shows player's changes of mindset and increased awareness towards sexism in both workshop and casual environments. Furthermore, discussions about sexism were also generated during and after playing the game.

Keywords: card game; conversation starter; gender stereotype; sexism

1. Introduction

Humans experience sexism in everyday life. It is mostly ingrained and rooted deep in the society and culture; hence people see sexist behaviors as the norm. Gender issues are rarely brought up in casual conversations. This is especially common in Asian countries, including Japan, which is ranked 110th among 149 nations in the Global Gender Gap Report 2018 by World Economic Forum (2018). Gender stereotypes such as "boys don't cry" or "girls are not good with math" are often reinforced early in the family and can easily be found in the media. They are harmful to all genders and should not be normalized. Conversations need to be encouraged to raise awareness about sexism and gender stereotypes.

Generating conversations regarding sexism and gender stereotype is a challenge, especially in a more "traditional" society where social values get passed on actively. There needs to be a way to trigger conversations about gender that is not too intrusive and acceptable for many people. To reach a wider audience within multiple environments, creating a fun and entertaining way to communicate a social issue is usually more favorable. This paper aims



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to illustrate the process of creating a card game as a conversation tool to raise awareness of sexism and gender stereotype, while also realizing own's bias towards gender.

2. Sexism and Gender Stereotypes

According to Lexico, the definition of sexism is prejudice, stereotyping, or discrimination, typically against women, on the basis of sex ("Sexism," n.d.). Further explanation by Encyclopædia Britannica states that even though originally created to raise the consciousness of oppression towards women and girls, nowadays, sexism has expanded to include oppression towards any sex, which includes men and boys, intersexual people, and transgender (Masequesmay, n.d.).

Different term but within a similar theme, according to the Office of the High Commissioner, United Nations Human Rights [OHCHR] (n.d.):

"A gender stereotype is a generalized view or preconception about attributes or characteristics, or the roles that are or ought to be possessed by, or performed by women and men. A gender stereotype is harmful when it limits women's and men's capacity to develop their personal abilities, pursue their professional careers and make choices about their lives."

2.1 Ambivalent Sexism Theory

Sexism is usually only perceived as harmful behaviors, although there is another aspect that projects subjectively positive feelings toward women and often goes together with sexist hostility. Peter Glick and Susan Fiske developed the ambivalent sexism theory, which states that there are two kinds of sexism: hostile sexism and benevolent sexism (Glick & Fiske, 1996).

Hostile sexism promotes hostility towards women while enforcing traditional gender roles. While its counterpart, benevolent sexism, sees women as delicate and "fragile." Hostile sexism represents negativity, male power and domination, degrading women, and promotes conventional gender roles. Benevolent sexism, on the other hand, seems subjectively positive because it promotes a chivalrous attitude of protection and care towards women while still enforcing male domination (Glick & Fiske, 1997).

2.2 Everyday Sexism

In April 2012, Laura Bates initiated The Everyday Sexism Project that became one of this research's primary inspirations. It is a website where people share their experiences on daily occurrences of sexism, in hopes that others who never experienced sexism first-hand would be able to see what is happening in real life (Bates, 2014). Many stories got submitted since then, and came from women of all ages, backgrounds, sexuality, race, and religion. In her book "Everyday Sexism," Laura Bates stated that sexism is an invisible problem, albeit the scale. The amount of evidence that stated sexism exists is the same as the protest to the contrary. People didn't want to acknowledge, to talk about, or to believe that sexism exists. The people who took this view are not only men but also women (Bates, 2014).

3. Media

3.1 Cards for Conversation Starters

While there are many tools to prompt conversations, cards seem to be a popular one. Organizations and companies use cards to prompt discussions for a better product or service.

The Institute for Research and Innovation in Social Services (IRISS) is a Scottish charitable company that focuses on improving the quality of social services in Scotland through research, resulting in a better experience for the users. The company developed some tools to generate conversations. One of them is "Relationship Matters," which is a set of cards to prompt discussions between practitioners that care for young people, to reflect their values, and come up with better ways to improve their services (Rice, 2016).

Feedback on the cards indicated that it successfully generated conversations about continuing care, especially the practical elements that are often overlooked by companies. It raised the user's awareness of their own and others' views and practices regarding the question in the cards (Rice, 2016). Based on this, it can be said that card is an effective tool to generate conversations.

Another example of card usage is *The Thing from the Future*, designed by Situation Lab. It is a deck of cards to exercise imaginations and discuss artifacts that may exist in the future. It is also a tool to help in prototyping, a scenario generator, and a game. (Candy, 2018).

We tested a version of *The Thing from the Future* within a workshop with high school students to talk about the future city with speculative design, and we got positive receptions from the students. It makes a complicated and abstract idea, the future, easier to imagine and talk about. These cards can be used for icebreaking, help exercise the imaginations, and works as an introductory guide to speculative design. But most importantly, the cards provided an engaging topic, which helped spark discussions between the students.

Aside from the above examples of cards being used as conversation starters, we can also associate cards with other uses, such as games.

3.2 Games as Learning Tool

Over the years, games have evolved to become not only a form of entertainment, but also a powerful learning tool (Koster, 2013). The combination of a non-entertaining purpose with a game structure can be classified as serious games (Djaouti et al., 2011). These games let the players gain an understanding of real-world issues through playing. Game is an excellent media to communicate and share understanding about social problems because players can experiment and think about possible solutions in a safe setting. In a multiple player environment, they can share opinions and experiences (Swain, 2007).

Tiltfactor is a game design lab located in Dartmouth College, dedicated to studying and design of games for social impact. Using a thorough research methodology in both their design and user study, Tiltfactor produced several games relating to health issues, metadata,

and reducing biases.

One of Tiltfactor's game is related to the topic of girls in STEM. Awkward Moment, a social card game, is part of a National Science Foundation (NSF) funded project called "Transforming Science, Technology, Engineering, and Math (STEM) for Women and Girls: Reworking Stereotypes & Bias." Designed primarily for middle school students, it aimed to reduce stereotypes and biases in the STEM field. The resulted outcomes are increased player's association in women and science and more assertive response to social bias (Tiltfactor, n.d.). They implemented an "intermixing" strategy, by mixing bias-related and neutral content, using a more stealthy approach for embedding persuasive message about stereotype and bias (Kaufman et al., 2016). Intermixing is one visible approach to design games for social change. But since the bias-related content itself becomes so little compared to the neutral content, it might not be a suitable approach to achieve the goal of this research.

4. Design

An initial user study was conducted to see the outcome of a gender-related discussion in a structured and controlled environment. With a total of 20 people, the participants were asked to get into groups of 5. Participants came from 7 different countries (Japan, China, Taiwan, Indonesia, Thailand, Oman, and Korea). Most of them are women; only two men were present at that time. For 5 minutes, participants reflected and wrote down their personal experiences about gender stereotypes into sticky notes. For the next 25 minutes, participants discussed and shared their experiences within the small group, and gave each other advice on what to say or do when facing stereotypical situations. Afterwards, a 15 minutes big group sharing was conducted. Some insights from the activity were:

- For some people, what classified as a stereotype is not always bad. They agreed that, for example, men should take care of women.
- The topic of gender stereotype is interesting but difficult because stereotypes differ among cultures.
- Everyone experienced stereotypes in their life, but not many talk about it casually. It is nice to have a conversation about that and realizing that they can relate to other's problems.

4.1 Concept

Based on literature reviews, related works, and user studies, a card game can be a suitable tool to communicate about sexism and gender stereotype in a fun way, in both formal and informal situations. Referring back to one of the related works, the card game "Awkward Moment" took the approach of mixing neutral and bias-related contents. This research focused more on being direct and relies on a straightforward approach. From the start, players will know that this card game is focused on combatting sexism.

The game is based on sexist situations that happened in real life, experienced by real people, directed towards both women and men.

Game Mechanism

Taking inspirations from Awkward Moment and some other card games out there with “matching” mechanism like Apples to Apples (“Apples,” n.d.), two types of card were designed, later dubbed as “situation card” and “callout card”. Players are expected to “converse” through the cards and build empathy with the element of roleplaying. The “situation card” provides sexist situations the players have to face. Then, players are required to act upon that by choosing an answer or action from provided “callout card”. We want to encourage the players to actively stand up against sexism by actions or words.

“Callout cards” were pre-made to give the players inspirations on what to say or do when dealing with sexism. When faced with sexist situations, more often people would not say or do anything. Through this, we want to normalize calling out sexist behaviors. “Callout card” acts as a guide and trigger for players to think about ways to call out sexism, with the hope that ultimately players can creatively come up with answers by themselves. With these 2 elements, players will have a base for further conversation and discussion.

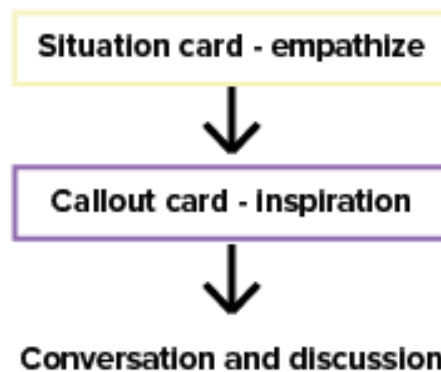


Figure 1 The concept of gameplay flow.

Naming

After further considerations, “Catcall” was chosen as the game name. It is an English word which, according to Lexico, means a loud whistle or a comment of a sexual nature made by a man to a passing woman (“Catcall,” n.d.). Catcall itself is a form of street harassment and is one form of sexist behavior.

Research shows that harassment like catcalls, whistles, or stares done by strangers can result in woman’s self-objectification, thus promoting psychological and behavioral problems (Fairchild & Rudman, 2008). After playing the card game, people are expected to be more aware of sexism and gender stereotypes, even the ones internalized in themselves.

Tone and Mood

The cards were designed to be simple, with text-only contents. It was meant to eliminate all biases and to avoid leading the players on, as everyone regardless of their gender can be sexist. It's up to the player's perception and personal experiences to understand the context of each card.

The mood and feeling of the game should be fun, playful, encouraging, and open. We want to normalize conversations on sexism and encourage calling it out. Players are free to express their opinion and share experiences. By playing this game, we're creating a safe space for players to exercise it. A suitable set of rules was designed to cater these characteristics.

4.2 Rules

The number of players recommended is four to six, but highly flexible based on situations. Gameplay duration is around 30 minutes. The rules are not made to constrict, but rather to help create conversations and generate interaction between players.

1. Separate the situation cards and callout cards
2. Shuffle both decks
3. Each player draws 7 callout cards
4. One player begins as the judge. The judge draws one situation card and reads it out loud
5. Everyone else gives an answer or response to the statement on the situation card by submitting one callout card face down to the judge. It can be a response from a bystander, or from someone who was involved directly in the situation
6. The judge shuffles the callout cards and reads the combinations one by one. The judge picks one best answer. It can be the funniest, the most educational, or anything the judge likes. Whoever submitted it gets a point and keeps the situation card
7. After the round, someone else becomes the judge, and everyone draws back up to 7 callout cards
8. Play again until someone wins the game with 5 points

There is a different dynamic when playing in a casual and formal environment. The basic rules are suitable for any situation, but sometimes in a formal classroom environment, a different gameplay mechanism could be needed. For example, having a facilitator instead of a judge, and implement a "voting" mechanism to determine the winner. Each round, all players vote for the best callout card. Alternative rules can also increase the replay value of the game.

4.3 Situation Card

The contents of the cards are divided into two main categories: situation cards and callout cards. To elevate the "fun" part, some humor were added within the contents. Initially

designed in English, later the cards were translated to Japanese for validation purposes with Japanese-speaking users. Some differences had to be made when translating because of the nature of both languages.

A situation card consists of conversation happening between a few people or a sentence containing sexist language or gender stereotypes we often see in daily life. Some are explicit; some are more ambiguous. The deck is a mix of hostile and benevolent sexism contents. Some cards have a more specific context, with additional information such as where does the situation takes place or who says it.

All the situation cards are based on real-life experience. A survey was conducted to gather people's experiences on sexism and gender stereotype. The survey includes a brief description of the project followed by questions about demographics and experiences regarding sexism within the workplace or educational institution, and within everyday life. While the primary purpose is to collect experiences, the survey stated that 65% of the respondents said they had witnessed sexism in the workplace or educational institution. 74% stated they experienced sexism in everyday life, and 82% witnessed it.

Some situations were taken from stories online, primarily the everydaysexism.com website. As the creator of the site, Bates explained about the validation of submitted stories. While there is no way to confirm the truth behind the stories, there is nothing to gain out of fabricating entries in the site. Since so many accounts are registered, posting a fake entry will gain the poster no fame. They also manage the site to remove troll posts. Moreover, the fact that similar stories were submitted by thousands of girls and women from different backgrounds, each of them with the same theme, it is too big of a coincidence for everyone to make up similar stories (Bates, 2014).

The amount of sexism towards women is dominant compared to sexism towards men, which portrays real-life conditions. It is also strengthened with the survey result; women are more likely to submit their experiences rather than men, both as a witness or first-hand experience. While the conversations that's written in the cards may not be 100% accurate with the submitted situation, the main idea is not modified. Some sentences were created to have a humorous tone in it.

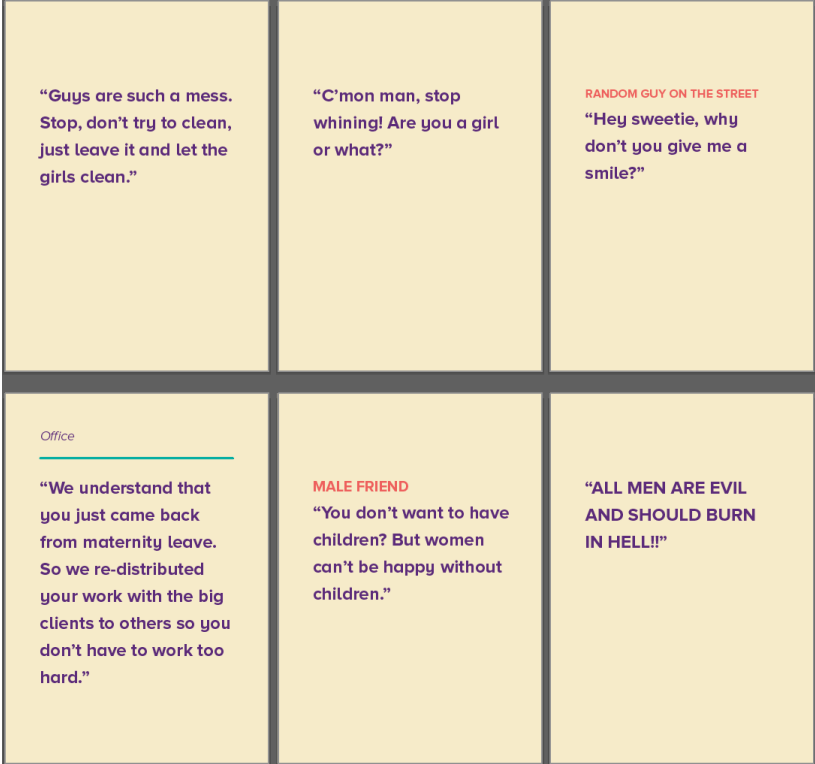


Figure 2 Examples of situation cards. The contents were created to be as broad as possible. However, some cards were given more contexts than the others to eliminate confusion.

4.4 Callout Card

A callout card is used as an answer to the situation cards. Players can choose between answering the sexist situation in an educational, passive, aggressive, assertive, or humorous way. The callout card contents are more free compared to the situation cards, and most can be paired with many situation cards. There are, in total, 295 callout cards.

Some callout cards were designed to be specific; these cards will only make sense when paired with the corresponding situation card. This system was implemented to enhance the replay value of the game. If all the cards can be paired with everything, the game can get mundane fast. The sources for designing the contents for callout cards are survey, interviews, personal experiences, and some internet memes to add humor.

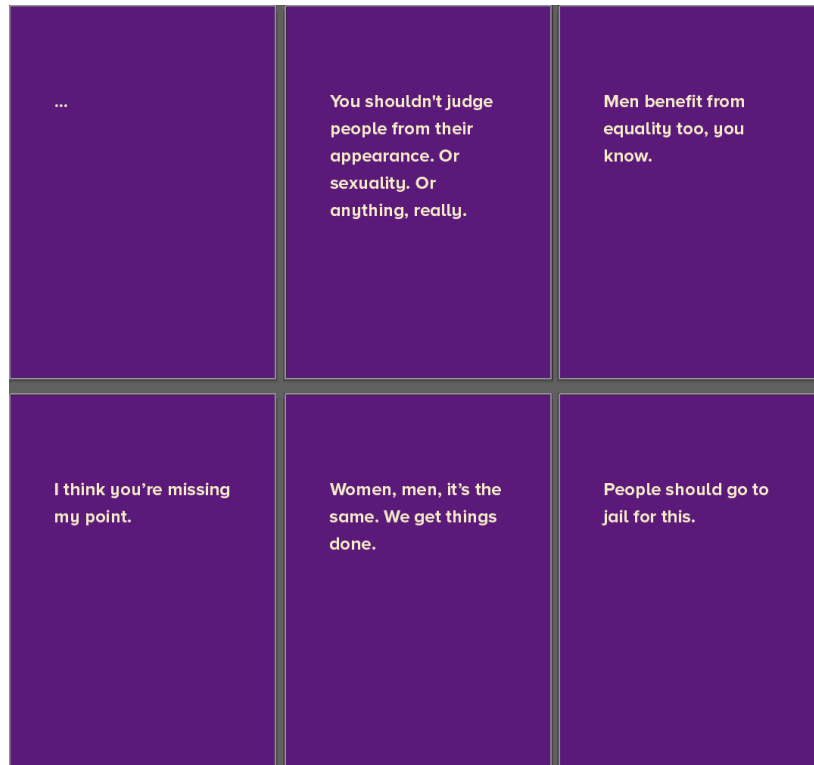


Figure 3 Examples of callout cards. Within 295 cards in total, different tones and moods were incorporated. Ranging from funny, intellectual, straightforward, savage, even a few internet memes.

5. User Test and Validation

The way to validate this research is through playing the game within different groups. There were two different conditions for the test. The first one is using the game in a workshop setting, with facilitators and a more formal atmosphere. The second one is playing in a casual setting, with no facilitator and a more relaxed atmosphere. This was done to look at the card game's versatility.

Within the workshop setting, a survey was distributed at the end of the sessions to get feedback from players. While in casual environments, interviews and group discussions were conducted after playing the game. Observations were also performed in both settings. Methods aside, the main points to evaluate were users' experience with the game, contents of the cards, and the topic of sexism and gender stereotype.

5.1 Workshop Settings

The first user test setting was conducted in a single session gender workshop with a Japanese human resource start-up. The game was used as an ice-breaking tool. 11 participants were divided into two teams of 5 and 6. Each team was assigned with one facilitator. Players picked the winner by voting for the best callout card each round.



Figure 4 Incorporating Catcall as an icebreaker within a gender workshop. Each group consisted of five participants and one facilitator.

The second user test was conducted in an event. For its correlation with SDG number 5, gender equality, the card game had a chance to be showcased in SDG Game Show for Youth and Educators, hosted by Kanazawa Institute of Technology (KIT) with Keio Media Design, Global Education project as co-host. Majority of the visitors were educators and teachers.

In both occurrences, participants who are mostly Japanese, were encouraged by the facilitator to discuss and think about the situations and answers alike. Based on observations, the game can be difficult to start because participants do not know each other and are hesitant to speak up.



Figure 5 Catcall in SDG Game Show for Youth and Educators, supported by UNDP Japan. Participants had a chance to try playing the game.

Based on the feedback, the majority thinks that the game was fun, the contents were funny, and they enjoyed playing it. One stated that the cards gave them inspirations on what to say if faced with harassment or sexist situation. Other said that it made them think of what would they do if faced in certain kinds of situation. Moreover, it had been a good lesson for them since they never thought about things like sexism and stereotype.

Because players do not know each other, a participant said that they hesitated a bit while playing. It was challenging to say what they wanted to say openly. However they said that, the contents, especially the situation cards, were relatable. They also expressed a wish to write their own answers in the callout card. Out of several groups participating, one consisted of two female adults, one male adult, and one boy. They enjoyed the game even though there was an age difference between some participants. While playing, they also discussed how real the situation cards were, and some shared their own experiences in similar situations. One male participant expressed that it was a good opportunity to understand women's feelings. Someone else reflected that in real life, calling out and saying "it's wrong" directly might not be taken well by others. But because it's packed in a game, players can be straightforward.

After playing this game, some participants realized how sexist they are, but unaware of it before. They did not realize what they said or did were discriminating towards gender. Through this game, the participants had a chance to reflect on their actions and how they reinforced gender bias unconsciously.

Finally, some of the participants expressed their interest in using this card within their community. Some wanted to play in a diversity training workshop, corporate training session, class meeting, even drinking party.

5.2 Casual Settings

In casual settings, the participant's demographic data was collected to see if it affects their way of perceiving sexism. The data consists of age, gender, nationality, occupation, and religion. During the playtesting session, there was no facilitator, and the participants were presented with a sheet of paper containing game descriptions and rules. They were asked to read and understand the rules by themselves. After a winner was determined, interviews and group discussions were conducted.

There were three different user test sessions with all different participants within different environments. The first playtest was done with members of a university female empowerment club. Second session was done with a group of master students from the same department, and the third session was done with roommates from different countries. The session were held in English.

The common feedback that came up after every sessions was the game was fun. A participant said that the sarcasm and humor worked well. In the case of female empowerment club members, more discussions arose during the session. This might be due to their perspective on gender issues are stronger than other people, being in a club that discusses such issue. They suggested creating one more card category as a winning "decider," as one participant said she hesitated to use the non-funny callout cards because she wanted to win. Another suggested implementing a penalty system for players who said something sexist. It is also an excellent practice to call out sexist behavior instead of brushing it off. Another aspect that they liked is the simplicity of the game and how easy it is to play.



Figure 6 Playtesting session with members of a university female empowerment club.

In the second session, all participants are of Asian background, with the majority being Indonesian. One student expressed that they felt pressure at the beginning of the game; they were not sure whether it's okay to give a funny response as sometimes people might take it

differently. A male participant said he could not relate that much to the situation, as most are directed against women, and he never experienced them. But later understood that such arrangements are based on real life situation. While on the other hand, a female participant said that the cards made her realize men can also experience sexism, not only women.

Participants for the third session were all male roommates within a similar age range (the 20s); one of Asian background and two others were European. Based on observations, the participants knew each other really well and were comfortable around each other. They enjoyed it and decided to play for two rounds. Participants said that the cards were well-designed and looked lovely. They wished for additional numbers of funny callout cards, jokes, and internet memes, as it was often the winning card.

During the post-game interview, the Europeans said that they could not relate to most of the situations that appeared. They felt like their generation is not like that anymore, and a lot of the cards would have a more significant impact on the older generation. However, the other disagreed, and he witnessed a lot of similar situations that were written on the cards. One participant followed that even though the situations seemed unreal, the fact that someone out there experienced those kinds of sexism, made him think about it. Even more as men, he often did not realize if sexism occurred, nor experienced it daily.

After the interview, one of the participants began to tell a story of his own experience with sexual assault, which is one of the topics covered by the situation cards. Initially, he thought it is not normal for guys to experience sexual assault, so no one talked about it. But after playing the game, he realized that it is fine to talk about sexual assault and did not matter if it's man or woman, people experienced it nonetheless.

5.3 Result and Discussions

Generally, the card game received good feedback from the validation processes. Players in both formal and casual settings said the game was, first and foremost, fun. It works as a game and can be played in different situations with different people. The game received a lot of praise for the simple, sleek design and straightforward mechanism that doesn't require a lot of preparation or set up.

Based on observations, when playing in a formal environment, players will less likely to joke around and would pick a right, safe answer. It also requires a facilitator to keep conversations flowing, especially since most of the time, the players do not know each other and might be hesitant to express their opinion. However, after a while, players would start opening up and play more casually.

As stated early in the design chapter, sexism and gender issue differs significantly among cultures. The game had a more prominent impact on Japanese people and other Asian countries compared to non-Asians. Feedback from participants with Asian background stated that playing the game made them think about their previous actions and mindset, how sometimes the things they did were unintentionally sexist and biased. Non-Asian players, however, were surprised by the fact that common sexist stereotypes still exist. For them,

sexist behaviors are a thing of the past. They were unaware that people are still experiencing it. All of these thoughts were generated and shared after playing the game.

Looking back at the design process, it is true that people from an Asian background submitted most of the experiences collected. This was proven to have a high impact on participants from Japan or other Asian countries when playing the game. The game might have to be altered according to nationalities or cultural background to have the best impact. In the future, if the cards are to be used by other people with different cultural backgrounds, it is best to alter the contents according to the user.

On the other hand, playing the cards with participants who are not from the same cultural background can still generate good results. Participants get to know what is happening on the other side of the world, and while sexism is not prevalent in their daily life, it is still happening in other countries. It raises their awareness of gender issues.

Since playing the game, some of the participants that the researcher still has close contacts with, showed more awareness towards sexism in daily conversations. On some occasions, they wondered if a particular statement was sexist, and a discussion was started because of that.

6. Conclusion and Future Possibilities

Sexism and gender stereotype is a challenging, sensitive topic, especially in Asian countries like Japan. At the same time, it is important to talk about sexism and call out sexist behaviors to reach gender equality. Through this card game, people shared their past experiences. They reflected on their attitudes. They were aware of different sexist situations in everyday life. Those were shared through conversations, within or after playing the game. Conversations were generated naturally, with the players sharing their personal opinion towards a certain topic within the cards.

It is beneficial to communicate social issues as fun and natural as possible. Catcall as a simple, straightforward card game is effective to raise awareness of the player's own biases. The "matching" mechanism is easy to familiarize with, and the text-only content serves its purposes. The message was delivered, although some players expressed that they would prefer some illustrations or visual guides to help them imagine the situations. A further research needs to be done on whether illustrations would help in this case.

There were certain limitations regarding player's cultural background and experiences. The design of the cards should cater to the target audience's cultural background. While not all the results are perfect, the cards meet the initial goal of creating conversations about sexism in a fun way. However, only that does not solve the gender equality issue. Men and women of all ages need to work together to solve this global problem together. This game works as an introduction to the bigger picture.

Until this paper is written, we have conducted some more workshop sessions utilizing Catcall to talk about gender biases. The inputs received were valuable to determine the next steps

in this project's development. The near-future plan is adjusting the balance of the game and create better localizations. We want to develop the contents to cater to more people from different backgrounds and age range. There have been requests from schools in Japan to conduct a gender workshop utilizing Catcall, and it would require some adjustments within the card contents, as some might not be relatable for high school students. Likewise, we also got requests from companies for a gender-training workshop, which would also require modifications of the contents. A possible co-creation workshop for content creation is also on the list.

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Incorporating behavioral theory in design ideation for changing sustainability behaviors

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Abstract: As design research develops, theory is increasingly available for designers. However, there is a limited understanding of how practitioners incorporate theory in activities such as ideation. This exploratory study aims to understand how novice designers respond to and incorporate theory in the ideation phase of the design process. A theory from behavioral economics – nudging – was introduced to the participants while ideating in problems of changing sustainability behaviors. Data collected included focused observations and interviews. Participants appeared to understand some behavioral theoretical concepts, which can be explained in the current pervasive use of human-centered approaches. While there were some mixed initial responses to the theory in terms of its ethical implications, all participants found the theory was useful to support and enhance their ideation. This study shows that designers are more confident with and appreciate theory when they can clearly see that theory supports their design process.

Keywords: ideation; theory-driven design; design for behavior change; sustainability

1. Introduction

When a designer is asked to develop a design solution to a problem, many factors go into that process. Some factors that previous research has shown to influence the ways in which designers tackle problems are personal mindsets (Hamat et al., 2019), contextual issues (Hu & Reid, 2018), emotional experiences (Tonetto, 2014), and creative-thinking skills (Davies & Talbot, 1987). Education is another critical factor that impacts a designer's approach to the design process. While design educators have different ways of teaching studio classes, most studio class design education settings revolve around traditional concepts of form, materials, and expression (Norman, 2010). Theories directly related to visual composition are used for teaching design studios to create well-rounded artifacts. However, several design scholars have expressed the need to broaden the use of theory as design approaches change from composition to communication and more recently social and behavioral change (Vezzoli,



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2003). For designers to effectively refocus their work on the goal of individual behavioral change in the context of socio-ecological problems, they must make assumptions about how to trigger such behavioral change, or engage with existing behavior change theories (Daae & Boks, 2014). Nevertheless, currently, limited research explains how designers deal with corresponding theories and how such engagement influences design processes. This study addresses this gap. It provides an exploratory study about how novice designers incorporate behavioral theory in ideation activities for solving sustainability problems. This study addresses the DRS conference theme of synergy between theory and practice.

2. Theoretical Background

Designers' mindset and approach usually form in the ideation phase, where the inspiration, framing, and molding of the project takes place. Kolko (2010) describes the process of synthesis as "an abductive sensemaking process" (p. 17). He also explains that a designer's creation is a combination of data manipulating, organization, pruning, and filtering. This can suggest that theory is capable of driving, framing, and influencing the ideation process. The process of design in practice is in part an outcome of design education that has been based on the master-apprenticeship model. Many instructors of studio courses utilize experiential approaches through experimentation and learning through trial-and-error (Sawyer, 2017), often unable to explain the theory and principles that guide their actions (Frascara, 2007). Basic design principles like form, space, and contrast will always be the foundation of design, but with time new concepts and guidelines have emerged. For instance, semiotic theory is as crucial as other contemporary approaches of design (De la Cruz & Mejía, 2017). The shift towards socially useful design (Thorpe & Gamman, 2011) has also influenced design education. In sum, theory has rarely been a core component for design education or design practice.

Designers tend to borrow theories from different disciplines and use them for decision making. Theory-driven design connects the design process with concepts and ideas derived from certain theories and models. For instance, employing theories from social sciences to identify, change, and maintain target behaviors is an effective tool in communication design campaigns (Fishbein & Yzer, 2003). As design projects become increasingly complex (Eastman, Newstetter, & McCracken, 2001), the need for grounding the design process on solid theoretical bases is critical. Theory is a model or set of principles derived from any discipline that can be an asset to practitioners. Friedman (2003) attributes design failures to lack of method, knowledge, and preparation and believes that theory-based approaches can enrich the creative quality of design. Raein (2004) argued that integrating theory in studio teaching is essential. When theory, text, and visuals are combined, he claimed students were able to attain a deeper understanding of their subjects. Raein further explains that approaches like empathetic design and problem-based learning also require students to seek suitable knowledge to attain innovative solutions. Theories, mindsets, and methods borrowed from other fields can be useful in design. In a case study of fashion design, Jung & Ståhl (2018) used a branch of philosophy called somaesthetics to elaborate somatic wellbeing

through combining bodily perception and fashionable creations. On a more science-based approach, Gentes and colleagues (2016) brought together design and fundamental physics as an interdisciplinary approach for a design experiment, and stated that it played a “reflexive role in design practice” (p. 564). In both previous cases, the authors suggested that introducing foreign theories into the design process is effective; yet, students struggled with digesting and implementing those theories in design. Additionally, time was considered as a limiting factor to comprehend complex concepts for design-oriented students. This suggests that the more the concept is further away from design disciplines the more time students require to understand and implement it in their designs.

2.1 Theory-Driven Design for Behavior Change

In design for behavior change, designers appear to demand behavioral theory to design effective solutions. Several contemporary strategies have been developed with the purpose of designing for behavior change, like Fogg’s (2009) *persuasive design*, Lockton’s (2009) *design with intent*, and Tromp and colleagues’ (2011) *social implication framework*. Tromp and colleagues argued that the type of strategy used is based on the desired behavior and presents a framework that explains the relationship between the product, human behavior, and the implication of that behavior. Such models have the potential to empower designers’ mindsets by providing them with a nuanced and empirically grounded perspective to entice change. The *persuasive technology* model emphasizes the need for three specific factors to create persuasive designs: motivation, ability, and triggers (Fogg, 2009). The model is a simplified theoretical framework to be used by practitioners in the design process.

The use of theory in the design of persuasive products has shown impacts on people’s behaviors. Studies have been focusing on empirically documenting the success of behavior change processes in design (Cash, Hartlev, & Durazo, 2017). Consolvo et al. (2009) used two theories from social psychology (*representation of self in everyday life* and *cognitive dissonance*) in their experimental technological designs to increase people’s everyday physical activity. Based on results from their two case studies of using persuasive technology, they concluded that the proposed merging of (a) theories from psychology and (b) design strategies can be effective in shaping and sustaining positive behaviors. This provides insights into the effectiveness of theory incorporation in the design process.

Another example of the use of social psychology theory in design for behavior change stems from John, Flynn, and Armstrong (2018). The authors not only focus on how visual stimuli trigger sensory determinants to encourage behavior but also incorporate Bandura’s Social Learning theory into their co-design methodology. As a scoring matrix, the latter assessed the validity of a design prior to testing and implementation. This suggests combining different methodologies of co-design with fundamental behavior change knowledge can create effective shifts in behavior. The study, however, did not provide details about the role of theory in the design process.

In the search for theories explaining human behavior, in particular consumer behavior,

the design discipline has recently begun to discuss theories from behavioral economics. In behavioral economics, researchers argue that people make irrational decisions based on intuition. Kahneman (2003) argued that individuals make decisions with two thinking systems: reasoning and intuition. Reasoning is an effortful and slow cognitive system used, for example, in mathematical computations and filling forms. Intuition is a fast and automatic cognitive system used, for example, in speaking one's native language. Thaler and Sunstein (2008) called these reflective and automatic thinking systems. They argued that the artificial environment can be designed considering cognitive biases of the automatic system to *nudge* people towards desired behaviors. Mejía (forthcoming) asserted that nudges can be particularly valuable for the ideation activities of the design process.

2. Method

Based on the literature review, it can be noted that although social-behavioral theories have been discussed in the realm of design, there is limited knowledge about how designers incorporate behavioral theory in design practice. This study addresses this gap. We conducted an exploratory case study to shed light on how novice designers incorporate and apply theory within the design process. We selected a theory from behavioral economics – nudging – as a current and prominently discussed approach to behavior change interventions in sustainable consumption (Lehner, Mont & Heiskanen, 2016). The research question we were trying to answer was: How do novice designers incorporate and apply behavioral theory in the design process?

The exploratory study uses case study research as the methodology. Case study research allows researchers to understand and explain complex phenomena that are difficult to control (Yin, 2017). Novice designers (senior design students) joined a three-hour design workshop session which included different ideation cycles towards problems of sustainable behavior change (Figure 1 and 2). Senior students were selected because their education and experience level are closest to being professional designers. A combination of industrial, interior and graphic students was recruited a week prior to the workshop. A total of nine participants: two males and seven females ranging from 20 to 33 years of age were involved in this study. Participants from each of the aforementioned majors were assigned into three teams with different design disciplines, and each team tackled a unique problem of design for sustainability. Participants aimed to entice positive behavior through their designs. Shorter shower times, less plastic consumption, and increased multimodal transit were the three predefined themes. Design for behavior change was used as the intention of the ideation session towards the specific target behavior. This study received the approval of the ethics committee (Institutional Review Board).

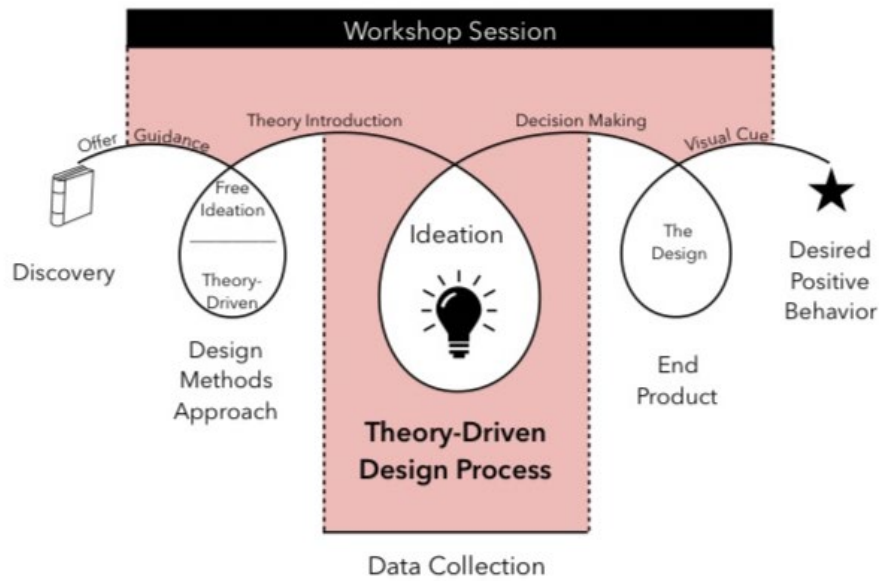


Figure 1 Approach to the case study workshop session.

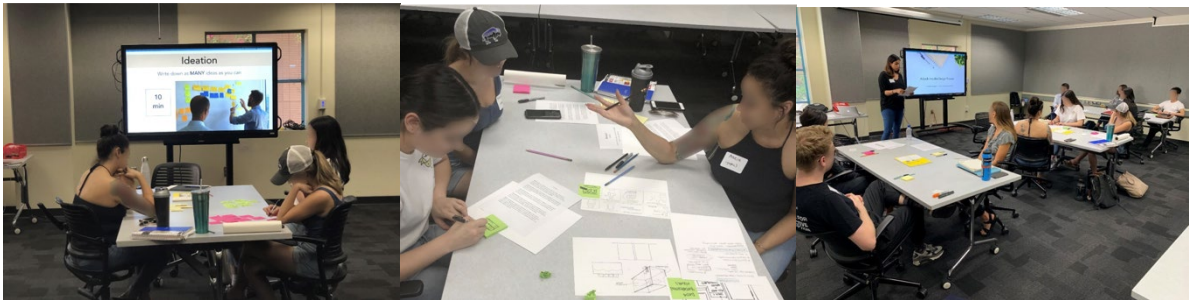


Figure 2 Photographs of the workshop session.

At the beginning of the design workshop, participants spent some time to ideate using sticky notes and sketch paper with their own framing and problem-solving tools. The goal of the first session was to warm up and allow for a comfortable ideation activity without the restriction of any predefined theory. Then, participants were introduced to nudge concepts from the theory of behavioral economics through a short presentation and a descriptive handout. They were then asked to go through ideation again utilizing nudge concepts this time. Doing so is considered a *method mindset* for designers as explained by Daalhuizen (2014). The introduction of nudge, therefore, acts as a *mental equipment* for the participants to produce effective inferences “about prerequisites and necessary conditions needed for an effective brainstorming session” (Daalhuizen, p. 58). The purpose was to observe how designers incorporate theory into their ideation process. There was no intention to compare ideation with and without theory. The purpose of the first ideation without theory was to have students develop ideas as they intuitively would first.

The workshop was broken down into six phases within the three-hour session:

1. Preliminary post-it ideation.
2. Discussion and sketching.
3. Theory presentation.
4. Theory-driven post-it ideation.
5. Theory-driven discussion and sketching.
6. Storyboard development of a selected idea, see figure 3.



Figure 3 Storyboards developed by the participants.

A qualitative approach is utilized to understand how participants incorporate, apply, and respond to theory in the design process. Since the objective was to understand the integration of theory in the design process, focused observations were conducted throughout the participant's ideation process. Semi-structured post-workshop interviews provided in-depth insights into the participants' experience with the theory. The interview guide included items about idea generation and selection, the use of theory, and the collaboration process. Participants articulated their thought process, idea inspirations, and decision making. Data was collected for investigating what participants relied on in their ideation; whether it was past experience, concepts from other disciplines, or purely based on creativity and aesthetics. Audio recordings along with direct observations documented the ideation process and the different discussions revolving around framing and decision making. Specifically, data was collected to reveal the information and knowledge that participants relied on to generate their initial ideas, and what happened after the behavioral economics theory introduction.

Data collected from all ideation activities resulted in a series of audio recordings, written observations, sketches, and notes from participants. The audio recordings were transcribed using an online speech to text transcription software - Temi. Results from transcriptions were later manually edited for inaudible parts. Some recorded segments of participant discussions during the ideation sessions were not audible and were therefore excluded from the analysis. Collected data was then thematically analyzed (Braun & Clarke, 2006). The web-based software for qualitative and mixed-method research analysis, Dedoose (Dedoose, 2018), was utilized to assist with coding the transcriptions and creating categories. The validated transcriptions were thematically coded to focus on the inspiration of participants for their ideas and how they responded to the theory introduction. The coded data were then exported into a structured text format for further analysis. From there, coded text excerpts

were extracted and grouped under similar themes to derive meaningful results.

3. Findings

This section is a report of the findings about the design process and how the novice designers use theory.

3.1 Influence of Design Education in the Design Process

Participants follow broadly established, generic practices taught in formal training. Half of the participants reported that in approaching problems they initially apply what they learned in their design education including brainstorming tools and design principles. For example, Participant 8 said, “It’s my education, what I’ve learned about typography and grids and balance and then a lot of it is, is just instinctual”. Another half expressed their approach being revolved around the end-user and using design empathy to relate to the user. For example, Participant 1 mentioned “[S]o it’s like really putting a lot of empathetic understanding to really put yourself in the user’s shoe[s] and understand what they need from this and do it”.

3.2 Presence of Non-Design Related Concepts in the Design Process

Designers are eager to use non-design knowledge. Half of the participants said that they used marketing and advertising knowledge in their designs. Participant 1 said “I definitely think like digital marketing, advertising, especially with something like this would be pretty I think pretty effective. And wow, this is the power of advertising”. Other participants mentioned disciplines further away from the design field influenced their designs, for example, participant 4 stated:

I’m taking sensation and perception right now for my psychology minor. So, I have a little bit of background in psychology. So, thinking about [things] like motivation and perception and how the brain works and how we intake stimuli like a lot of that it just comes naturally to my brain and knowing how we form habits.

3.3 The Design Process Between Research, Functionality, and Brainstorming

Half of the participants elaborated on their design process; for instance, participant 5 stated: “I like to do research, before I start ideating. So, it was really interesting for me trying to just come up with something just made reading like a little brief that you guys gave us”. Some said that they initially focus on functionality of the design and later on the aesthetics; participant 5 said “we can kinda lay out like the features, the benefits of the idea that we have and later on actually like develop the aesthetics”. Others said that they start their design process with sketching their ideas, for example, participant 8 stated: “So I mean the foundations all there [...] I will draw things out and try it and you know, go back and take my time and then let it rest for a day and then go back to it”.

3.4 Intuitive Awareness of Behavioral Theory

All participants explained their awareness of external influences on behavioral outcomes in their personal experiences. Half of the participants recalled their own personal encounter with businesses effectively using such approaches and incentives. Almost all reported that they instinctively knew some of the rules or incentives to change behavior without knowing specifically about the behavioral theories. One participant claimed knowledge of the nudge theory, awareness of the published material, and interest in learning more about it prior to the ideation session. Others claimed that they did not know of its existence and lexicon. They, however, strongly felt that their ideation thinking was related to the subconscious applications of human behavior concepts. Even though their previous knowledge was neither accurate nor linked to a specific theory, it was related to theoretical concepts of human responses to certain prompts or stimuli. In the first free ideating activities, participants intuitively included aspects of behavioral theory. Those of which include reduced inattention, positive and negative reinforcement, and using senses to make people more aware of the effects of their behaviors. Participant 1 explained by saying: “Actually even before you even said this [nudge theory], I was thinking about these rules and theories without knowing what they were [...] I already kind of was using it without knowing the theory”.

Data analyzed from the first ideation activities of one team revealed that participants as a group intuitively used aspects of behavioral theory. They alluded to *social norms* in their discussions by saying “it’s really fun if you make it culturally cool, like everyone’s saving water now. Everyone will do it”. In response, another group member states “if everybody is doing it, you are being conscious of like doing it too. It’s more like a movement and then everyone like follows”. In another team, they focused more on the visual impacts on behavior and how visually seeing damage can effectively influence behavior. One participant explains by saying: “every disposed plastic bottle, I guess it’s displayed, I can, be able to see like this is how much plastic we’re using and he’s just so like you kind of feel bad for it”.

3.5 Influence of Personal Experiences and Cognition in Ideation

Half of the participants asserted that their personal experience drives their designs and how they perceive it through their own eyes. They recalled their own personal encounters with similar campaigns and would constantly relate the situation to themselves. For example, participant 2 said: “I thought about what would work on me, thought about similar initiatives on the campus and how they had been done and what I thought was successful.” Similarly, participant 9 explained: “I picture myself in these situations. I mean obviously I’m only one perspective on planet earth, but I think of why I don’t do this or why I do that.”

3.6 Mixed Attitudinal Reactions to the Nudge Theory

Participants had mixed responses to the nudge theory. Three participants expressed positive views, four participants a neutral position, and two participants were objecting to some of the premises of nudging theory. Participant 1 expressed excitement about the potentially

powerful theoretical contributions of nudging:

But then after really thinking about like the nudge theory and after the examples that you gave us, I was like, oh my god, this is effective because it changes my behavior even so, and I didn't even realize so I'm like, it will be really effective if we do implement it.

Among the more reserved participants, two indicated that they had intuitively used the theory before. Participant 9 stated "we were probably thinking subconsciously about this as well before we were introduced to it, like in the first part of the ideation process". The other two participants thought that it's a good way to start the ideation but not to solely depend on it. Participant 6 explained by saying:

I think ideation is based on theory so that you can try things based on what has worked in the past or what theoretically could work in your head, and then you sketch it out to how you think it could work in theory. You know, and then you further it by trying it, you know, and then through like projects in school, I've learned that theory doesn't always work. Like you have to try it through the process of it and then alter like your idea based on that.

Two participants held some initial concerns about the theory, pertaining mainly to the ethical permissibility of using nudging. They, however, had different views after they had discussed it further. Participant 4 said:

But it's hard to knowingly implement those things because it almost feels like you're manipulating the end user. But when you think about the cause that it is for, you kind of understand the necessity, the necessity and you're just kind of using the brain's processes like for the benefit of your cause instead of, like, for evil or for malicious intent.

3.7 Impacts of incorporating Nudge Theory in the Ideation Process

Most of the participants stated that the nudge theory had an impact on their design outcomes. Participant 6 elaborated that the theory "started to influence the solution to the problem... it can be more focused". Participants expressed that it gave them a more developed, effective and solid idea. Participant 2 said, "I think after having that review over the nudge theory, then we were able to create a more concrete and tangible product that would create a result". Participants mentioned that they used specific aspects of the nudge theory, naming the exact terms from the theory, for example, participant 1 explained:

The social norms is like huge. Like if everybody else is doing it, like humans just feel a need to, like, blend in with everyone else and fit in. So you're so much more prone to doing it if everyone, it's like peer pressure. It's like if everyone is doing it, it's cool now. And it's like a cultural change development.

Although there were mixed responses to the nudge theory, participants clearly valued the theory. Some participants relied on the theory to give more credibility for their ideas, for example, participant 5 said: "at first it was just like a really rough idea. But once it relates to a specific nudge, I think there'll be more effective now because it's been studied and it has a base". Other participants thought of it as a good tool for ideation. Participant 1 said "but then after post to knowing the theories, I developed more ideas from it. So I feel like theory

is actually are probably the core of ideation". When using nudge theory in ideation, one participant changed their idea about positive reinforcement to negative reinforcement and said "so maybe it's best not to show the positive impact people are having. Maybe it is best to show just the negative, you know".

4. Discussion

The influence of studio-based education was highly visible in the participants' design process and approach. Not only did they use basic design principles in their ideation, but also strongly relied on brainstorming tools such as mind mapping and sketching. This suggests how curricula are highly absorbed and grasped by design students. The employment of contemporary design approaches, such as design empathy and human-centered design, was also evident in both ideation sessions. This proposes how emerging design approaches can be relevant and salient in framing design practices.

In addition, personal interest in non-design topics had an apparent influence on participants' processes. Participants that have pursued minor degrees or taken electives such as in psychology, entrepreneurship or marketing adopted certain concepts that supported their judgment throughout the design process. Generally, the participants displayed a strong interest in expanding their knowledge base either by taking classes or independent research outside of formal education. This could be either a result of (a) institutional efforts that support and invest in inter/transdisciplinary learning modules or (b) personal efforts and curiosity. Both of which can fluctuate with different institutional programs and personal interests.

Furthermore, participants intuitively applied some social behavioral concepts in their unrestricted ideation activities. Although their application did not necessarily reflect a high level of sophistication, its tangential implementation was certainly apparent in the data. This can be explained by the proximity between design and psychology, and how subconsciously designers utilize human connection and behavior into their designs. Further, designers today are actively using human-centered design theory and methods. Exposure to these design products in everyday life could result in forcing participants to unconsciously make sense of human behavior even with tacit knowledge about behavioral theory. Another reason could be that social-behavioral theories are intertwined with contemporary design and marketing campaigns, which can be seen when participants recalled experiencing nudges in their everyday lives. There were no issues with participants grasping concepts of the nudge theory after it was introduced to them. Previous authors such as Gentes et al., (2016) and Jung & Ståhl (2018) have reported cases where designers needed more time or had difficulties digesting and employing theories foreign to the design field. Results from this study provide new insights towards the practicality in the applications of theory-driven design in relation to nudging theory.

Although the participants did indicate their application of design education throughout the design process, most of them leaned into their personal experiences, logic, and cognition

to relate and tackle the issue at hand. While its effectiveness can be debatable, this could suggest how much designers prefer to initially approach a design problem with their personal intuition and knowledge, which is an abductive thinking process (see Kolko, 2010). A sense of comfort was observed with participants who grew excited knowing more about the nudge theory after it was introduced. The same participants heavily relied on this new knowledge and applied it systematically and diligently throughout their design process. Others perceived applications of nudge theory as manipulative or coercive, but still recognized its effectiveness and credibility when applied. These dichotomous perspectives have been widely debated in behavioral economics in regards to ethics (Blumenthal-Barby & Burroughs, 2012; Haug & Busch, 2014). Haug and Busch (2014) raised these ethical concerns in the use of nudges in consumer goods. They urged designers to be ethically responsible for their designs by being mindful to vulnerable users who can be easily targeted and cognitively challenged.

Despite the diverse responses, all participants ultimately integrated the theory into their design processes. This was evident in the analyzed data from observations, post-workshop interviews, and more so in the participants' documentation using the storyboards (Figure 3). The participants believed that they were able to strengthen and improve design ideation processes using the theory. Some participants were comfortable and excited to have guidelines from a validated theory to back up their decision making throughout the design process. The credibility of the theory made participants more confident in their designs. Some participants felt that the theory was an effective ideation tool, sourcing them with ideas that are diverse, developed and more tangible. This supports Mejía's (forthcoming) assertion that "nudges are a rich source of inspiration in design processes". The simplicity and practicality of nudge as a theory is also to be regarded for such ease of incorporation. The time and effort needed from participants to digest the theory was not a limitation and thus implies the relationship between complexity and usability. It is relevant to note that participants applied consciously or unconsciously concepts and methods from a variety of theories.

As with any other research, this study has some limitations that were identified as part of the workshop and data collection methods. First, the participants were few, inexperienced, young, and novice designers. Second, the type of theory chosen was considered simple and thus comparatively easy to incorporate. Theories with increased complexity can be difficult to comprehend and thus could have led to different results. Third, the length of the workshop was found to be a limiting factor for generating and developing more ideas. Additionally, participants' brainstorming was inherently restricted; while unintended, they had no access to resources such as a simple web search to gather additional information. They were also tasked with a specific ideation process (sticky notes documentation and collaborative sketching activities), which might have controlled the way they naturally ideate. Lastly, some of the data collected through audio recordings of ideation sessions were found inaudible, which influenced data analysis to some extent.

5. Conclusion

This exploratory case study focused on the early stages of the design process, the ideation, and framing and how designers approach problem-solving using a theory. With theory-based ideation activities, participants were able to gain another perspective. Instead of focusing on the effectiveness of the end designs, this study focuses on how theory-driven approaches affect the ideation part of the design process and how designers respond to and incorporate theory.

The study findings indicate that the participants generally approached ideation with their personal intuition and design education. Some participants utilized concepts and knowledge gained from other non-design classes to generate ideas. Some ideas shifted after the nudge theory was introduced in the ideation. Although most participants felt that they applied similar concepts intuitively, yet they had mixed responses towards it. Excited participants used it as guidelines to base their ideas on, neutral participants thought that it can improve their designs while helping stem more ideas, and hesitant participants thought it was restrictive and manipulative yet credible and necessary when justified. Regardless of their responses, they seem to easily digest and apply the theory. This suggests that when designers are exposed to an environment where they encounter social theories (i.e. for marketing and advertising purposes), they are prone to relate and use some aspects of it in their own design processes. On the contrary, scholars have discussed some cases that designers struggled with applying theories further away from the design field (e.g. Gentes et al. 2016; Jung & Ståhl, 2018). Further, novice designers not only apply theory that is intentionally introduced in their activities but also apply consciously or unconsciously a variety of theories they hold in their minds.

The findings of this study suggest a number of noteworthy areas for future research. For example, there is a need to study differences between professional designers, novice designers, and students when they incorporate theory in the design process. Also, additional studies employing different behavioral theories are needed, as the literature indicates that the complexity of theory could be a major factor in altering designers' approaches and methods. Future research should also aim to utilize and study different intervention formats (e.g. longer workshop sessions) and their outcomes on theory embracement in design processes.

The need for evidence-based design strategies to address the behavioral dimension in grand societal challenges like sustainability is pressing. The field of design research is challenged to respond to this need by experimenting with and consolidating approaches to incorporate theoretical insights from other disciplines and increase the effectiveness of design solutions. This study was a first exploratory contribution to this effort.

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Processes that cause invisibility for women in Australian graphic design.

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Abstract: Graphic designers are generally invisible as the authors of their own work. A deliberate effort must be made in order for them to be seen and acknowledged. The collaborative nature of design, associations with clients, and the involvement of production teams further hinders an individual graphic designer's visible authorship. However, gender also has a major influence on the invisibility of women in the history of this industry. Historically, the most celebrated practising graphic designers in Australia have been men, as evidenced by their overwhelming presence in books and on Hall of Fame platforms. My research has explored and addressed the key processes that cause this gendered inequity, including the representation and understanding of the name 'graphic design', the biases in historical narratives, and the disparate understandings of 'success' and 'significant contributions'.

Keywords: australian design; graphic design; women in design; invisibility/visibility

1. Introduction

It is rare to see a graphic designer's name, their collaborative team, or even a studio they are a part of, identified in the work they produce. It is often the case that the commissioning client and their messaging is the most visible aspect of the work. However, visibly participating in the wider design community is one way that graphic designers can reclaim their authorship and make their contributions visible. History books and archives also offer curated spaces for graphic designers to be recognised with some longevity. 'Visibility' therefore is a term used in this article to simply describe the state of being seen as an author of graphic design. Conversely, 'invisibility' refers to the whole or partial absence of this authorship.

The attention associated with authorship and the problem of how to connect it to designers is reinforced by Michael Rock in his essay *The Designer as Author*, where he states:

"The word [author] has an important ring to it, with seductive connotations of origination and



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agency. But the question of how designers become authors is a difficult one. And exactly who qualifies and what authored design might look like depends on how you define the term and determine admission into the pantheon.” (Rock, 1996)

Complexities surrounding the attribution of both peer-assigned and self-assigned authorship are further complicated when it comes to recognising the many women who practise graphic design. In 2009, Australian design researcher’s Dr Yoko Akama and Dr Carolyn Barnes lamented the lack of data about women who have made an impact in Australian graphic design. They concluded:

“Women designers ... remain a small minority in the roll call of prominent Australian graphic designers. It is beyond question that these groups make a productive contribution to their field. The failure to acknowledge this contribution through public visibility and leadership undercuts the industry’s ability to engage with the complexity of Australian society, characterized as it is by an ever-increasing multiplicity of peoples, identities, cultures and social circumstances.” (Akama and Barnes, 2009, p.29-40)

There are three distinct process that are identified and explored in this article that suppress the visibility of women in graphic design. The first of these is the confusion surrounding the term graphic design, the second is the way history is written and the final point is the biases at play in the way ‘success’ and ‘significant contribution’ are defined by the industry (Connory, 2019).

2. Graphic design’s identity crisis

Graphic design is observed in popular culture through a disparate lens. Sometimes it is viewed with disdain and other times as ‘cool’. FYI I’m a graphic designer is a short film on YouTube which edits together clips of people commenting on graphic design (Mercer and Streule, 2015). Eighteen Hollywood movies and popular US and UK television shows—like Juno, Parenthood, and The Office—show people struggling to explain the depth and breadth of what a graphic designer does. They simplify the complex processes, skills and knowledge into comments like, “...we do menus and logos and things like that” to “... you make pamphlets and DJ flyers” (Quinn and Bisutti, 2010; Cilella and Curran, 2013). Graphic design is seen as both “edgy” and “creative” as well as being a “sell out” profession and something that “anyone with a laptop can do” (Mercer and Streule, 2015). The level of insight into graphic design and its professional standing is limited and misrepresented.

Steven Heller, a design critic, positions this lack of understanding as an “identity crisis”, and explains how this extends to both graphic designers themselves as well as to the industry bodies that represent them (Heller, 2007). Simply not knowing how to consistently label themselves through time, Heller says, graphic designers add to this confusion. They use a divergence of names, including “humdrum commercial designer” to the convoluted “human-centred interface designer” (Heller, 2007). Both the AIGA (formally the American Institute of Graphic Arts) and AGDA (the Australian Graphic Design Association), now both insist on referring to themselves by acronyms. This is done so as not to draw attention to the grey areas, that is, the words ‘graphic arts’ and ‘graphic design’, denoted by initials within their

names. The AIGA announced this change in 2005, while AGDA went through a major rebrand in 2014 (Twigg, 2005; Ricki 2014).

Alan Young attempted to address this issue by examining the localised discourse surrounding graphic design in Victoria, Australia. His research also revealed a disparate system of classification with a list of educational courses, institutions and businesses that linked graphic design, as a comparative career throughout history, to “Graphic Art, Commercial Art, Industrial Art, Design Arts, Decorative Arts, Applied Arts, the Minor Arts and Visual Communication” (Young, 2005). However, Young’s research did not directly ask the graphic design community what they called themselves. I designed the Invisible Women Survey, to fill this gap and to reclaim a clearer understanding of what the typology of Australian-wide graphic design might be throughout history—in the eyes of those involved (Connory, 2019).

The responses reinforced the idea that graphic design has an identity problem. In 2016 the Invisible Women Survey was conducted which underpins much of the findings in this paper. The survey was sent to a random sampling of stakeholders in Australian graphic design and was circulated online by local and international industry blogs, professional bodies, and design commentators.¹ A series of closed and open-ended questions were asked in relation to the themes of the evolution of the graphic design, the historical record of graphic design and the scope of significant contributions. Open-ended questions asked respondents to name women who had made significant contributions to Australian graphic design since 1960. The survey revealed 61 in over 50 industries. Graphic designers were shown to create everything from logos and advertising to services and apps. The tools they used were shown to evolve rapidly since 1960, from Indian ink and rubber cement to Adobe software and Mac computers. Finally, the purpose of a graphic designer was shown to have changed from selling products to social activism.

Frustrating as this complex lexicon of graphic design is, one of its negative consequences is the way it hinders the visibility of graphic designers themselves. Victor Margolin, a professor of design history, labels this phenomenon as a “crisis of design” (Margolin, 2013, p.400-07). He claims, “In the realm of discourse, there is insufficient understanding of design’s scope, which results either in much design activity remaining invisible to critics, editors, curators and others whose function it is to present design to the public...” (Margolin, 2013, p.400-07).

Within these muddy waters, it is women who have become much more invisible in comparison to men. For example, the visual portrayal of the graphic designer has been typically male. In his 1993 paper, “Research in Art and Design”, Christopher Frayling elaborates on who a stereo-typical designer is throughout history, labelling a progression from a “pipe smoking boffin”, to a “solitary style warrior” and finally to a “research scientist – who in most cases “tends to be a man (Frayling, 1993, p.1-5). *A Fine Line: A History of Australian Commercial Art*, (1983) the only comprehensive and now ageing history of

1 All research and data storage, including the surveys and interviews conducted in the following project, were given a Human Ethics Certificate of Approval by Monash University, with the project number CF16/848 – 2016000425.

Australian graphic design, unapologetically pictures a commercial artist on its cover. He is shown as a smiling, enthusiastic white Aussie bloke, wielding a brush and wearing a crisp shirt, tie and vest (Caban, 1983).

This disparate view of graphic design in popular culture, its confusing lexicon, its ambiguous purpose, and the stereotype of a graphic designer as male, all hinder the visibility of women in Australian graphic design. However, academia has proposed some solutions to this problem. Design historian, Martha Scotford, through a contextual typology of the roles undertaken by women in graphic design, contends for a distinctive female perspective to elevate their level of importance and visibility. She argues, “In studying women designers, it is important ... to understand the private and public roles available to women at each particular time” (Scotford, 1994, p.367-876).

It was therefore important to add the specific opinions of women to this article. I conducted interviews in 2016 with women in Australian graphic design, who had been identified as making a significant contribution since 1960 by the Invisible Women Survey participants. These interviews will be referred to throughout the article and were also a series of open ended questions that collected the participants demographic information and covered the themes of significant contributions, the evolution of graphic design and visibility.² These women’s responses ranged from identifying with the name of the degree they had undertaken to appreciating the ambiguity of graphic design nomenclature. For example, Abra Remphrey the co-owner and director of Detour Design in Adelaide, tied her identity to her education, which clearly defined her in line with the name of her degree—as Visual Communicator. Dianna Wells, who established her career at Another Planet Posters, achieved a printmaking degree at the Canberra School of Art rather than a design qualification. She felt the name ‘designer’ encompassed the array of creativity and diversity of skills she brought to the role. Jessie Stanley, now an artist who develops installations for public spaces in Victoria, liked to exploit the undefinable element of the profession, saying she has always been interested in “Redefining the role of graphic design...”. While Sandy Cull, with over 30 years of experience in the publishing industry, called herself a book designer, simply because “I’m not interested in doing anything else”. Suzy Tuxen, owner of A Friend of Mine in Melbourne, spends a lot of time clarifying the process of graphic design to her clients, saying “... it is something that you have to constantly explain to people...”. Sue Allnutt, owner of Nuttshell Graphics and Lynda Warner, owner/operator of her business in Tasmania, both have the longest careers among those interviewed. They also prefer the simplicity of being called a graphic designer.

Through the responses of these women, it is clear that there is no consensus to the way in which they label or define graphic design. Time in the industry, the title of their qualifications, and client expectations, all have influence over their interpretations, but the ill-defined and inconsistent nature of the profession remains present in the experience

2 The transcripts and interview notes are archived privately on the Monash digital system called FIGshare. There are elements on each of these documents that the interviewees requested remain anonymous.

of their careers. While there is much ambiguity about nomenclature the sheer number of women employed as designers' merits greater advocacy for their contributions to the profession. Maybe if the consistency and clarity demanded of a well-designed brand was applied to graphic design's identity, the visibility of those who practised in the profession would also gain more prominence and recognition.

3. History repeating itself

The published histories of graphic design also distinctly add to the invisibility of women in Australian graphic design. By and large, men have authored the vast majority of our western histories, favouring a narrative focussing on other men. However, this is not a problem isolated to Australian history. As long ago as 1946 Mary Beard, in *Women as a Force in History*, identified the particular ambiguities and false presumptions of men simply writing about "mankind" (Beard, 1964, p.57-85). In 1964, during the height of the second wave of feminism, Edward Hallett Carr pointed directly to the negative impact of these implicit biases, saying that, "... the historian is engaged on a continuous process of moulding his facts to his interpretation and his interpretation to his facts" (Carr, 1964). More recent writings, like those of Jill Matthews, sought theoretical underpinnings to this phenomenon (Matthews, 1985). Others continue to dispute the ability of history to be purely "objective, scientific knowledge" that reflects "universal truths," but rather characterises it as an "exercise of power through activities surrounding historical knowledge..." where "...women, non-Europeans, amateurs, local events, and domestic life [are] inferior, superficial, less well developed, less important" (Smith, 1998, p.90). There will always be a subjective nature to writing histories, even when it consists of scholarly research from quality sources. However, history reflects the fact that male authors are conditioned to value and prioritise the stories of men. This is an issue which continues to hide the significant contributions of women in Australian graphic design.

Empowering women and minorities to record and write histories is the obvious solution to this problem. However, defining how best to record the history of graphic design has been contested over recent decades. Another solution, and one that most scholars, historians and practitioners agree on is the merits of simply making the historical narrative more inclusive. Clive Dilnot outlines that making the definition of design clearer has the potential to give historians a more inclusive sociological perspective (Dilnot, 1984, p.6). Bridget Wilkins has pushed for historians to look beyond the aesthetic values of graphic design ephemera, and to question the stories behind the makers in order to reveal graphic design's true historical value (Wilkins, 1992). Tony Fry warns us to "beware of neat narratives" and to look into the marginalised messiness of design history (Fry, 1989, p.15-30). Margolin, also argues for a shift from "... a history of objects, to a history of practice..." and Teal Triggs highlights the integral role that the voice of the designers themselves should have in forming such histories (Margolin, 1996; Triggs, 2011, p.3-6).

A more extensive and personal perspective of the field can widen the filter of inclusion

and begin to include silenced voices in the history and currency of graphic design. It can justify the acceptance of women as significant contributors and highlight how existing homogeneous male perspectives have consistently omitted and lessened the contributions of female practitioners. Such comparative and broad research methodologies are shown as essential by Martha Scotford, “to conceptualise the inclusion and significance of women in graphic design” (Scotford, 1994, p.367-87). Juliette Peers is also critical of existing design history methodologies, saying they have led to “alternative and minority positions being overlooked, such as women artists, queer artists, artists outside the nationalist/landscape themes, talented but conservative artists, the often Eurocentric interests of design, applied arts and architecture” (Peers, 2011, p.1-18). Cheryl Buckley suggests that patriarchal perspectives on design history has meant women’s roles in collaborative and domestically focussed design is often devalued and thus excluded. She suggests critical assessments of why women are invisible in historical narratives and encourages the development of feminist frameworks that widen the breadth of these narratives (Buckley, 1986, p.3-14). Judy Attfield mirrors Buckley’s sentiments arguing that historians need to apply a feminist perspective to their research, be “sensitive to diversity” and question object-based conventions existing in design history (Attfield, 1989).

However, there is opposition to focusing on individuals as sole geniuses—of any gender—in these methodologies. Bridget Wilkins states that the old-fashioned approach of identifying single heroes, as done in the historical record of art, is too linear and fixed in its approach. She argues that the change that needs to be made is simply through explaining “why graphic design looks the way it does” (Wilkins, 1992). My counter argument here is that this “why” can actually be found within the lives experienced by these designers and the social contexts that influence them as they built their careers. This innate complexity of designers in competition with what they design is best summarised by Edward Hallett Carr, when he writes, “the question, which comes first—society or the individual—is like the question about the hen and the egg” (Carr, 1964). Yet, the absence of women within this complexity must be scrutinised and remedied because of its stubborn reoccurrence.

Similarly, an insistence on the inclusion of women within histories because of their gender can be problematic. It can frame women as the oppressed martyrs and victims of the patriarchy rather than raising the value of their unique contributions, which are often different to men’s, due to the contextual economic and societal expectations of their times (Beard, 1968). Here, framing such inclusion as ‘feminist history’ rather than ‘women’s history’ begins to resolve this problem, with the differences being simply explained by Sheila Rowbotham. She writes, “Women’s history is defined by its subject matter—women. Feminist history is defined by its conscious standpoint—feminism” (Rowbotham, 1975). Although the definition of feminism has moved through several ‘waves’ since the Suffragette movements’ struggle for the right to vote in the early 1900s, this research simply defines feminism as a form of activism working towards equity. This feminist lens is raised as a challenge to historians, by Ann Curthoys and John Docker, both Australian historians, “... to insist that the traditional or existing historical periods are understood equally in terms

of their meaning for women as for men” (Curthoys and Docker, 2006). This viewpoint is also offered by Patricia Grimshaw, who sees the rethinking of feminist history as closely intertwined with the writing of Australian history; she expresses hope for “not only a new history of Australian women, but the effective writing of a new Australian history” (Grimshaw, 1991, p.151-69).

This connection between women omitted from graphic design in history and the way Australian narratives have been overlooked and undervalued in the history of graphic design can be seen as a side-effect of the trend towards a global design history. This globalised view of the discipline is particularly problematic, not only because of its “marginalisation of women and indigenous people” but because of its “inevitable outcome [of] an homogenised world modelled on Europe or the United States of America” (Huppertz, 2015, p.182-202). However, the future of this “geographical power play”, where innovations and experiences of design in Australia are overlooked, can also be diverted (Huppertz, 2015, p.182-202). According to design historian Daniel Huppertz, this can happen by addressing “where to situate the history (or perhaps the pre-history) of indigenous design in Australia” (Huppertz, 2014, p.205-223). Historical graphic design canons often begin their timelines with Palaeolithic cave paintings in France and Spain and claim that these images are the genesis of graphic design (Jubert, 2006; Drucker and McVarish, 2013; Meggs, 1992).

However, ongoing testing of indigenous rock paintings in remote Australian locations have dated them as up to 65,000 years old. This disputes the origins of the discipline as Eurocentric and pre-dates the images found at Altamira, Lascaux and Chauvet by 25,000 to 30,000 years (Weule and James, 2017). Proper consideration of indigenous histories in Australia, along with ethnographic studies of this culture that still exists, is “crucial in the development of a more inclusive Australian design narrative and identity” (St John, 2018, p.1-19). Although this article focuses on the lack of representation of women post-1960, rather than on indigenous contributions to Australian graphic design, this call for a proper examination of Australian history and “social contexts” is central to its methodology. One which embraces intersectionality (that is the diversity of age, race, religions and abilities, as well as gender) at all stages of the narrative.

Filling the gaps left by the absence of women in history is not a new concept, and it has gained momentum through prominent Australian and global publications like *Places Women Make*, *Chasing the Sky*, and *Women in Graphic Design 1890-2012* (Jose, 2016; Dewhirst, 2017; Breuer et. A., 2012). These revisionist histories all take different approaches to historicising design. More recently international efforts have also continued this momentum towards gender equitable narratives. The Hall of Femmes has published a series of books and podcasts on women in art direction and design, and design historian Cheryl Buckley has continued her work by delivering the paper *On the Record: Researching Women and Design* at the Swiss Design Network Research Summit in 2018 (Unknown, 2009; Buckley, 2019). More books like *Women Design: Pioneers in architecture, industrial, graphic and digital design from the 20th century to the present day*, by Libby Sellers have been published and continue to fill the gendered gaps in the history of graphic design (Sellers, 2017). Some focus

on the forgotten stories of women, some on the individual profiles of women in Australian architecture, and others on a more academic approach in the form of scholarly essays. However, all are in line with the previously mentioned methodologies in advocating for increased diversity within histories. The goal of such work, in addition to learning from the women's experiences, is to create a permanent legacy that we can learn from and celebrate.

4. Success and significant contributions

Defining what a significant contribution is for a graphic designer is as personal and varied as determining what it means to be successful graphic designer. This breadth of scope can also affect the visibility of women in Australian graphic design. Both of these terms— 'success' and 'significant contribution'—are used interchangeably in this article. This is done with the deliberate intention to encourage those women, who I interviewed, to think beyond how success might be defined in the traditional and gendered sense. Empirical studies show that success can be "multi-dimensional", related to "self-concept", and a subjective variable related to an individual's feelings (Gattiker and Larwood, 1993, p.78-94; Van Eck Peluchette, 1993, p.198-208). One way to comment on success is through the understanding of achievement measured by an internal or intrinsic drive; however, success can also be interpreted through more traditional "extrinsic job successes" (Nabi, 2001, p.57-74). For example, remuneration, and moving up the corporate ladder.

One existing measure of success for Australian graphic design is the criteria for the AGDA Hall of Fame, Australia's pre-eminent platform for recognising significant contributions throughout the history of Australian graphic design (Rendoth, 2018).

- These criteria include:
- Longevity of career;
- Extensive and consistent body and quality of work;
- Uniquely high standards of work, of research, investigation and innovation;
- Professional integrity;
- Industry/government awards;
- Peer recognition;
- Published works;
- Exhibitions;
- Powerful and measurable contribution;
- Social, cultural, economic, environmental and political impact;
- Public recognition;
- Educative contribution; and
- National and international participation.

There are intrinsic measures in this criterion, namely integrity, but most of the measures are weighted heavily towards extrinsic values, for example, recognition and power. On top of this, the process through which individuals are inducted into the AGDA Hall of Fame remains subjective. The current implementation of these criteria is performed by the AGDA Hall of

Fame Committee. Initiated in 1992 by Gary Wilson (himself now a posthumous Hall of Fame member), the committee still comprises a majority of men. This brings the issue of gendered and implicit biases and their effect on the AGDA Hall of Fame admissions to the fore, along with differing personal values related to intrinsic and extrinsic criteria. These biases are worthy elements to consider when exploring the visibility of women in Australian graphic design (AGDA, n.d.).

Table 1 AGDA Hall of Fame Inductees.³

Year	1994	1996	2000	'02	'04	'06	'08	'10	'12	'14	'15	'16	'17	'18	'19	Totals
Women	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	4
Men	3	4	2	2	2	2	0	2	1	4	0	1	1	1	1	26
Total	3	4	2	3	2	2	0	2	1	4	0	2	1	2	2	30

Lorraine Dyke and Steven Murphy have shown that there is a distinct difference between how women and men define success. Their qualitative interviews with both women and men showed that “Clear gender differences did emerge, and [that] they echo[ed] in significant ways the gender role stereotypes that still reverberate in our culture” (Dyke and Murphy, 2006, p.357-71). Women predominantly defined success as a balance within their life. This was not a rejection of traditional values like financial rewards, but an overall approach that measured this in equal parts to emotive outcomes. Men, on the other hand, were more likely to equate perceptible gain with success. This bias is evident in the AGDA Hall of Fame criteria, which ultimately celebrates more men than women, as shown in Table 1 (above). For example, many of the male biographies published on the AGDA Hall of Fame point out extrinsic signifiers as a measure of success including, “naturally he bought an MG”, “an attention getter” and “Australia had never seen such bravado in graphic design” (AGDA, n.d. B). AGDA’s propensity to weight its judging on the states of acceptance and appreciation has the potential to omit people who view success as a balance of career and caring responsibilities.

In order to gain a clearer picture of what success might mean for graphic designers in Australia, on a broader scale, the respondents to the Invisible Women Survey were also asked to rate the importance of 24 possible indicators of significant contribution. The top five indicators became: “working experimentally”, “mentoring others”, “having a profile amongst their peers”, “working towards social good”, and “supporting themselves financially as a designer.”⁴ The lowest indicator of significant contribution—rated as “not important” by 72 per cent of the women respondents and 93 per cent of males respondents—was “making a six figure income”. Four of the top indicators only had a 5 per cent difference in responses from women and men; however, the top rating indicator, “working experimentally” had a 14 per cent difference, with women at 32 per cent and men at 46 per cent. This could again be due to the different ways women and men perceive success.

Apart from the risk-taking inferred in men’s preference to work experimentally, what these

outcomes demonstrate is that both women and men in graphic design have a balanced view of what they classify as a significant contribution or as a measure of success in their industry. “Mentoring others” and “working towards social good” both hold intrinsic values, where giving rather than receiving is seen as of “vital importance.” “Having a profile amongst their peers” and “supporting themselves financially” are more extrinsic values, also seen as of “vital importance,” that focus on recognition and financial returns. The top response of “working experimentally” hints that the creativity of graphic designer’s experience internally, and the creativity they express externally through their roles, has both intrinsic and extrinsic elements to it. This, again, is evidence that the participants in the Invisible Women Survey and the wider graphic design community in Australia have a differing opinion as to what classifies as a significant contribution in comparison to the AGDA Hall of Fame.

Table 2 Demographics of participants in the Invisible Women Interviews (2016).⁵

Age	Year of graduation	Highest design qualification	Location of practice	Time in practice	Employment status in practice
30-39	2000s	PhD	VIC	20 to 29	Owner with no employees
30-39	2000s	Bachelor	VIC	10 to 19	Owner with employees
30-39	2000s	Bachelor (Honours)	TAS	10 to 19	Owner with employees
30-39	1990s	Bachelor	VIC	10 to 19	Owner with employees
30-39	2000s	Bachelor	NSW	1 to 9	Owner with employees
40-49	1990s	Bachelor (Honours)	NSW	10 to 19	Partner/Owner with employees
40-49	1990s	Bachelor	VIC	10 to 19	Owner with employees
40-49	1990s	Bachelor	NSW	10 to 19	Partner/Owner with employees
40-49	1990s	Bachelor	SA	20 to 29	Partner/Owner with employees
50-59	2010s	PhD	VIC	10 to 19	Education/ Research
50-59	2000s	Masters	VIC	20 to 29	Owner with no employees
50-59	1980s	Bachelor	VIC	10 to 19	Owner with no employees
50-59	1980s	Diploma	VIC	10 to 19	Creative Director with employees
50-59	1970s	Diploma	TAS	30 to 39	Owner with no employees
60-69	1970s	Diploma	VIC	30 to 39	Owner with employees
-	1970s	Diploma	SA	40 to 49	Education/ Research
-	1970s	Diploma	VIC	20 to 29	Owner with employees
-	1990s	Bachelor	VIC	10 to 19	Partner/Owner with employees
-	2010s	Masters	VIC	1 to 9	Owner with no employees
-	1990s	Unassigned	VIC	10 to 19	Partner/Owner with employees

⁵ The *Invisible Women Survey* asked respondents to name women who had made a significant contribution to Australian graphic design. The 22 most mentioned women who agreed to participate in this project contributed this demographic data.

-	2000s	Bachelor (Honours)	VIC	10 to 19	Partner/Owner with employees
-	1970s	Bachelor	VIC	30 to 39	Owner with employees

But what of women specifically? As previously stated, 22 of the most mentioned women in the Invisible Women Survey were interviewed and asked what they saw as their significant contribution to Australian graphic design. Table 2 (above) outlines the demographic data of the women interviewed. While some women were hesitant to do so, or even to accept that their peers had labelled them as significant contributors, others expressed gratitude that their efforts were recognised. Overall, their responses reflected Dyke and Murphy's research, which demonstrated both personalised and individual responses that had a very balanced view of internal and external drives (Dyke and Murphy, 2006, p.357-71).

Several themes were common among the women; the first was longevity. The graphic designers perceived a career, maintained since graduation, as a high achievement. Enduring economic highs and lows, the impact of motherhood, and the navigation of complex relationships—within studios and with clients—were also common to this theme. Abra Remphrey saw her studio, Detour Design, which she founded in 1992 with Cathy Bell in Adelaide, as her significant contribution, simply saying, "I am very proud of that achievement". Zoe Pollitt and Natasha Hasemer, co-founders of Eskimo in Sydney, both felt their contribution came in the form of "having a successful, independent and profitable 18-year young business. Rosanna Di Risio, the Creative Director of ERD in Melbourne, saw staying involved in the industry since 1980, even when her son was young, as one of her most significant contributions.

Sue Allnutt was proud of contributing 33 years to her studio, one led and founded by her, to the Australian design landscape. This legacy of longevity is reflected in the fact that she now plans for her daughter, Zoë Allnutt, to take over Nuttshell Graphics in Melbourne on her retirement. Over half of the women interviewed shared that they were mothers and indicated that this was often a hurdle to maintaining their longevity. Finding ways to balance careers with caring responsibilities was also equated with success. Laura Cornhill (Figure 1), who is a founder of Studio Binocular in Melbourne, saw her commitment to being a working mother and to breaking the stereotype of leaders as male, as a proud accomplishment, while Suzy Tuxen at A Friend of Mine in Melbourne agreed, saying that managing a family and a career was a significant contribution.

The second theme to emerge from the interviews was the ability to balance the intrinsic view of graphic design as a vocation with the ability to earn a living. Here, women equated the pairing of personal creative fulfilment and financial stability with a high level of success. Jessie Stanley articulated this by expressing the satisfaction she got from both being creative and making a living through graphic design. Sandy Cull saw her work on books with large unit sales, like Stephanie Alexander's *A Cook's Companion*, as equal to her passion for design. Her measure of success was "Find something you love and let it kill you". Gemma O'Brien, a lettering artist/designer, thought she could never "make enough money to live off" when she

started out her career. However, she now works full time all over the world, while managing a lifestyle where she can “work all night and then go to the beach,” which is another one of her passions.



Figure 1 Iron Designer was a self-initiated project Laura Cornhill and Studio Binocular developed for the State of Design Festival in Melbourne and for Sydney’s Design Week, 2008/2010 (left). Image reproduced with permission from Laura Cornhill. Laura Cornhill (right), photographed by Carmen Holder and Deborah Jane Carruthers, 2016.

Still other women who ran their own studios saw nurturing the independent careers of employees through a healthy workplace culture as a significant contribution. Kate Owen, owner of Futago in Tasmania, saw offering stable employment and “growing an industry that ha[d] clear pathways for people” as her significant contribution. Simone Elder, a co-founder of studio Ortolan along with Kat Macleod and Chloe Quigley, was proud that her studio had both contributed to the success of other emerging designers and prioritised a work/life balance. This theme of helping others often extended beyond the women’s studios. Many of the graphic designers saw their conscious efforts at advocating for women in design and best practice for their industry as their measure of success. Michaela Webb of Studio Round (Figure 2), the most mentioned woman from the Invisible Women Survey and thus one of the most visible, used her profile to encourage other women to increase their visibility and positions of power. Rita Siow (Figure 2) was integral to the running of AGDA for over 20 years. She said that the power that her leadership offered has left a legacy in the Australian graphic design industry. She implemented the first ever Design Effectiveness Award in the AGDA Awards. She also linked the graphic design community throughout Australia by insisting that AGDA events run in all states and territories, not just Melbourne and Sydney. On reflecting on her contributions, Siow mentioned, “I would love to see that effect, not only on practice, but also on aspirations [for AGDA members]...”.



Figure 2 Michaela Webb, from Studio Round (left) and Rita Siow, formally of AGDA (right), photographed by Carmen Holder and Deborah Jane Carruthers, 2016.

Lastly, a common theme in the definition of significant contribution was that of imbuing positive change into Australian graphic design. Lisa Grocott, a Professor at Monash University, discussed the importance of “finding personal courage to do different, difficult things,” which is something her role as a researcher and educator has contributed to in New York, New Zealand and Australia. Maree Coote (Figure 3), now a gallery owner and publisher, began her career in advertising. She was one of the first women to be in charge of establishing a large advertising agency in Australia, the John Singleton Advertising agency, in 1995. She views her significant contribution as injecting some empathy into a male dominated industry. Fiona Leeming established her advertising career in tandem with Coote and is currently the Executive Creative Director of Honey Communications but is clear that “making change” is still the focus of all her creative contributions. Lastly, Wells’s sensitive advocacy work with indigenous communities, including the Nyinkka Nyunyu Art and Culture Centre in Tennant Creek and the Kanaky people, also sought to make positive change through design.



Figure 3 In 1997, this Crown campaign became one of the largest ever TV productions at the time, worth \$2.5m(left). Image reproduced with permission from Maree Cootee. Maree Cootee (right), photographed by Carmen Holder and Deborah Jane Carruthers, 2016.

There are many discrepancies between how the AGDA Awards, the Invisible Women Survey respondents, and the interviewees all define success and significant contribution. These many differences reinforce the idea that there is not one homogenous definition to success, but rather, many unique and individual approaches to what it means. However, these differences, or rather the prioritisation and experience of these definitions, can also hinder the visibility of women in Australian graphic design, especially in the case of the AGDA Hall of Fame criteria. Longevity for women and men can be very different in Australian graphic design because of the effect of gendered societal pressures, including parenthood, as mentioned in the above interviews. Work/life balance and the injection of passion into a financially sustainable career is not mentioned in the AGDA criteria, but it is noted as a high indicator of success in the interviews and the Invisible Women Survey responses. An experimental practice, also highly prioritised by the Invisible Women Survey respondents, is also overlooked by AGDA. Together, these discrepancies also point to the idea that women can ignore opportunities, like the AGDA Hall of Fame, because it is irrelevant to their personal drive and definition of success and significant contribution. Thus, this gendered influence leaves them less visible in the industry. Rosanna Di Risio summed up this sensitivity well when she said, “It’s not very cryptic. I think women generally don’t care about the accolades”.

5. Conclusion

In summary, graphic design inherently leaves its practitioners invisible. However, findings from the Invisible Women Survey paired with interviews with women in Australian graphic

design demonstrate three distinct processes that directly affect the invisibility of women. These include the disparate understanding of graphic design, the inequitable historical record of graphic design, and the heterogeneous understandings of ‘success’ and ‘significant contributions.’

The complex lexicon surrounding graphic design leaves both the public’s perception of the industry and graphic designers themselves, cloaked in confusion. This murky identification of what a graphic designer should be called has left many women invisible. Similarly, women are excluded from historical references about the industry simply because these narratives are often written by and about men. Women’s contributions have therefore become less valued, less celebrated and inevitably more invisible. The last factor that contributes to this invisibility are the terms ‘success’ and ‘significant contribution’. My research has shown that industry bodies, like the AGDA Hall of Fame have entry criteria that are skewed towards extrinsic values of success. Research has shown this is something frequently associated with success by men and has resulted in more men being awarded into the AGDA Hall of Fame. This has left many women invisible and has discredited alternative views of success.

Having identified specific processes that decrease the visibility of women in Australian graphic design, further research could begin to improve upon this problem. How we might decide on a clear definition of graphic design, generate equitable histories and more broadly prescribe success can raise the visibility of women, not only in Australian graphic design but in a much broader concept of the workplace.

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Appendix

Table 3 *Invisible Women Survey. Q) What do you think is important when deciding that any individual has made a 'significant contribution' to the graphic design industry?*

	Not important		Somewhat important		Important		Vital		N/A		Weighted Average
1. Working experimentally	7%	11	17%	27	38%	59	36%	56	1%	2	3.05
2. Mentoring others	6%	10	15%	23	50%	77	28%	44	1%	1	3.01
3. Working towards social good	8%	13	23%	35	45%	70	23%	36	1%	1	2.84
4. Having a profile amongst their peers	10%	15	23%	36	39%	61	27%	42	1%	1	2.84
5. Supporting themselves financially as a designer	11%	17	19%	30	45%	69	24%	37	1%	2	2.82
6. Having a long career (10+ years)	10%	16	25%	39	39%	60	25%	39	1%	1	2.79
7. Having returning clients	9%	14	30%	47	38%	59	22%	34	1%	1	2.73
8. Publishing personal projects	15%	24	31%	48	41%	63	13%	20	0%	0	2.51
9. Working with new technology	23%	36	28%	43	30%	47	18%	28	1%	1	2.44
10. Presenting at seminars/conferences	23%	35	30%	47	35%	54	12%	18	1%	1	2.36
11. Having a recognisable style	28%	44	28%	43	26%	41	16%	25	1%	2	2.31
12. Balancing a family and design career	30%	46	20%	31	33%	51	13%	20	5%	7	2.3
13. Being an active member of professional body	32%	50	31%	48	28%	44	8%	12	1%	1	2.12
14. Teaching in the field	26%	40	44%	68	24%	37	6%	9	1%	1	2.1
15. Working at a reputable studio	32%	50	32%	50	29%	45	5%	8	1%	2	2.07
16. Having accredited qualifications	35%	54	36%	56	26%	40	3%	5	0%	0	1.97
17. Winning prestigious awards	32%	50	45%	69	18%	28	5%	8	0%	0	1.96
18. Working with start-up clients	42%	65	34%	52	19%	30	4%	6	1%	2	1.85
19. Owning a business	44%	68	32%	49	19%	30	3%	5	2%	3	1.82

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20. Working with large clients	43%	66	35%	55	15%	23	5%	8	2%	3	1.82
21. Having a senior job title	49%	76	26%	41	17%	26	6%	10	1%	2	1.8
22. Working overseas	54%	83	29%	45	15%	23	2%	3	1%	1	1.65
23. Having employees	61%	94	27%	42	8%	13	2%	3	2%	3	1.51
24. Making a six-figure income	78%	121	14%	22	5%	8	1%	1	2%	3	1.27

NB// The total number of participants who answered this question was 155. The top five contributions are highlighted.



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Enhancing Interactivity: How has design exploration of physically and intellectually interactive picturebooks enhanced shared reading?

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Abstract: Children’s book design can have a significant impact on shared reading practices, interaction, and engagement. We hypothesise that books designed with the intention to specifically enhance the author’s story through interactivity will provide opportunities for new experience design outcomes that are both human-object and human-human centred. The multi-faceted problem of children’s books has been explored by linguistics, history, and education researchers, yet seldom using a design lens. In previous work we developed a traditional and highly interactive picturebook which we observe here being used by families. The study explored how physical and intellectual enhancements change the level and types of interaction within a shared reading environment. The inclusion of physical and intellectual enhancements within the book promote a greater level of interaction and engagement from the parent and child. However, this is only the case if the enhancements provide meaningful interaction, and have relevance to the story. Our results provide design solutions for designing effective children’s books in the future.

Keywords: picturebooks; interactive books; children’s books; paper engineering

1. Introduction

Shared reading between a parent and child is an important opportunity for learning, development, and growth for young minds. Children’s books, including picturebooks, whether used by individuals, or in shared reading situations, enable a wide range of learning opportunities. Children’s books also afford the opportunity to engage readers in interactive learning and reading experiences that could further enhance the shared reading experiences as well as the learning opportunities. However, the level of interaction and engagement that occurs within these shared reading sessions has the potential to vary greatly depending on the parent, child, and the design features within the book itself. Given the many variables that lead to interaction and engagement in shared reading sessions we believe that further



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investigation into the design of books that encourage reader participation is required.

In this paper we focus our work on children's picturebooks. An expansive definition of a picturebook was provided by Bader (1976):

A picturebook is text, illustrations, total design; an item of manufacture and a commercial product; a social, cultural, historical document; and foremost an experience for a child (p. 01).

Put simply, Kiefer states that a picturebook can be described as "an artefact of culture that contain[s] visual images and often words" (Kiefer, 2010, p. 01). In our work we posit a definition whereby a picturebook can be understood to be a book in its many forms (physical or electronic as well as the many sub classifications therein) that may combine text and image in some form. Specifically, in this paper we are concerned with physical picturebooks.

Previous work has investigated design features of successful children's picturebooks, and recommendations for appropriate language and story content (e.g. Hall, 1990; Bloom, 2002) and imagery (e.g. Piro, 2002; Gibbons, 1999) have been presented in the literature. In turn, there has been a broad range of home and school education techniques developed to encourage successful shared reading practices. Missing from the literature is evidence to support the design of highly interactive picturebooks that enhance shared reading. Interactivity provided by picturebooks and the experience of shared reading is hypothesised to support learning (e.g. Cheng and Tsai, 2014). Piehl (1987) explains that interactive features should be included to enhance the narrative of the book or, in the case of non-fiction interactive books, help the reader to better understand the textual content.

Examples of interactivity in printed books discussed in the literature have included physical interactions that draw upon the basic learning principle of 'touch', as discussed by Silverman (2006) or as Goodwin (2008) suggests, "invite involvement" (p. 29) or exploration of the content and more recently augmented reality exploration (e.g. our related work; Vanderschantz et al. 2018 & 2019).

Considerations relating to children's digital books have also featured throughout the literature including for example interaction design (e.g. Vanderschantz and Timpany, 2012; Wasik and Bond, 2001) and typographic design of electronic texts (e.g. Vanderschantz, 2009; Vanderschantz et. al. 2010; Walker and Reynolds, 2000). We posit that specific consideration of the interactive properties of books provide opportunities for enhanced reading experiences and could further enhance the shared reading experience. We therefore propose investigation into features of interactivity that would create numerous opportunities for interaction with the book and could therefore be considered a *highly interactive picturebook*. This potential for synergising the literature and providing guidance for designers is central to the research presented in this paper.

We present a user observation study that compares a traditional children's picturebook with an interactive children's book designed specifically to provide meaningful human-object and human-human interactions. Seven families with children aged between four and six years old

participated in a series of user observation studies and from these we identified increased interaction amongst parent and child when presented with the highly interactive version of the picturebook. The results provide design solutions and frameworks for the successful design of children's interactive books in the future.

2. Related Work

The value of children's books has long been advocated, with researchers showing that children's books are important not only for learning literacy, but also aspects of problem solving, socialisation, hand-eye coordination, creativity and understanding the world (Freedman-DeVito, 2004). It is important for children to be able to emotionally engage with picturebooks and identify with the story quickly (Goodwin, 2008), allowing them to become involved in the narrative and have an active desire to discover the outcome (Norton, 2011). We focus the related work on discussion of interactivity, particularly with reference to physical objects including books, and how interactivity can enhance shared reading situations.

2.1 Interactive Books

'Interactive' is a broad term that encompasses a wide range of variables. "Interactivity is a theoretical construct that grapples with the origins of captivation, fascination, and allure" (Rafaeli and Sudweeks, 1997, para. 1). Rafaeli and Sudweeks (1997) state that interactivity is not tied to a medium, but is a communication process. When defining interactivity types of affordances can be identified based on the role they play in supporting interactivity, physical affordance and cognitive affordance based on the work of Norman (1999), as well as sensory affordance and functional affordance (Harston, 2003).

Interactivity occurs in message-based, and participant-based, dimensions and on continua from low to high on each of these dimensions (Downes and McMillan, 2000). The attempt by Downes and McMillan (2000) to define interactivity reveals that there are many variables when describing interactivity and the motivation of the individual in the interactive environment plays a part in determining how interactive an environment is.

Interactivity during reading occurs in a range of ways. Interaction can be naturally afforded by the physicality of a traditional book, while designers, authors, and publishers also incorporate intentionally interactive features into books by way of illustrations, text presentation, textual instruction, or physical enhancements. Selznick (2008) suggests that at its most basic level interactivity with a book comes with the turning of the page. Silverman (2006) discusses the importance of physical engagement by stating that, "learning comes through touching and physical sensation. Thinking is anchored by movement, and touch..." (p. 71). This physical interaction is one of the earliest forms of learning, and consequently is why 'touch and feel' interactive books are so effective and engaging for young readers. The *Smithsonian Institution Library* discusses how "movable and pop-up books teach in clever ways, making the learning experience more effective, interactive, and memorable" (National

Museum of American History, 2010, p. 7). By promoting a hands-on approach to learning – both figuratively and literally – interactive books allow the depiction of a written concept in visual form. While there are potentially many benefits of using pop-up books in educational contexts, Taylor and Bluemel (2003) also highlight the benefits of using interactive books in shared reading situations.

Timpany and Vanderschantz (2012) investigated interactivity in printed books and identified two types of interaction, *Physical Interactions* and *Content Sequencing Interactions*. Timpany and Vanderschantz suggested that in a book interaction can be identified as occurring through both the physical enhancements of the page itself (physical interaction), as well as the intellectual enhancements that promote interaction in the form of questions, answers, and sequencing of content (content sequencing). That is to say, a reader can interact with both the physicality of the book as well as with the content of the book. Timpany and Vanderschantz suggest that interactive features of books encourage further interaction as well as providing learning tools that can assist the child to understand a new concept either physically or intellectually.

Timpany and Vanderschantz's (2012; 2013) research provided the first categorisation system to aid researchers and publishers to describe interactive properties of children's books and can be used when analysing, selecting and designing children's books. Their classifications (see Table 1) provide a way to discuss, analyse and understand the interactivity levels within children's printed books and how this leads to reader interaction.

Timpany and Vanderschantz concluded that interactivity can be viewed as a continuum, where the medium of the book demands different types of interaction from its readers in order for the content to be consumed. They suggest that with a more complex enhancement, children will be prompted to interact and engage with the book at a deeper level. That is to say, depending on the level of interactivity, interactive children's books allow young readers to become more engaged in the literary experience and gain more from the book. Timpany and Vanderschantz recommend that children's books be designed with these frameworks in mind in order to ensure that children gain the greatest enjoyment and educational possibilities from reading sessions. To date the literature does not describe works that have been developed specifically to engage high levels of interactivity nor have these works been tested with users.

Table 1 Timpany and Vanderschantz (2012) Dual Categorisation System for Describing Children’s Interactive Printed Books. Physical Enhancement (L) and Content Sequencing (R).

<i>Physical Enhancement</i>	<i>Content Sequencing</i>
Level 0 - Reader is required to open book and turn pages	Level 0 - Reader’s attention is guided in a linear course through page content
Level 1 - Reader is required to pen book and turn pages with some additional interaction within the book	Level 1 - Reader’s attention is internationally guided in a non-linear course around page content
Level 2 - Reader is required to pen additional inner pages to reveal further content	Level 2 - Reader’s attention is internationally guided in a non-linear course around page/book content and drawn back and forth between set areas of contrasting content
Level 3 - Reader is required to lift flaps, turn wheels, pull tabs, push buttons etc	Level 3 - Reader is required to solve puzzles/challenges to/or determine the order in which the pages are read
Level 4 - Reader is required to interact with multiple layers of interactive elements or create/arrange content themselves	Level 4 - Reader is required to progress through the book by making decisions that will affect the ultimate story line
	Level 5 - Reader is required to carry out activities or actions guided by content of the book externally

2.2 Shared Reading

Shared reading is the act of a child and adult reading together, and is widely considered to be beneficial for helping with early literacy and language development (Ezell and Justice, 2005). Shared reading is suggested to promote both a child’s understanding as well as their engagement with texts and stories (Worthy et al. 2012). The practice of shared reading enables one-on-one learning, where the child can progress from not being able to read, to being able to read independently. Goodwin states that adults within shared reading situations “act as mediator between the text and the book” (2008, p. 30), therefore helping the child in this transition from non-reader to independent reader. Shared reading is important for children’s literacy development not simply because of the act of a child listening to a parent or caregiver read, but through observing, participating in, and interacting with the reading experience (Justice and Kaderavek, 2002).

The quality of shared reading experiences impacts the facilitation of language development, particularly that of expressive language development (Fletcher, 2005). Girolametto and Weitzman (2002) discuss three key behaviours and their associated techniques designed to gain responses from young readers and promote further learning and engagement; Child-oriented responses, Interaction-promoting responses and Language-modelling responses. These three “responsiveness” behaviours, explored further by Ezell and Justice (2005), rely on parents reacting to situations and acting accordingly. Han and Neuharth-Pritchett (2013)

investigated strategies that can help to maximise the benefits of at home shared reading with pre-schoolers. They classified the shared reading practices between a parent and child into meaning-related or print-related. These dialogic reading practices were identified when the child and parent become active partners in the reading experience through meaningful interactions, including providing feedback and asking questions which Han and Neuharth-Pritchett refer to as “wh- questions”, or “who”, “what”, “where”, “when”, and “why” questions. These features of shared reading identified in the literature all highlight the role of interaction in shared reading. Interaction between adult and child, interaction between adult and book, and interaction between child and book.

While it is clear that the role of the adult in a shared reading situation is critical it is fair to assume that not all adult reading partners will be well versed in structuring a reading situation that is optimal for a child’s development. Mol et al. (2008) discuss that interactive reading techniques were not spontaneously applied in observational studies, suggesting that parents need training on how to practice these techniques to assist with teaching language. Bus et al. (1997) go so far as to suggest that helping participants to improve their reading habits is required to fully support and facilitate effective learning for young people in shared reading situations. Certain features and criteria enable shared reading to be more productive, depending on the choice of book and the participation of both parent and child. A book chosen for shared reading should “invite involvement” (Goodwin, 2008, p. 29) from both the child and the parent. The interaction between the parent, child, and book can become a “process-related communication” as discussed by Rafaeli and Sudweeks (1997). In this regard, any reading experience when properly facilitated by the parent can become a shared reading experience. By utilising books with engaging content that challenge the young reader, children will be encouraged to push themselves and strive to understand at a higher level (Goodwin, 2008). Given the need to further support adults, caregivers and parents to facilitate meaningful learning opportunities and interactions with picturebooks for their children we hypothesise that books that are designed with interaction as a central premise will assist with improving shared reading situations.

3. Method

We undertook a user observation study to investigate how interactive features in children’s picturebooks change the interactions, engagement, and book use between a parent and child in a shared reading situation.

- This research sets out to determine;
- How do children and parents interact with books during shared reading sessions?
- Do interactive features of books affect how parents and children use books?

3.1 Procedure

Seven families were invited to participate in two 20-minute shared reading observation sessions. These sessions were video recorded and manual field notes were taken. Each

session included an observation of shared reading and a post-observation semi-structured interview. An initial interview was conducted before the first observation session to capture demographic information and an understanding of the child and parents' reading habits. Interviews and observations were conducted with all seven families in their homes, and at times that were selected by the families.

Table 2 Coding and categorisation of interactions.

Observations	Theme Code	Classification	Code	Physical	Intellectual	Non-Book
Emphasis	1	Voices -parent	1.1	1.1.1	1.1.2	1.1.3
		Exaggeration – parent	1.2	1.2.1	1.2.2	1.2.3
		Exaggeration – child	1.3	1.3.1	1.3.2	1.3.3
		Pointing out feature – parent	1.4	1.4.1	1.4.2	1.4.3
		Pointing out feature - child	1.5	1.5.1	1.5.2	1.5.3
		Singing – parent	1.6	1.6.1	1.6.2	1.6.3
		Singing – child	1.7	1.7.1	1.7.2	1.7.3
	Physical	2	Touching book – parent	2.1	2.1.1	2.1.2
Touching book – child			2.2	2.2.1	2.2.2	2.2.3
		Actions – child	2.3	2.3.1	2.3.2	2.3.3
		Actions – parent	2.4	2.4.1	2.4.2	2.4.3
		Noises – parent	2.5	2.5.1	2.5.2	2.5.3
		Noises – child	2.6	2.6.1	2.6.2	2.6.3
		Looking closer – parent	2.7	2.7.1	2.7.2	2.7.3
		Looking closer – child	2.8	2.8.1	2.8.2	2.8.3
Questions	3	Reader – Child	3.1	3.1.1	3.1.2	3.1.3
		Child – Reader	3.2	3.2.1	3.2.2	3.2.3
		Book – Child	3.3	3.3.1	3.3.2	3.3.3
Answers	4	Reader – Child	4.1	4.1.1	4.1.2	4.1.3
		Child – Reader	4.2	4.2.1	4.2.2	4.2.3
		Child – Book	4.3	4.3.1	4.3.2	4.3.3
Comments	5	Reader	5.1	5.1.1	5.1.2	5.1.3
		Child	5.2	5.2.1	5.2.2	5.2.3

Following the initial interview, the child and parent took part in the first observation, a shared reading of the traditional (control) version of *'Hannah's Favourite Place'*. The second session took place no earlier than one week after the first reading observation and involved

observing the parent and child participating in shared reading with the interactive version of *'Hannah's Favourite Place'*. After each of the shared reading sessions, a short semi-structured interview was conducted that asked the parent and child questions about how they interacted with and used the features of the book, and what they enjoyed about the book that they read.

Parents and children were interviewed, interactions with the books were video recorded with audio, and photographs as well as researcher notes were taken. Observations of the observed interactions by the parents and children and how these were guided by the book features, were coded according to the categorisations presented in Table 2. The codes used were developed to encode whether the observations noted were based on; emphasis, physical interactions, asking questions, answering questions or commenting. Emphasis interactions were encoded when a participant made voices, exaggerated a word, or sang. Physical interactions that were coded included touching the book, making actions or acting out the story (some of which included noises). Question and answer interactions were those between child and adult and may have been prompted by the book, or by the readers themselves. Finally, comment interactions were used to code general discussion throughout the reading session.

3.2 Materials – Hannah's Favourite Place

For this study we use the book *'Hannah's Favourite Place'* by Fiona Mason. *Hannah's Favourite Place* was developed as a research tool specifically to allow comparison between a book that includes no specifically designed interactive content (referred to throughout as the *traditional picturebook*), and one that encourages interaction through the inclusion of purposefully designed and developed interactive elements that enhance the story and the reading experience (referred to as the *highly interactive picturebook*). The two books have the same narrative and base illustrations in order to facilitate direct comparisons of the opportunities created by the different book formats.



Figure 1 Front Cover (L) and Spread 2 (R) of the traditional picturebook version of Hannah's Favourite Place.

The highly interactive picturebook (Figure 2) that was developed incorporated a range of physically and intellectually interactive enhancements throughout the book. Design decisions were taken to develop a highly interactive book that rates high on both of Timpany and Vanderschantz (2012) physical and content sequencing scales (see Table 1). We took cues from Timpany and Vanderschantz as well as the wider literature in order to develop this interactive printed picturebook. While we set out to design and implement a highly interactive picturebook when developing Hannah's Favourite Place, we were guided by the assumption that there is a fine line between being an effective reading tool and simply a game or an interactive feature that exists with little purpose. Itzkovitch (2012) argues that interactivity must be considered to ensure the reader is engaged in learning experiences that are enhanced by the interactive reading experience and are not distracted from the reading or learning intention. Timpany et al. (2014) expand on this based on their shared reading study stating that activities or games that are inconsequential or included 'for the sake of it' have the potential to add nothing to the storyline, and may in fact hinder the overall learning experience.



Figure 2 Front Cover of the traditional picturebook version of *Hannah's Favourite Place* (L) and Spread 2 of the of the highly interactive picturebook version of *Hannah's Favourite Place* (R).

When developing the highly interactive picturebook we implemented physical (see Table 3) and intellectual enhancements (see Table 4) aimed at promoting both physical as well as intellectual interactions. Our goal was to develop enhancements that would promote multi-faceted learning opportunities and afford human-object as well as human-human interactions.

Table 3 *Hannah's Favourite Place* physical enhancements

Spinning Wheel
Simple and complex pop up structures
Tactile Letters
Lift the Flaps
Envelopes containing objects
Pull tabs
Windows
Moving elements – swinging jack
Accordion mechanisms
Sliders
Dry-Erase page

An example of the physical enhancements includes the addition of a tactile alphabet letter on each page to promote letter recognition through physical interactions. Another example is that each spread’s illustration was enhanced with a tactile or illustrated ‘hidden’ cupcake for search and find activities that afforded both physical and intellectual interaction. Table 3 presents the physical enhancements included in the book. Further intellectual features were included in the form of goals that are listed in the front of the book, along with instructions to guide the parents in the shared reading activities provided. The goals were designed to encourage parents to focus on different aspects of the book and to assist parents to adjust the reading experience according to a level appropriate for their children. Table 4 presents the intellectual interactions included in the book.

Table 4 Hannah’s Favourite Place intellectual enhancements - goals

G1	Find the cake or cupcake on each page
G2	Point out the letters and talk about the alphabet
G3	Talk about words, meaning and spelling
G4	Find something to count on every page
G5	Find different shapes, talk about them and draw them
G6	Identify the colours
G7	Ask questions about the book and the real world
G8	Talk about your favourite places and draw them
G9	Imagine what your favourite place could be

3.3 Participants

We used the snowball recruitment technique to find participants through personal contacts, within the community, and through referrals. The participant sample included seven families, each with children between the ages of four and seven. Table 5 provides a detailed overview of the participant sample.

Table 5 Participant Sample - interactive children’s books

Family ID	Family 1	Family 2	Family 3	Family 4	Family 5	Family 6	Family 7
Age	5	4	4	6	6	4	4
Child	M	M	M	F	M	M	F
Parent	F	F	F	F	F	F	F

4. Results

Here we discuss the results of the two observation and interview sessions. To help illustrate the results of our observation study we will describe some of the individual family observations (paper limits mean we cannot describe all interactions made by each family).

4.1 Observation Session 1 — non-interactive picturebook

Session 1 was the first time that the families had seen and read *Hannah's Favourite Place*. During Session 1, all children stated that their favourite part of the book was the pictures with five of the seven parents also stating that they enjoyed the pictures. Four parents commented on their enjoyment of the text with Parent 4 describing the rhythm of the story as “Dr Seuss-y”. Alternatively, Parent 2 commented that they did not like the story due to the “made up word” (Glubmumpkin).

During Session 1 we noted a wide range of behaviour and interactions by the parents ranging from pointing out features of the book to asking questions and making comments. We noted the total number of interactions varied per family. Family 2 made the highest number of total interactions during Session 1 (149 total interactions) compared to Family 6 who made only four interactions (see Figure 3). The fact that the total interactions varied so greatly provides evidence for the need for educating parents about effective shared reading practices, and demonstrates that books themselves must give parents the tools for participating in such a way. We further detail the interaction types undertaken by the families in Figure 4. Figure 4 shows that each parent appears to approach interactions when shared reading in a different manner. No parent we observed used a high number of all interaction types, instead, typically favouring one or two interaction types. In the case of families 4 and 6 we see that they undertook very few of any interaction types, but still favoured one or two interaction types in the small number of interactions they had.

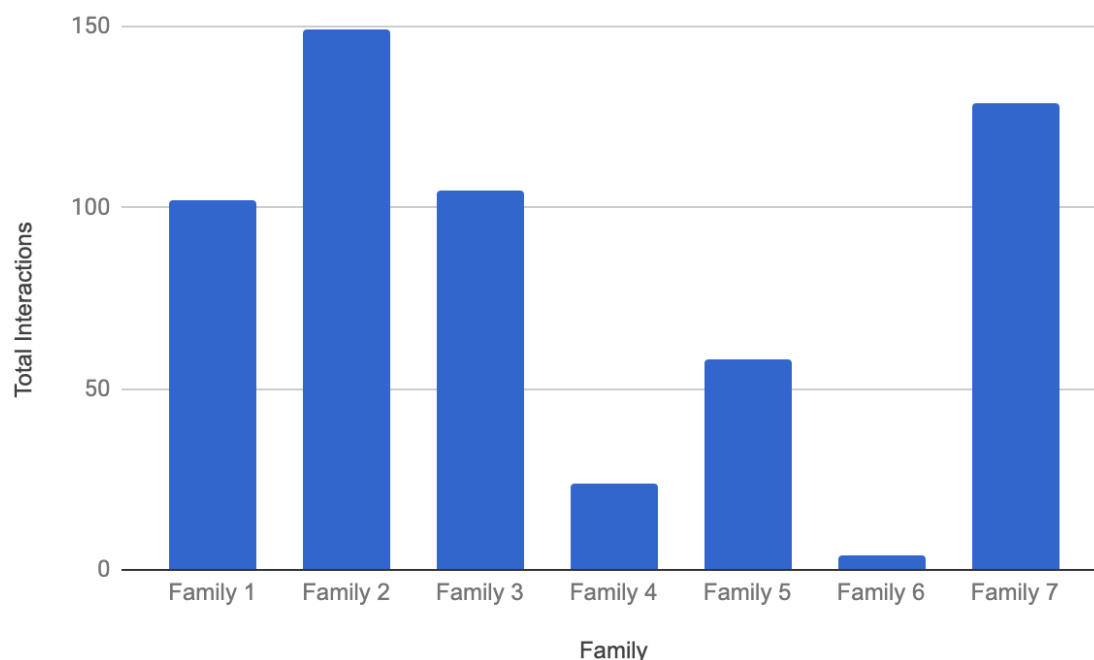


Figure 3 Total number of interactions by all 7 families – Session 1

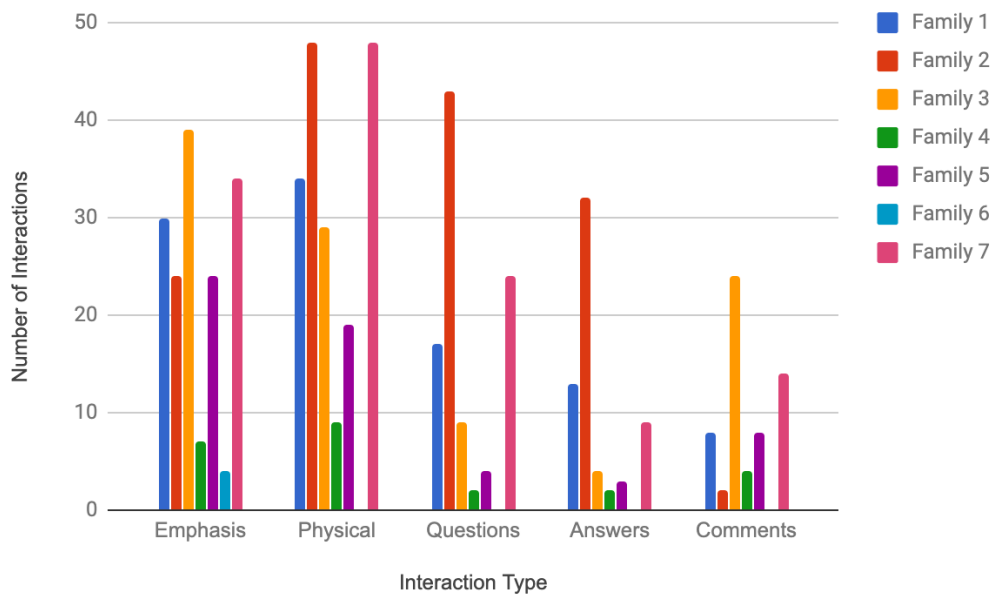


Figure 4 Total interactions by all families according to interaction type – Session 1

When asked about their reading session all parents stated that their actions were intended to keep their child interested in the shared reading experience. This shows an understanding of the importance of keeping children engaged in the shared reading practice, whilst demonstrating that the understanding and undertaking of effective shared reading practices varies greatly from family to family. Six parents believed engagement was accomplished by involving the child in the reading activity, and one parent (Parent 6) believed that, to keep the child attentive she had to read the book as fast as possible.

During the interview process, it was found that Family 1 participates in shared reading on a daily basis, with the parent actively seeking out aspects within books to “keep him listening... keep him engaged”. This shared reading practice was demonstrated in Session 1, with 102 interactions noted in total – 45 of these driven by the parent, and 57 by the child (see Figure 3). Parent 3 encouraged her son to touch and turn pages during the first observation session. When asked about this they stated that the practice “stimulates the brain and encourages him to explore”. This demonstrates Parent 3’s understanding of the importance of touch in the learning process, even in a non-interactive book. Family 4 included one of the oldest children in the study – 6 years old – during the initial interview, the mother stated that shared reading only occurs between the pair twice a week, however the child undertakes independent reading on a daily basis. Throughout both reading sessions, both mother and daughter took turns to read through the text.

4.2 Observation Session 2 – highly interactive picturebook

During Session 2 we again noted a wide range of behaviour and interactions by the parents and children. Family 2 again made the highest number of total interactions during Session

2 (400 total interactions) compared to Family 6 who still made the fewest interactions with only 100 interactions (see Figure 5). We further detail the interaction types undertaken by the families during Session 2 in Figure 6. The results in Figure 6 show that even though the number of interactions increased overall for all families each parent still seemed to engage more in one or two interaction types. Families 4 and 6 increased their numbers of interactions, but with a strong preference for physical interactions, as encouraged by the book. For all families the greatest number of interactions were physical, but the second most common interaction was either emphasis, questions, or comments.

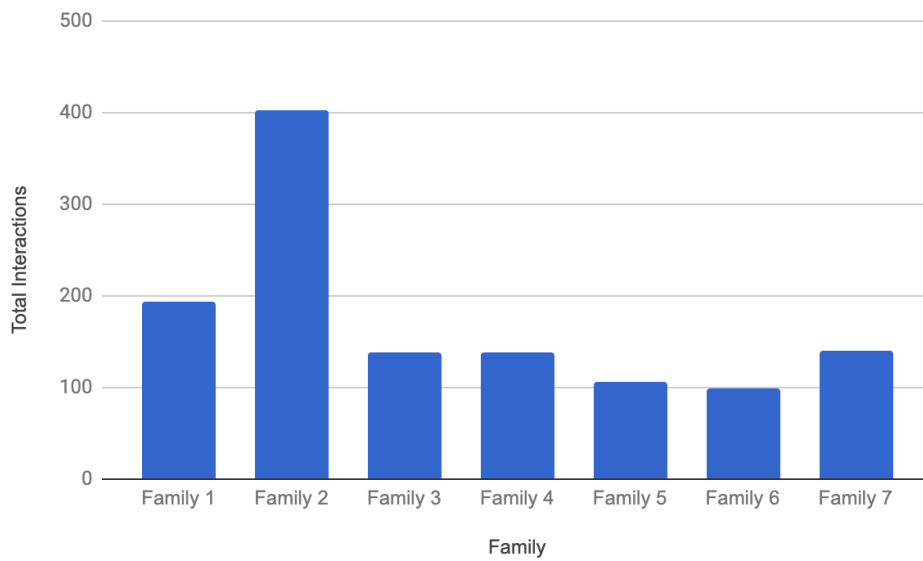


Figure 5 Total number of interactions by all 7 families – Session 2

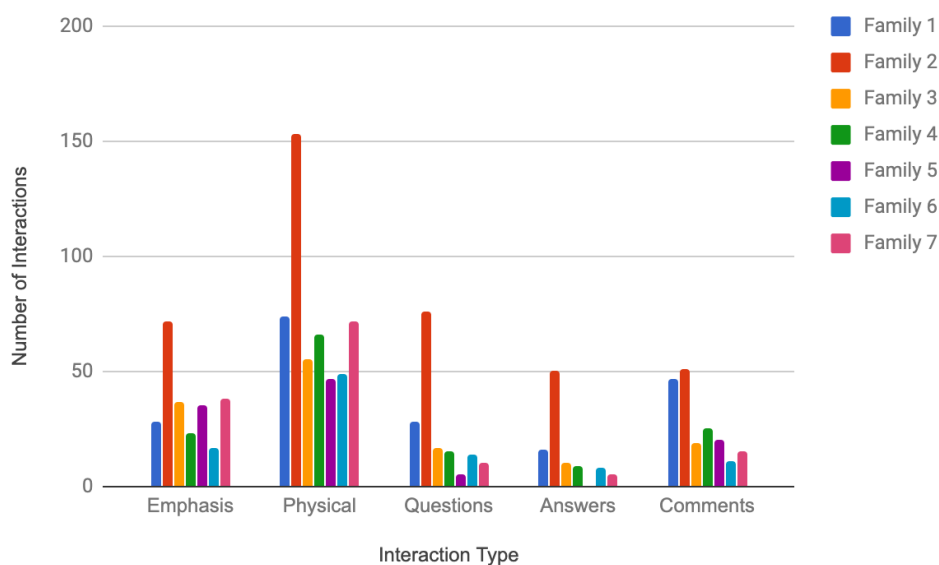


Figure 6 Total interactions by all families according to interaction type – Session 2

The total number of interactions more than doubled from Session 1 to Session 2 (571 to 1217, see Figure 7). The increase between Session 1 and 2 can directly be attributed to the physical and intellectual enhancements of the highly interactive version of *Hannah's Favourite Place*. Examples of these increases from session to session include Family 4 made only 24 interactions in total (see Figure 3) in Session 1, with 15 of these undertaken by the parent, and nine by the child. Yet, Session 2 saw a large increase in interaction from both parent and child (101 total interactions, see Figure 5). This is significant due to the fact that the pair rarely participates in shared reading in the home setting. This demonstrates that effective shared reading practices continue to be beneficial for children through their higher levels of reading and development. Equally, Family 6, a family who reads once a month together and who made only four interactions in the first session, made 99 in the second session. Out of the 138 total interactions noted in Session 2 by Family 3, 99 of these were driven by design features of the book (44 interactions were conducted by the parent, and 55 by the child).

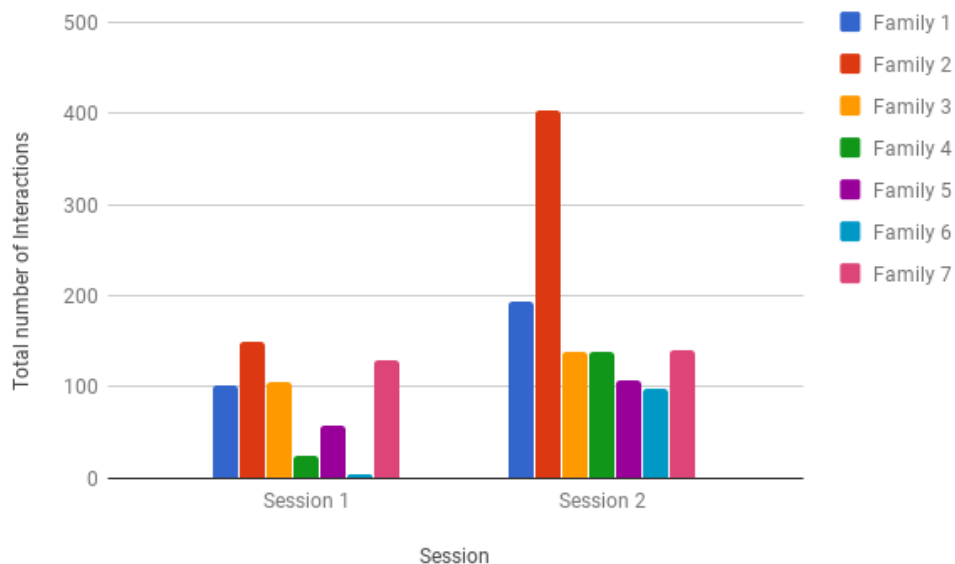


Figure 7 Comparison of total number of interactions per family over Session 1 & Session 2

Whilst there was an overall increase in total number of interactions between the two sessions, it is interesting to note where these increases were most significant, and which interactions were lacking. The physical interactions increased the most from Session 1 to Session 2, (187 in Session 1 to 516 Session 2, see Figure 8). Family 7 showed the most significant increase in physical interactions, which jumped from 42 physical interactions in Session 1 to 72 physical interactions in Session 2. 51 of these 72 interactions were undertaken by the four-year-old child, demonstrating how the addition of physical interactive features promotes tactile, 'hands on' learning especially for these younger participants.

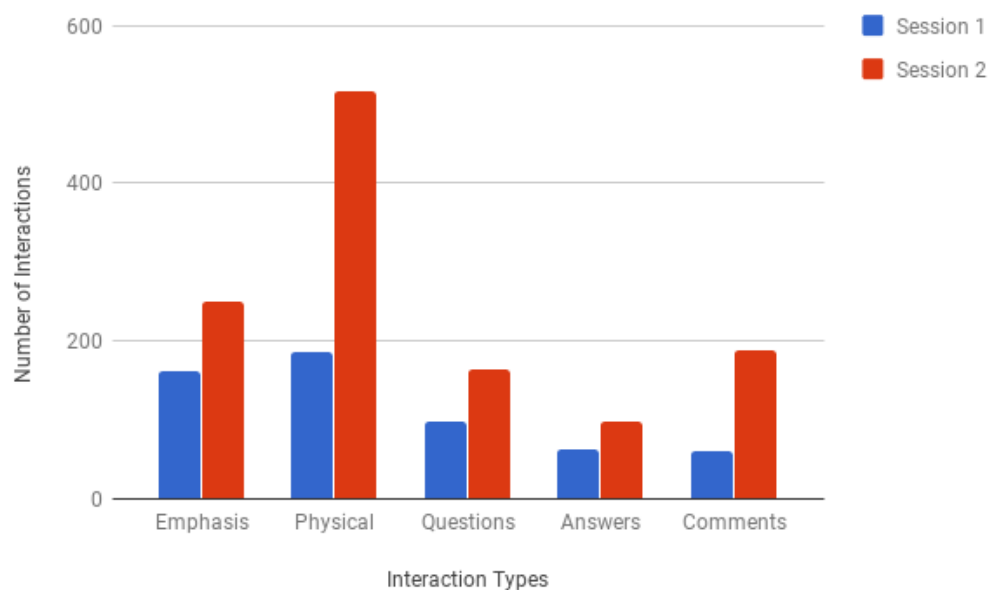


Figure 8 Total Interactions that occurred over the two observation Sessions

Emphasis interactions increased from 162 in the first session to 250 in the second session (see Figure 8). The physical and intellectual enhancements within the interactive version of *Hannah's Favourite Place* encouraged both parents and children to point out features, ask questions, and to make further connections between the storyline, illustrations and enhancements on the page. An example of a coded Emphasis Interaction for Family 1 was when the child pointed to the paper enhancements and stated “these are the flowers that reach to the sky” making the connection between the storyline and the physical enhancement of the book.

Questions and Answers were the interaction types that occurred least often (see Figure 8). In Session 2 it was noted that there was a tendency for parents to either repeat questions or reword a question previously asked. This was seen to happen both within a single spread and across multiple spreads. For example, Parent 1 was noted to ask her son “can you see some things?” when pointing to the spinning wheel on Spread 1, and also “can you see what’s in there?” when pointing to the flower paper-engineering-enhancement on Spread 3. Another example was when Parent 2 pointed to the boat on Spread 14 and reworded her question “what are they on?” to “what are they sitting on?” in order to further prompt the child for an answer and redirect his attention.

Whilst the occurrence of comments was not particularly high when compared to physical interactions, the increase in comments between sessions is noteworthy. There was an increase of 128 interactions between the first and second observations – from 60 comments to 188 (see Figure 8). This increase in comments demonstrates how the inclusion of physical and intellectual enhancements can allow the book to become more relevant to the child and the ‘real world’. This was seen with all families when discussing the ‘hidden cupcake’.

The families used this feature to discuss food, taste, nutrition and appropriate times to eat cupcakes. Consequently, the inclusion of such interactive features encouraged the reading partners to make connections between the book and the real world, in turn enriching the learning experience.

During the final semi-structured interview after the second session, all parents noted that they enjoyed the highly interactive version of *Hannah's Favourite Place* due to the fact that their children were having fun. Parent 4 stated "I enjoyed that she enjoyed it. She was obviously having fun." This indicates that the parents' level of enthusiasm and consequent engagement can be directly linked to that of the child. Conversely, four parents discussed the fact that the interactive elements may be somewhat distracting, and stated that they had the potential to take away from the story content itself. Parent 1 addressed this concern, and the consequent solution, by stating that her child was "more engaged in the book, but [I] don't know if he followed the story... but maybe he learnt more by doing [because] on the drawing page he wanted to draw a unicorn [alluded to in the text] and toast". This idea was observed by the other three parents who were concerned about the distracting nature of the interactive elements. Consequently, it could be said that parents understand interactive books differently to children - where children seamlessly jump between the elements and the story, parents seem to separate the two. All seven children stated that their favourite part of the interactive version of *Hannah's Favourite Place* were the interactive elements themselves.

5. Discussion

This study has provided insights into the success of implementing physical and intellectual interactivity into picturebooks. We take this opportunity to discuss how the designed interactions developed in *Hannah's Favourite Place* have facilitated the recommendations for shared reading and picturebooks that we presented in the related work section of this paper.

5.1 Shared Reading

The non-interactive picturebook version of *Hannah's Favourite Place* saw great variation in total interactions over the seven families. Whilst all parents stated that their actions were intended to keep their child interested in the shared reading session, their total number of interactions and attempts at engaging the children were drastically different, varying from 4 – 149 total interactions. Six parents believed engagement was accomplished by involving the child in the reading activity and shows some understanding of the benefits described by Justice and Kaderavek (2002) of children participating in the reading experience. However, not all parents engaged in the full array of interactive reading practices (Ezell and Justice, 2005; Han and Neuharth-Pritchett, 2013) with the traditional picturebook suggesting that even effective shared readers would benefit from guidance in order to further the learning experience which supports the recommendation made by Mol et al. (2008).

All seven families increased their total number of interactions between the two sessions.

This shows that the physical and intellectual enhancements of the book promoted more interaction from both parent and child, and allowed young readers to become more engaged in the literary experience and gain more from the book (Timpany and Vanderschantz, 2013). As features are touched and pointed out, questions are asked, and comments are made, the parent and child actively engage with each other and the book. These observations are therefore evidence of development of literacy, as well as communication (Timpany and Vanderschantz, 2012), social skills (Zeece, 2009) and further emotional development (Norton, 2011). Equally these increased interactions have provided an in-book tool to train and support shared reading practices for parents as recommended by Mol et al. (2008) and Bus et al. (1997).

5.2 Physical Interaction

Silverman (2006) notes that children learn through play and it is important that designers take this into account when creating children's books. The fact that all parents stated that they enjoyed the interactive, version of *Hannah's Favourite Place* due to the fact that their children were having fun indicates that this 'fun factor' is imperative when designing effective children's books. Silverman (2006) also notes that children have a tendency to 'learn through doing' and therefore physical interaction and 'touch' is important within the shared reading and learning environment. Our study has shown that an interactive book that encourages this practice leads to further engagement from the child and a significant increase in interaction compared to a traditional picturebook. Our study also indicates that the design of meaningful physical enhancements act as a bridging device to promote a range of interaction types for both children and adults. As children are encouraged to explore, discover, and understand cause and effect, they are also prompted to participate in responsive interactive reading behaviours (Girolametto and Weitzman, 2002; Ezell and Justice, 2005). These behaviours were observed as shared readers pointed out features, asked questions and made connections between the book and the real world.

Whilst a number of parents voiced their concern over the distracting nature of the physical enhancements, it is important to understand that children and adults view the world differently. Children seamlessly jump between the physical enhancements and the story, whilst parents seem to separate the two. We suggest that because "movable and pop-up books teach in clever ways, making the learning experience more effective, interactive, and memorable," (National Museum of American History, 2010, p. 7) it is important that parents embrace the learning possibilities of interactive books in the shared reading environment. As Goodwin (2008) discusses, the parent acts as a mediator within the shared reading session, therefore we would argue that the parent can help to guide the session if they believe that the child is getting too distracted by the design enhancements. An effective interactive children's book can provide the tools for successful shared reading, so parents need to embrace such books and be open to broader learning opportunities within the shared reading environment.

5.3 Intellectual Interaction

The increase in comments from the traditional book to the interactive book demonstrates the increased successes of the children in our study relating the story to the 'real world' and potential evidence of emotional growth and attachment (Goodwin, 2008; Norton, 2011). Comments such as "I have my favourite place now", from the child of Family 1, demonstrate how physically and intellectually interactive books can provide further engagement in the story, and hence the possibility for emotional understanding and growth (Zeece, 2009).

As children develop their reading skills, it is important to encourage further learning opportunities. Family 4 demonstrated how shared reading with older children can promote language-modelling behaviours (Ezell and Justice, 2005), and encourage continued learning of reading and literacy in the home environment. Whilst this family stated that they did not often participate in shared reading in the home environment, the interactions noted, as well as the increase of interactions during the second session, proves that shared reading is a practice that can evolve with the age and stage of the child. Consequently, it is important that independent readers continue to be supported through books such as the highly interactive version of Hannah's Favourite Place.

6. Conclusion

We undertook a user observation study of seven families engaging in shared reading sessions with non-interactive as well as interactive picturebooks. This study showed how physical and intellectual enhancements to picturebooks can change the level of interactivity and types of interaction within a shared reading environment. The findings of the study demonstrated the importance of designing effective children's books which include, an appropriate story, illustration, theme and the creation of an emotional relevance or connection with the child. In addition, the physical and intellectual enhancements prompted children and parents to interact and engage with the book at a much higher level than the traditional version of the book. The study demonstrated the broad learning possibilities of a highly interactive picturebook while also presenting design innovations and solutions for future printed interactive picturebooks.

Our study showed that meaningful physical and intellectual enhancements that promote a range of interaction behaviours can be observed when shared readers point out features of the book, ask questions, and make connections between the book and the real world. We posit that it is important that effective interactive children's picturebooks include enhancements that add to the story and engage children on a number of emotional and intellectual levels. We further conclude that these design choices should ensure enhancements add value rather than cause distraction during individual or shared reading sessions.

All shared readers would benefit from further support, which we have found can be offered through the design features of an effective children's picturebook. We recommend development of tools that encourage and teach adults, including teachers and parents, how

to facilitate engaged and interactive reading. In order to ensure that varying interactions and shared reading practices take place, addition of goals, such as used in our interactive book, provide tools for adults that can be used when they share this, or any other book, with their child. Equally, a well written and illustrated book should lend itself to questions from the parent and consequently will promote interaction. Questions that include *who, what, when, where, why, and how*, and engage children in the imagery, storyline and relevance of the theme of the story and relate this to the real world will create strong learning opportunities for children.

To design an effective interactive children's picturebook, three basic steps must be taken. The book needs to include the fundamental principles of a successful children's picturebook, including appropriate story, illustration, theme and the creation of an emotional relevance or connection with the child. In turn, the book must provide support to shared readers through instruction or guidance in order to ensure that both parties benefit from shared reading situations. The book must include physical and intellectual enhancements that provide meaningful interactions, and have a relevance to the story outcome or storyline itself. These aspects combined will enable both the shared reader and the child to gain more from the shared reading session, and promote fun, enjoyment and education in the home environment.

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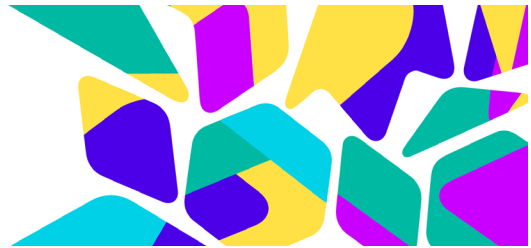
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Navigating contemporary complexities in the design of sexuality education materials

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Abstract: More than ever quality comprehensive sexuality education is needed to help children make sense of increasingly complex and fluid notions of sexuality, gender and relationships. Designers of sexuality education are faced with the task of navigating issues such as earlier onset of puberty, changes to normative family structures, changing ways of conceiving and birthing, and the impact of technology and social media. This paper explores how some of these complexities influence the design of sexuality education by analysing the design of three books aimed at younger children, and through interviews with the Australian, Canadian and Danish creators of the books.

Keywords: sexuality education; graphic design; illustration; children

1. Introduction

Sexuality education (sex ed) is generally thought to belong to the fields of education and public health. Beyond these classifications sex ed can also be seen a graphic design problem. It belongs to the field of education because the goal is to communicate the right information in an age appropriate way. It belongs to the field of health because the goal is to assist children and young people to make healthy choices. It is a problem of graphic design because for the first two goals to be achieved the visual communication must be effective. The text and visuals must be put together in such a way that the information becomes visually appealing, easy to understand, memorable, and as much as possible, non-offensive.

This last point is partly what makes creating sex ed materials a difficult task. Not only do the materials need to communicate highly complex human interactions, relationships and biological processes to a young audience, they also need to do this in such a way that they do not offend. This can be problematic in a culture where many adults still feel uncomfortable talking about sexuality to children, and where often conservative political and religious forces still oppose the kind of sex ed that is needed in an increasingly complex society (Rhodes, 2018; Stark, 2016).



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Sexuality, biology and human relationships have always been complex issues. However, stricter social norms in the past sought to simplify them. Up until recent times the status quo in most Western societies decreed that: A child had a mother and a father; conception happened within the institution of marriage between a man and a woman; masturbation and lust was shameful; children were without sexuality; gender was fixed, as were gender roles. Because of these conceptions sexuality education when it was first officially introduced in the first half of the 20th century was relatively simple—its main purpose being to combat promiscuity and venereal disease or explain the basic biology of reproduction (Zimmerman, 2015).

Though some cultural, political or religious groups still adhere to this traditional paradigm, major shifts in perceptions around normative family structures, reproduction, sexuality and gender in the second half of the 20th century and the first two decades of the 21st have led to a need for an entirely new way of discussing, understanding and visualising sex ed. Those creating sex ed resources in the past were expected to enforce the normative view and explain biological functions. Those creating sex ed resources today need to explain biological functions, while also making sure no one feels excluded. They navigate the fine line between showing too much, and offending those with conservative views; or showing too little, and offending those with progressive views and those with lived experiences that differ from traditional conceptions of “normal” bodies, gender, sexuality and relationships.

In this paper I will look at two contemporary sex ed books aimed at children: *The Amazing True Story of How Babies are Made from Australia* (Katauskas, 2015), and *What Makes a Baby from Canada* (Silverberg & Smyth, 2012). I will compare these to an older book: *How a Baby is Made (Sådan får Man et Barn)* from Denmark (Knudsen, 1971). As well as exploring the visual language of the books I will use material from interviews I conducted with the creators of the books. The reasons for choosing books from these three countries are: I live in Australia; I am from Denmark; and Canada has similarities with Australia because of its British colonial past, and similarities with Denmark because it is often seen as progressive. By comparing an older book, which was ground-breaking in its time, with two newer books that each take a different approach to explaining reproduction, it is possible to get an idea of the complexities the creators are grappling with, and the solutions they have found.

2. Sexuality Education as a Design Problem

The research that exists within the field of sexuality education tends to focus on the experience of those receiving the education (i.e. children and teens), the experience of those providing it (i.e. teachers and parents), and the effectiveness of different approaches (e.g. Mitchell, Patrick, Heywood, Blackman, & Pitts, 2014; Brugman, Caron, & Rademakers, 2010; Weaver, Smith, & Kippax, 2005; Walker, 2001).

To my knowledge no academic studies have looked at the visual culture of sex ed materials. Nonetheless, exploring sex ed as a graphic design problem could be greatly beneficial to those creating future resources. Resources communicating the same information can be

dismissed as irrelevant or boring to its audience if designed badly, or useful and interesting if designed well. The effectiveness of the resource, thus, may depend on how well it has been designed.

My current interest in the design of sex ed materials is an extension of my PhD research, which looked at the notion of taboo in relation to HIV prevention campaigns aimed at men who have sex with men in Australia (Kolff, 2015). This is also an area that is mainly researched within the field of public health, though some research has examined the design of HIV prevention materials (e.g Chan & Donovan, 2006; Chan & Donovan, 2007; Mackie, 2008).

Generally within the field of graphic design target audiences, historic context, cultural trends, or designs themselves are analysed. The methodology of qualitative interviewing, common within social sciences, is less often used. I found in my PhD research that by interviewing the creators of HIV prevention campaigns it was possible to get a useful insight into the dilemmas and thought-processes that shaped the final design. I was able to explore how certain visual strategies became prevalent and how others were omitted entirely. By researching the design-process it was possible to better understand how the notion of taboo plays out in the creation of campaigns, and as a result, how the visual culture of HIV prevention is shaped.

Similarly, by interviewing the creators of sex ed materials useful information about the dilemmas they face and the solutions they find emerge. The findings in this paper are part of a broader research project, which explores how the creators of sex ed materials aimed at children and teens navigate notions of taboo.

3. Visualising How Babies are Made

The three books discussed in this paper all share a similar size and format. They were all created because the creators could not find books that told the story of conception and birth in a way they found suitable and useful. As a result, each book is ground-breaking in its own way.

Per Holm Knudsen's book was seminal in starting a no-nonsense approach to sex ed. A young left-wing graphic artist living in Denmark at a time in the late 1960s and early 1970s when sexual liberation was at its peak, Knudsen decided it was time to create a book that was straightforward in its visual language, as well as in the words it used to describe body parts and intercourse. His book, though somewhat controversial, became a success, and has been reprinted many times and translated into many languages. This is the book my mother read to me in 1980, when I was 22 months old and about to become a big sister. The English version of the book briefly became an online sensation when Facebook users followed by media outlets, delighted in the kitsch value of the 1970s explicitness and style of drawing (Morrissey, 2009; News.com.au, 2015). As a graphic artist his illustration style is dictated to a large degree by the technology of production available at the time, which involved cutting out each shape in foil using a light board (P. Knudsen, personal correspondence, 18 May 2015).

This method resulted in simple aesthetics that could communicate clearly to very young children.

Fiona Katauskas, an Australian cartoonist and illustrator, decided to create a contemporary sex ed book after having difficulties finding a good up-to-date book to teach her children about sexuality. She worked on the book in conjunction with expert advice and research to find relevant information. Her goal was to make a book relevant for 21st century families, which as a result includes explanations of in vitro fertilization (IVF) and sperm donation. To her surprise the book became internationally known online and in the news media after someone who was outraged that the book was for sale in Kmart posted a picture of the conception scene on Facebook (Katauskas, 2018). The book uses a simple illustration style, and often has humorous speech bubbles and funny details, which make the book's tone light and casual.

Cory Silverberg is a Canadian sex educator. He is himself a gay man, and has a diverse friendship circle, which includes transgender people who have had children. His book project started when he wanted to create a book that could be read to these children about their story of conception and birth. Rather than making a book specifically aimed at children of transgender people, he decided to make a book that could be read by any child or family. In other words, it had to be completely inclusive (C. Silverberg, personal correspondence, 29 November 2017). The illustrator, Fiona Smyth, created bold and colourful, yet simple, drawings that are fun and friendly.

4. Bodies

4.1 Bodies of the mother and father

When teaching children about sexuality the first step is usually to discuss bodies. How boys and girls are different, how men and women are different, and sometimes how bodies change from child to adult. In Knudsen's book this is very briefly explained by a single illustration of the parents standing naked (Figure 1). Their body parts are named, in the Danish version with colloquial words. The focus is specifically on the process of making a baby. Knudsen's book is aimed at very young children, so he chose to use straightforward visual language that simply shows the mother and father naked. They are the same in body shape, height, facial expression and posture, but have different hair, chest and genitalia.

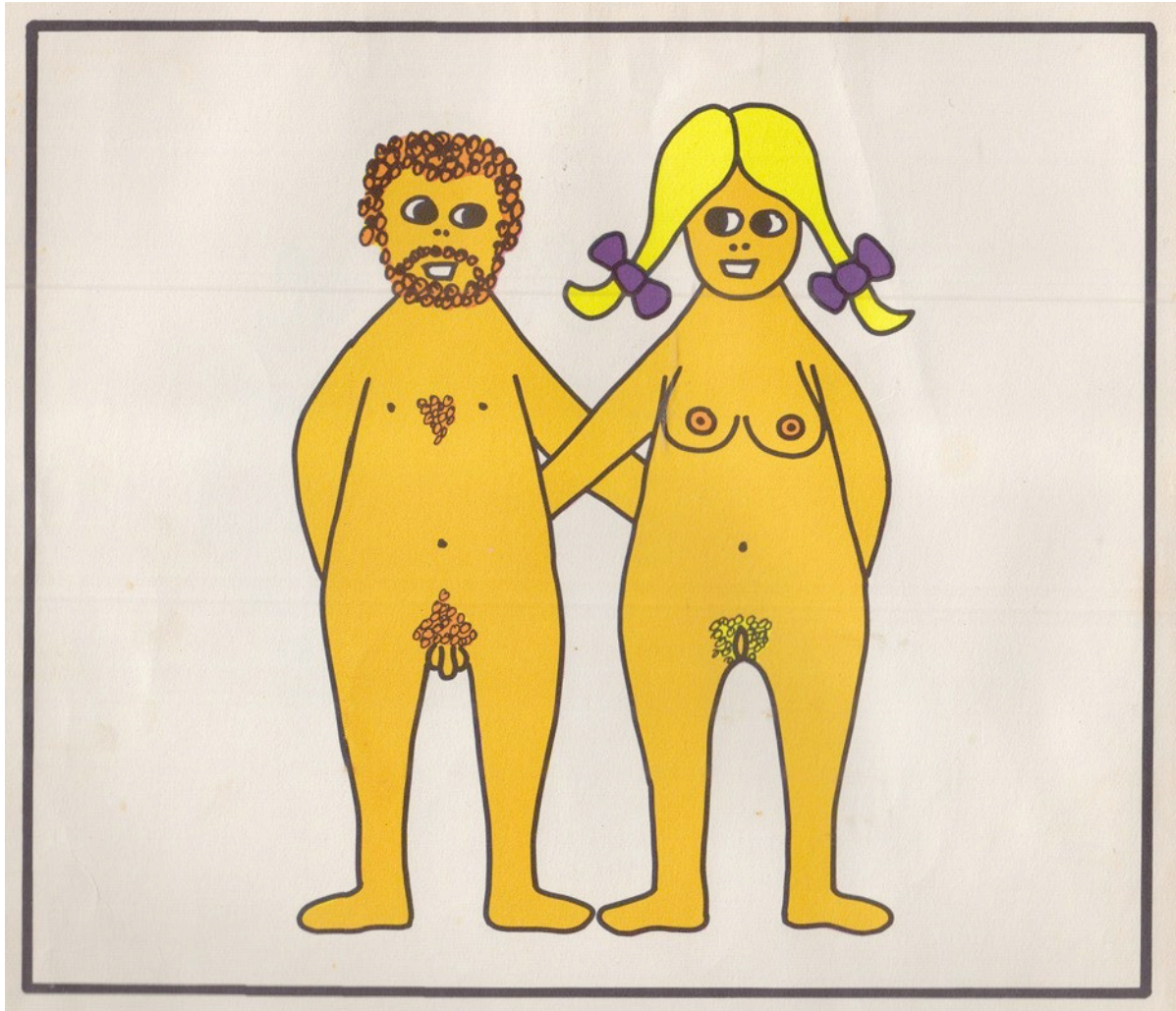


Figure 1 Illustration from “How a Baby is Made” (Knudsen, 1971)

4.2 Looking at female anatomy

Katauskas (2018) decided on the name of her book based on Knudsen’s English title *How Babies Are Made*. However, she wanted to tell a more complex story, and the words “the amazing true story” were added to the title of her book so it reads *The Amazing True Story of How Babies are Made*. Rather than beginning with the story of conception, Katauskas first shows how boys and girls look different. She explains things like circumcision and how boys can get erections. The latter is accompanied by an illustration of a boy on a swing shouting “My willy is starting to wonka!” In this way Katauskas brings in many moments of humour in her text and illustration. In a scene where she is explaining the changes that happen in puberty one man with clown hair also has clown pubes (Figure 2). These little funny interludes help diffuse what many readers might otherwise see as awkward topics.



Figure 2 Illustration from “The Amazing True Story of How Babies are Made” (Katauskas, 2015)

One of the more controversial images in the book shows a girl bending over with a mirror looking at her vulva. Katauskas purposefully included this view of the female anatomy because she felt it was usually absent from childrens’ sex ed books (Figure 3):

“Every book I could find, had the same kind of diagram for the boys: A cross section of the boy’s penis and testicles inside. And they have the girl’s one as a cross section from the top of the thighs to the waist, just the uterus, the fallopian tubes and the vagina, but none of them had a diagram of girls’ genitalia. I thought, is this a taboo? I thought this is crazy, why is it seen that girls can’t know the names of their different parts. And it’s not something girls usually see unless they make an effort. Boys see their penis all the time there out in front. But girls have to make a special effort to see it.” (F. Katauskas, personal communication, 5 September 2018)

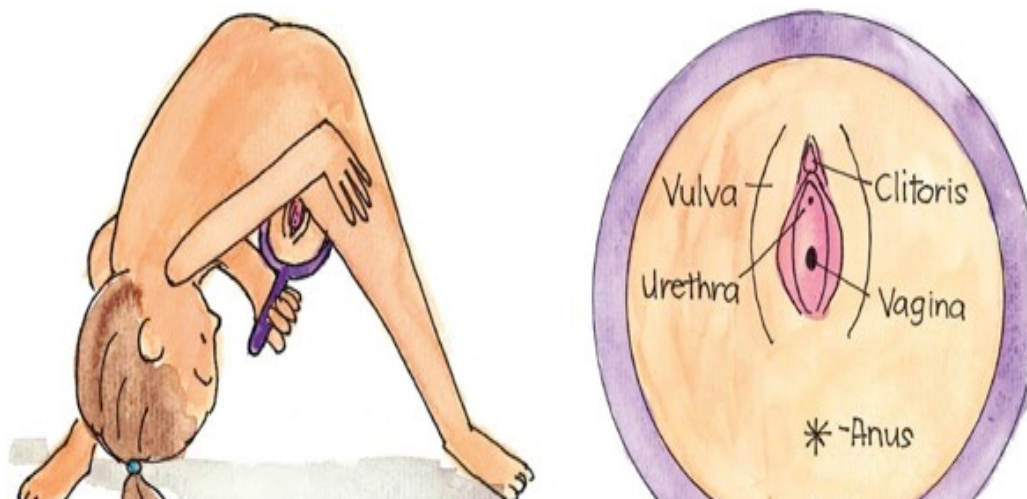


Figure 3 Illustration from “The Amazing True Story of How Babies are Made” (Katauskas, 2015)

When comparing Katauskas' book with Knudsen's it becomes clear that just showing a naked body from the front is no longer seen as sufficient. It is commonplace for books to show that girls and boys are different, and that children and adults are different. However, the fact that the female genitalia is hidden away, and rarely seen by the girl or woman herself makes it even more important to visualise and name the female anatomy as seen from below. This follows a trend that has seen adult books published in recent years focussing specifically on myths about female anatomy and biology (e.g. Christensen & Laub, 2016; Brochmann, Dahl, & Moffatt, 2018; Enright, 2019). By girls knowing and naming their body parts correctly they can take ownership, and feel more confident and assertive about their bodies and pleasure as they grow.

4.3 Some bodies have eggs, some have sperm

Silverberg's book, being specifically designed so as not to exclude any child or family, regardless of the way the child was conceived, birthed, or the gender and sexual orientation of the parents, does not show any genitalia at all. Bodies are discussed more generally, and gender is never mentioned. We are told that: "Not all bodies have eggs in them. Some do, and some do not" (Figure 4). Another page explains the same about sperm. Rather than focusing on the anatomy of the body parts that hold the egg and the sperm, Silverberg focuses in on the egg and sperm themselves, and the many "stories" they contain about the bodies they come from (Figure 5). That is to say, the genetic codes that the egg and sperm hold become the centre point of the narrative. These genetic stories exist in every conception regardless of the type of body or type of relationship they come from.

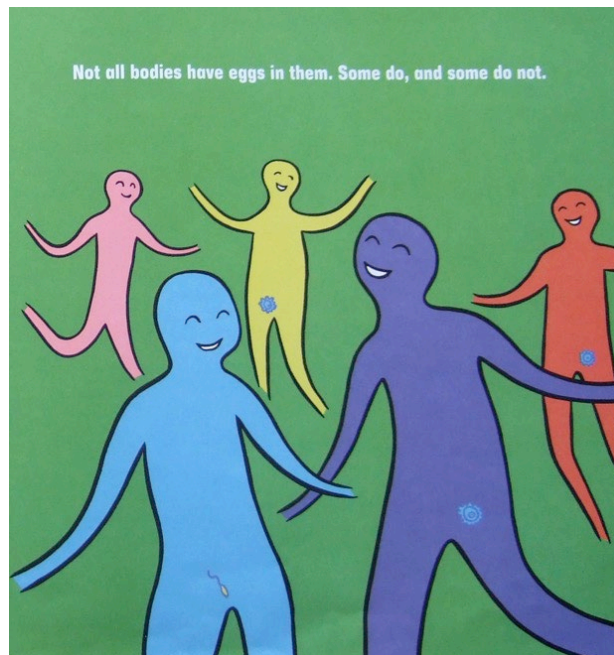


Figure 4 Illustration from "What Makes a Baby" (Silverberg, 2012)



Figure 5 Illustration from “What Makes a Baby” (Silverberg, 2012)

Silverberg describes how the illustration style intentionally helps keep interpretation open:

“I feel like the illustrations that we made are intentionally a little rough around the edges, because I don’t actually want them to look like a medical illustration. Because I feel like when you see a picture its authority somehow is conveyed to you, and those medical illustrations, people are standing straight like this. I have a very clear memory of looking at pictures like that and thinking, “My body is never going to be like that.” Which is funny because my body is the kind of body that people who are called boys have. I have all the parts that those people have, and yet I never saw myself in male bodies. And I kind of imagined and fantasised myself into female bodies, but I also knew those weren’t my bodies either. So having something rough is to me how you get more kids to relate. That’s how you don’t just indoctrinate. It’s how you leave open possibility. It’s how you make stuff that actually bites. Because none of us know what any specific kid thinks. Our kids don’t know who they are and we don’t know who they are. It’s a process of them finding out.” (C. Silverberg, personal communication, 29 November 2017)

Whereas Knudsen’s book was radical at its time because of its straightforward depiction of bodies (including an image of the man being shown with an erect penis), Silverberg’s book is radical today because of its complete eradication of what contemporary sex ed books generally do: show the anatomy of girls and boys, men and women in a comprehensive way. Silverberg takes a decisive step away from diagrams of genitalia, in contrast to Katauskas’ approach, because his starting point is different. Whereas Katauskas wants to make it possible for both boys and girls to know their body parts and the transformation their bodies will go through, Silverberg wants every child to be able to identify with the figures that are neither male, nor female—nor of any particular race or cultural background.

5. Conception

5.1 From biological function to pleasure.

In earlier times sex ed almost solely focused on explaining the biology of conception and pregnancy. Sex was a transfer of sperm to egg. For instance, in his 1946 book *How Life is Handed on*—which was at the time seen as highly progressive—Cyril Bibby (1946, pp. 32-33) writes about rabbits:

“The penis becomes rigid, and this makes it easier for it to be placed inside the vagina. After a while the semen leaves the penis and enters the vagina... In humans, also, the penis is placed in the vagina; and the sperms swim up through the vagina and womb into the egg tube.”

This is the only account of sexual intercourse in the book—it is purely biological and does not mention pleasure. Bibby does go on to describe that humans are different to animals in that sexual intercourse takes place between a man and a woman who love each other, and are usually married. There are no depictions of intercourse, only of the genitals of humans and rabbits (Figure 6).

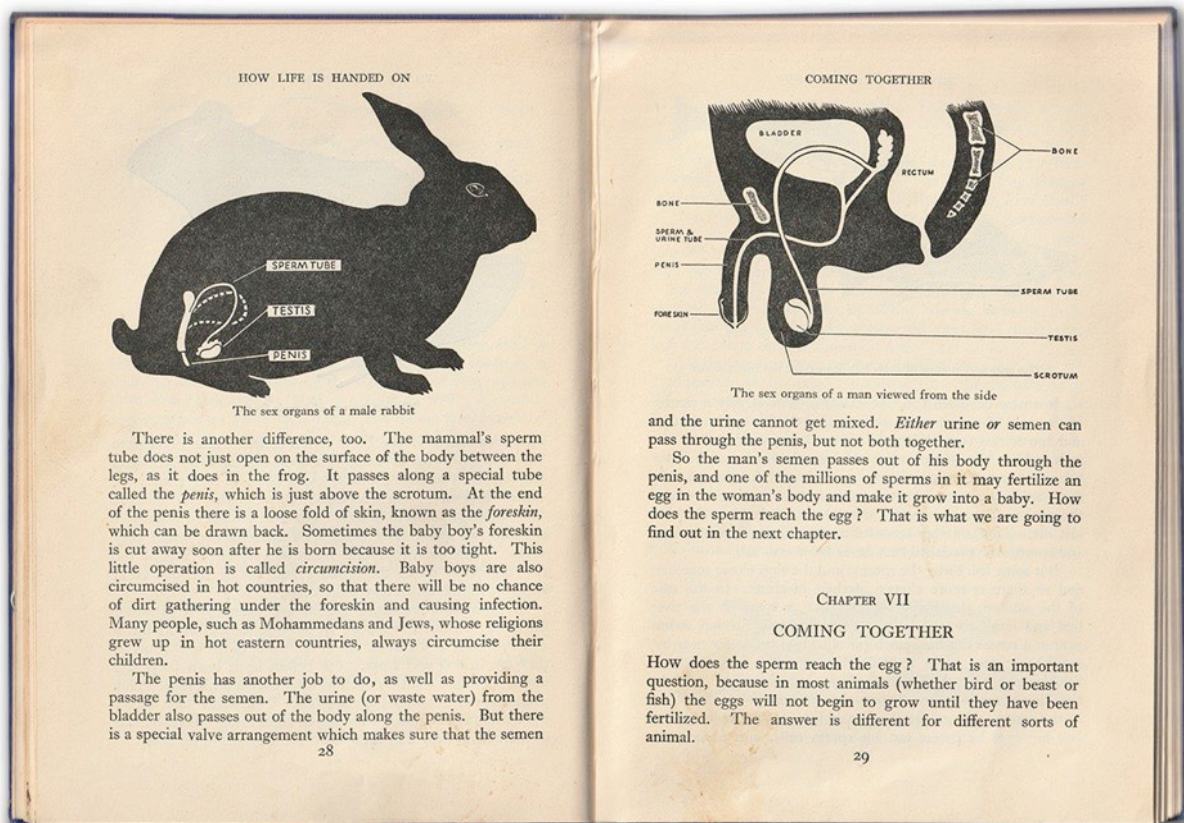


Figure 6 Spread from "How Life is Handed on" (Bibby, 1946)

In the second half of the 20th century, notably after the sexual revolution of the late 1960s,

sex ed books start including pleasure as part of the description surrounding intercourse and conception. This meant that an extra layer of complexity was added. Particularly in Scandinavian countries, sex began to be recognised within sex ed as not only a physical function, but also as something that brings joy and pleasure (Zimmerman, 2015, p. 90).

In Knudsen's book the parents are described as loving each other, and wanting the penis to enter the vagina because it feels good. As one of the first and for a long time only books it also shows the actual intercourse using a cross section of the couple having sex (Figure 7). This image is particularly what has made Knudsen's book unique right up until current times, where most sex ed books still hide the actual sexual act behind blankets.

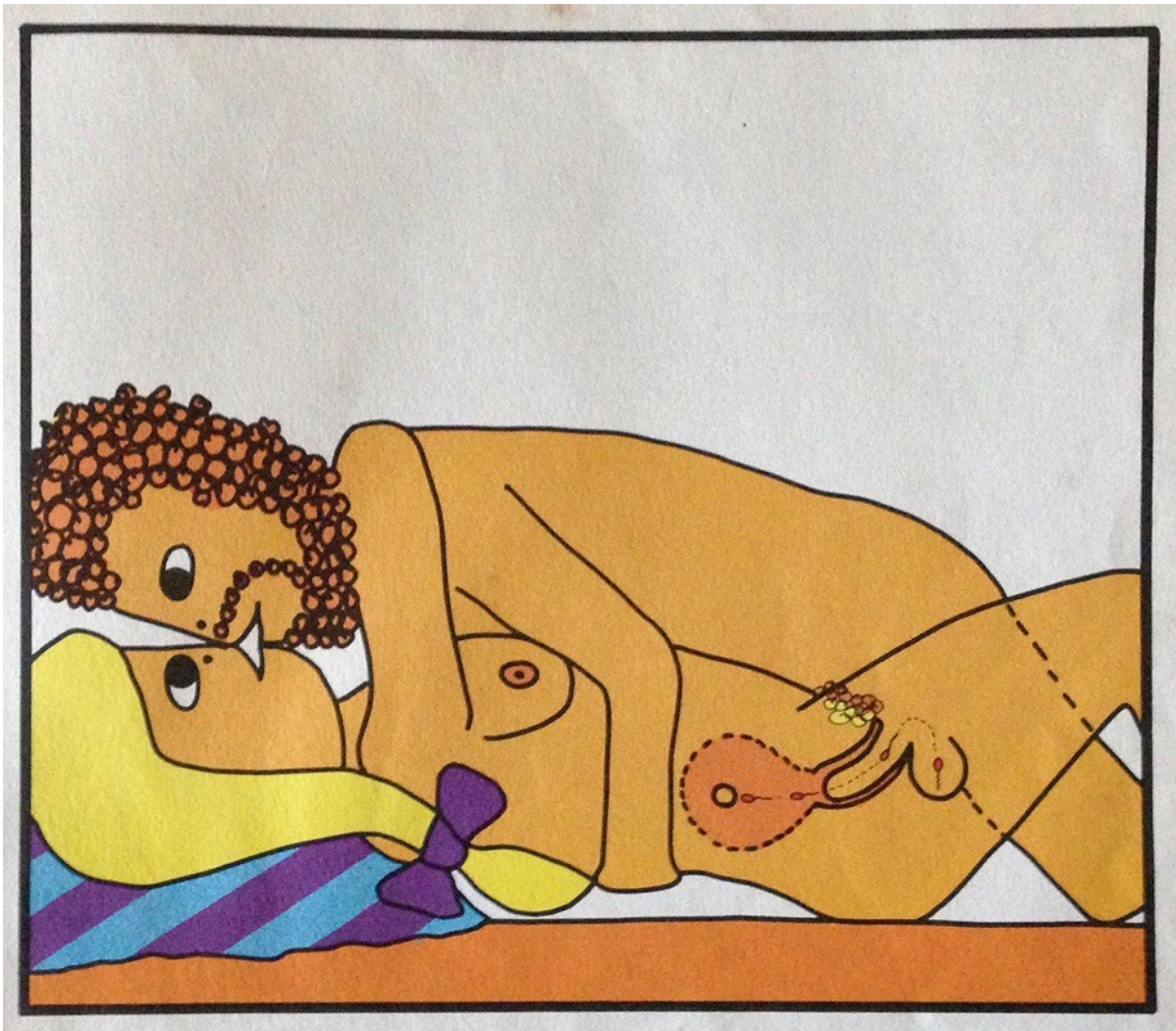


Figure 7 Illustration from "How a Baby is Made" (Knudsen, 1971)

Katauskas continues on in the same vein as Knudsen. She describes how for adults sex can feel "special and exciting", and that the vagina becomes wet and the man's penis hard till they fit together like a puzzle. She then tells how the interaction gives them both a "tingly, excited, and very loving feeling", which intensifies until the sperm shoots into the vagina. In

this way the pleasure of sex is emphasised. Her illustration of the interaction is also similar to Knudsen's (Figure 8). She describes her desire to make the scene look loving:

"I did think specifically about the sex scene. That I wanted them to have no blanket. I thought a lot about that I didn't want it to look super lusty. I wanted them to be looking into each other's eyes and smiling. Looking loving, but also liking each other. Not hot and steamy. I want there to be a bit of a joy about it. It's nice. It's a special thing. It's a connection."

(F. Katauskas, personal communication, 5 September 2018)

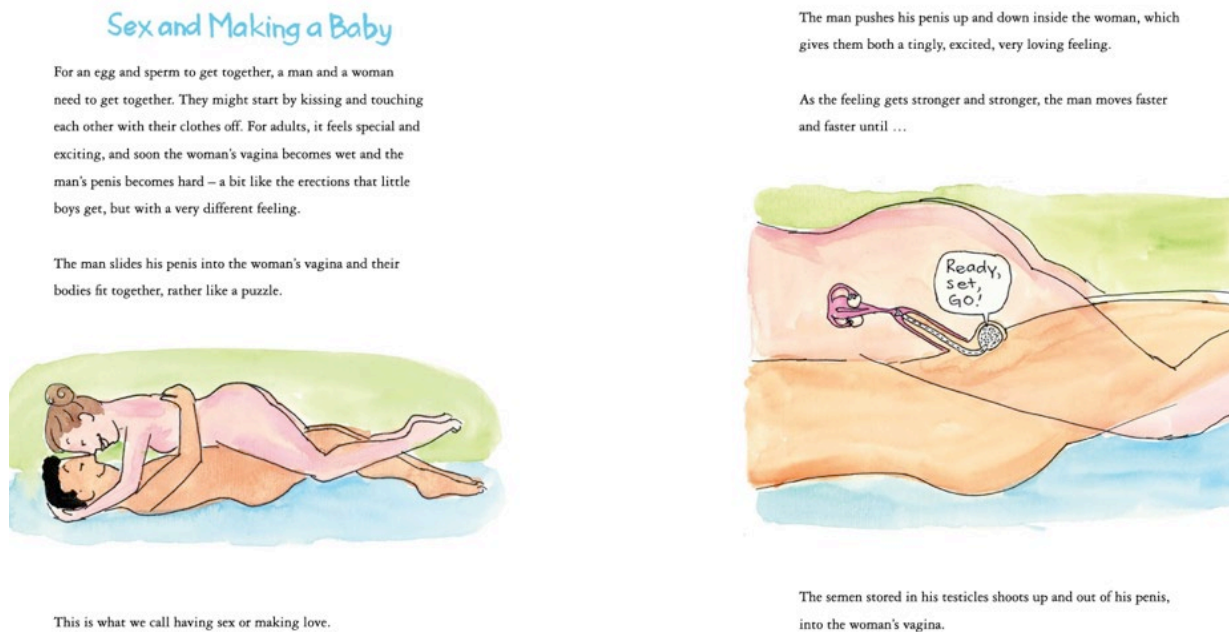


Figure 8 Spread from "The Amazing True Story of How Babies are Made" (Katauskas, 2015)

5.2 Alternative conceptions

At the time Knudsen's book was written IVF was not an option. The availability of IVF, as well as the lesbian, gay, bisexual, transgender, intersex (LGBTI) rights movement of the late 20th and early 21st century, has added complexity to the biological narrative of conception, as well as the interpersonal one. While the relatively simple story of conception put forward by Knudsen is easier for young children to grasp, today's creators of sex ed materials need to find ways of describing and visualising the diverse and sometimes complicated family structures and biological and medical processes through which babies can be conceived.

Katauskas goes on from her description of heterosexual conception by intercourse, to firstly describe multiple births, and secondly describe alternative conceptions such as IVF and sperm donation. In Australia 1 in 25 births are IVF, and worldwide more than 8 million children have been conceived through IVF (Aubusson, 2018; Science Daily, 2018). By including these narratives Katauskas broadens the scope of children and families who are able to identify their own story of conception (Figure 9).

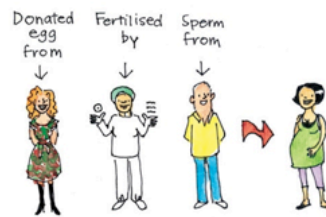
Some people who want children find they can't make a baby by having sex. Sometimes, the father's sperm are not strong enough to find the egg, or maybe the mother's egg can't get down the fallopian tube. These people will need some help from a doctor. This is called in-vitro fertilisation, or IVF.

IVF doctors take an egg from the mother and some sperm from the father and put them together in a special small glass dish so they can find each other.

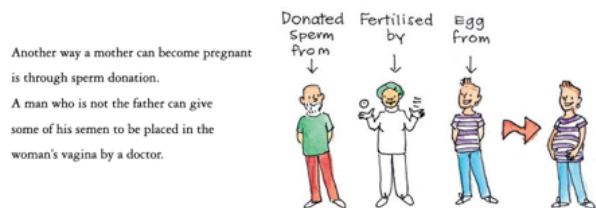


When the egg and sperm have formed an embryo, the mother goes to hospital. The doctor puts the embryo in her uterus and it begins to grow – just like other babies!

Sometimes there's a problem with the mother's eggs and they're unable to make a baby.



An IVF doctor can use eggs donated by a different woman and fertilise them with the father's sperm to make an embryo. The embryo is then put in the mother's uterus and grows there.



Another way a mother can become pregnant is through sperm donation.

A man who is not the father can give some of his semen to be placed in the woman's vagina by a doctor.

Figure 9 Spread from "The Amazing True Story of How Babies are Made" (Katauskas, 2015)

Katauskas also ensures that throughout the book the people depicted are of different racial and cultural backgrounds. Though gay and lesbian couples are shown in the illustrations of park scenes at the beginning and end of the book (Figure 10), she does not, however, specifically discuss same-sex couples. In her interview she describes the thoughts behind this decision:

"One thing that I thought about, I wanted my book to be so that people who had any sort of conception story could pick it up. But I don't explicitly talk about same-sex couples. I have scenes in the beginning and end of the book, where there are two women, or two dads with kids. I've known both straight and gay couples who have had sperm and egg donation. I did probably err on the side of caution instead of having a specific thing about same-sex couples. Partly because I wasn't sure how to fit that in the story. I did also think, is this something that publishers or stockists will go, 'This is too out there.'" (F. Katauskas, personal communication, 5 September 2018)

Here Katauskas describes a situation where the complexity is becoming too great. Not only are there many ways of conceiving, but there are many different family structures, including same-sex ones. Not only could an attempt to include all family structures in the narrative make it too complex; it could also create difficulties with distribution in an Australian society that is still on many fronts conservative, especially when it comes to teaching children about LGBTQI relationships (Law, 2017). As a result, Katauskas opts for a simpler story, while making sure same-sex families are visually represented, so that they can still identify with the book.



Figure 10 Spread from “The Amazing True Story of How Babies are Made” (Katauskas, 2015)

5.3 Stories of the egg and the sperm

Rather than adding complexity, Silverberg opts for simplicity in the quest for inclusion. By not describing sexual intercourse or how the sperm finds the egg at all (whether in the fallopian tube or a petri dish), he manages to tell a simple narrative of a sperm with many stories that meets an egg with many stories to create a new life with a combination of stories. Instead of focusing on how a baby is made, Silverberg focuses on what makes a baby:

“I just had all these friends who were having kids, and there were no books about what makes a baby, because all the books that were out there, all of them said ‘When you were a baby, this is how you were made. Your father had a sperm, your mother had an egg.’ And then they do this ridiculous... I mean the imagery is so horrifying. It’s always like the egg is wearing a tutu and she is on her back, and the sperm goes barging into her. So I was thinking about the story. I was focused on the information.” (C. Silverberg, personal communication, 29 November 2017)

As a result the scene of conception, rather than showing a man on top of a woman, shows two non-gender-specific humans who want to have a baby (Figure 11). They are depicted on one spread with sperm and eggs around them, but they are on separate pages. We are told what three ingredients are needed for a baby to grow: sperm from one body, an egg from another body, and a place for the baby to grow. This wording and visual strategy means that any variation of conception is covered. Whether it is through heterosexual vaginal conception, IVF, sperm donation, a surrogate mother, adoption, a transgender man conceiving, or any other combination of possibilities, every family and child can identify their own conception story.

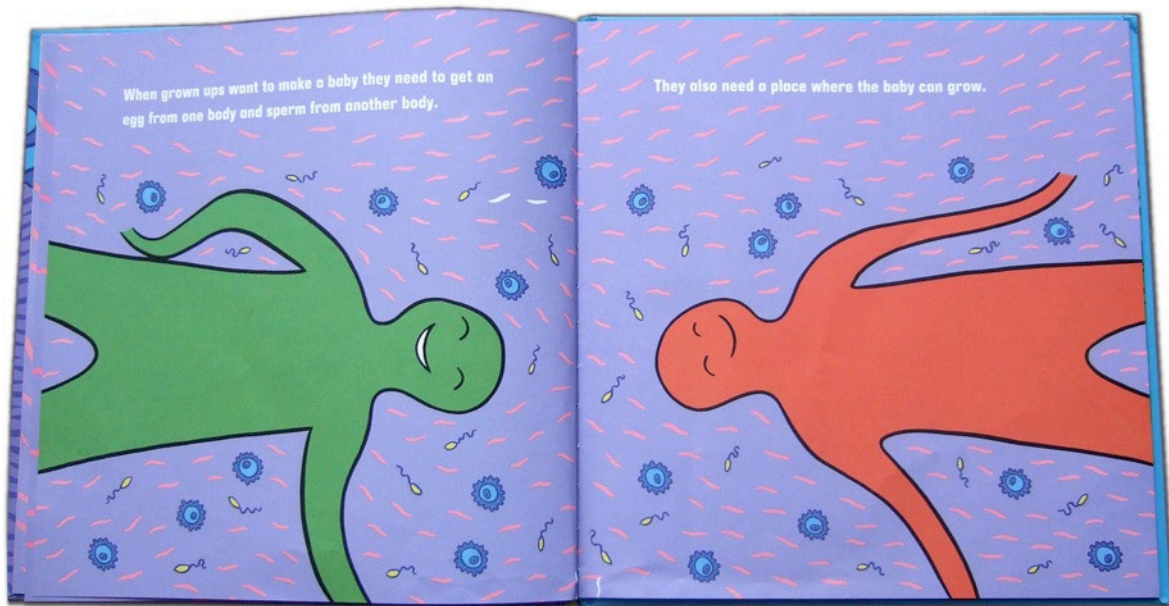


Figure 11 Spread from "What Makes a Baby" (Silverberg, 2012)

Silverberg goes on to explain that for a baby to grow a uterus is needed, but that not everyone has a uterus. He shows how the egg and the sperm find each other and swirl together in a special kind of dance, telling each other their stories of origin (Figure 12). In a speech bubble the two people from whom the egg and sperm came are shown. Again, the non-specificity of these people means that they can be either the parents the child knows, or they can be anonymous donors.

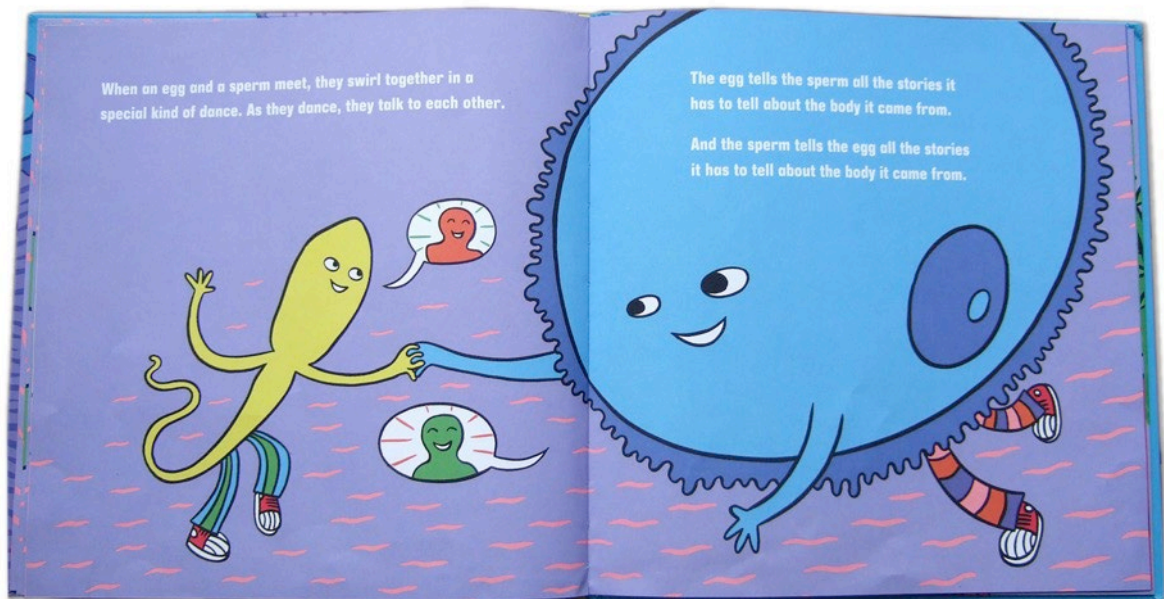


Figure 12 Spread from "What Makes a Baby" (Silverberg, 2012)

6. Birth

In Knudsen's book the birth of the child happens in hospital with a male doctor standing next to the bed. When it was first published Knudsen was criticised by feminists because the doctor was an authoritarian male (P.H. Knudsen, personal communication, 18 May 2015). This scene is was found to be entertaining in the recent social media and online commentary about the book (Morrissey, 2009; News.com.au, 2015). Online commentators particularly found it amusing that the baby comes out smiling with its arms outstretched (Figure 13). Knudsen had seen a children's drawing where the child was shown coming into the world with outstretched arms. He thought this was a nice way to show the joy of birth. However, in later reprints Knudsen has removed the arms after some criticism that children might become frightened when seeing a real birth, which does not look like this (P.H. Knudsen, personal communication, 18 May 2015). The birth scene in Knudsen's book is passive. The two males are non-participative, and the birthing mother is passive on her back, while her face is hidden. In this way Knudsen unintentionally portrays the mother as a non-personalised birthing body.



Figure 13 Illustration from "How a Baby is Made" (Knudsen, 1971)

Worldwide births by caesarean section have been rising rapidly, to a point where in some countries half of babies are born in this way (Davis & Long, 2018). In Australia about 29% of first time mothers give birth by caesarean (Australian Institute of Health and Welfare, 2019). To reflect this reality Katauskas included an image of a caesarean birth (Figure 14), as well as one of a premature baby in an incubator. Again complexity is added since the 1970s, not only in the way babies are conceived, but also in the way they are born. In the vaginal birth scene all parties are active, in contrast to Knudsen’s birth scene. The father is holding the mother’s hand and encouraging her, the mother is actively birthing, and the midwife is about to receive the baby. The joy and struggle of birth is visualised.

With each contraction, the baby is squeezed further towards the opening of the vagina.

When the mother feels a strong urge to push, the baby is almost born. You can even see the top of her head! By now, the mother is usually very, very tired, but she gives one last big push ...

And out comes a brand new little baby!



Sometimes a mother can't give birth through her vagina, so she has a special operation instead. The doctor gives her some medicine so it doesn't hurt then makes a cut in her tummy and through the uterus to take the baby out that way. This is called a caesarian birth.

Figure 14 Page from *"The Amazing True Story of How Babies are Made"* (Katauskas, 2015)

For Silverberg the complexity comes not only through the addition of caesarean sections, but through the complexities of gender fluidity and non-heterosexual relationships. Having a friendship circle that includes a transgender male, who has born a child, Silverberg was aware that by showing a woman giving birth he was excluding the experience of such men. The creation of the birthing scene was therefore done very carefully in conjunction with the illustrator, Fiona Smyth. They were careful only to show the birthing person from above (Figure 15), as Silverberg describes:

“So where gender didn’t need to be is the birth scene. The important thing is what is happening. There is a baby coming out. So the question is, how do you do it? Because what I didn’t want is to ever show a head-to-toe pregnant person. So then what do you do? Do you take off the breasts if it was a trans-man and he had top surgery? Of course there are women who have had mastectomy for other reasons, but I just didn’t want to do it. So Fiona just did this illustration that has the belly. I don’t know if I would say men giving birth is taboo, but certainly men giving birth isn’t something most people think about. The nice thing is I think most people would just think, ‘Oh, this is a woman giving birth.’ But if you are a man who has given birth you could see yourself in this, possibly.” (C. Silverberg, personal communication, 29 November 2017)



Figure 15 Spread from “What Makes a Baby” (Silverberg, 2012)

Silverberg’s birth scene focuses on a baby coming out of a body. That this body could be male or female allows for inclusion. The scene is not focused on relationships between the father and mother, but rather on the action of birthing. One of the birthing scenes is depicted as a home setting, thereby further including the experience of those who have birthed at home.

7. Conclusion

At every step in the narrative of sexuality education the stories that need to be told have increased in complexity. From traditional sex ed, which focused purely on the biology of reproduction and the heterosexual institution of marriage; to the 1970s where the sexual revolution meant a more open approach to sexuality and pleasure; to today’s society, which has seen new advances in reproductive technology, growing rates of caesarean births, and social norms that are striving to become ever more inclusive of different family structures and gender fluidity.

These changes have meant that those creating sex ed materials have to find new ways of visualising the story of how babies are made. Knudsen revolutionised the way in which reproduction was taught to young children in the 1970s by introducing straightforward language, and simple graphics that showed exactly what happens during sexual intercourse, and by introducing the notion of sexual pleasure. Katauskas built on this approach, but expanded upon it to tell a broader story of female genitalia, puberty, and the alterative ways in which children can be conceived and born. Silverberg tackled the complexities of an ever more inclusive society, not by making the visual story more complex, but by simplifying it to such an extent that anyone can see themselves in his book.

At every step of the way the creators have had to carefully consider the words and images they used to ensure that a topic many adults find difficult to discuss, could be easily accessed and understood by young children. They have done this by taking a complex design problem and creating a simple visual narrative.

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Process matters: from car owner experiences to automotive design proposals

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Abstract: Collecting and analysing user experiences, communicating discovered patterns, translating information into design proposals and materialising designed features is central to design driven research. This process immerses design teams into all aspects of users' experiences, helping them empathise with and scrutinise every detail until designers own the experiences and produce design proposals addressing end users' needs in unique ways leading to disruptive innovation. Design practice's strength is crystallising solutions into visualised and interactive proposals, presenting in-depth details of the look, feel and emotions they stimulate, and assisting decision making in product, service and business innovations. Existing research focusses on early stage collection of lived user experiences and final visualisation of the design proposal, yet seems to miss detailed discussion of the core bridging of user experiences and precise design proposals. We describe optimising a process supporting designers continuously switching between gathering user experiences and industry/market contexts when generating automotive design proposals.

Keywords: experience study; design research process; design process; automotive design proposals

1. Introduction

User experience studies have been used by Human Computer Interaction (HCI) and product designers for decades and are at the core of design research. Most publications addressing experience focus on defining experience (Dewey, 1980; Forlizzi & Ford, 2000; Forlizzi & Battarbee, 2004), framing the experience process (Karapanos et al., 2009), prototyping experiences in innovation processes (Buchenau & Suri, 2000), methods for collecting experience data (Gaver et al., 1999; Wu, 2012) and discussing evaluation (Vermeeren et al., 2010). However, addressing how to plan and refine a research process which allows designers to step in and out of the experience data while making the transition from data to design proposal seems to be missing. User experience research can point to cases describing



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how to collect user insights and lived experiences (Dow et al., 2016; Gaver et al., 1999; Bichard et al., 2015; Wilson & Tewdwr-Jones, 2019). However, few researchers illustrate the process of transforming analysed experience data into design proposals, especially how designers act when processing experience data and implementing their own interpretations as design proposals at each research stage. Some studies address similar questions, for example, discussing designer's emotions and actions elicited during the design process (Biagioli et al., 2018) and reviewing the literature describing how experience data can inspire, interpret and explain when generating conclusions for art and design research (Koskinen & Lee, 2009). Neither articulate design research processes that facilitate the conversion of experience data into conclusions. This paper presents an automotive research project seeking new design spaces for vehicle owners, dissecting the research steps designers used to empathise with individual experiences to create vehicle service proposals. We show the value of combining design driven visualisation and empathy (Koskinen et al., 2003) in an iterative process addressing end users and clients, delivering proposals at different levels. The main objective is to illustrate a research process where distinct research activities are used including gathering and analysing car owners' experiences, investigating business processes, and collecting insights from the client, which are then used to visualise design proposals.

1.1 User experience study: from data collection and analysis to design proposals

HCI user experience study has significant momentum but is criticised for being vague, elusive and ephemeral (Hassenzahl & Tractinsky, 2006), mainly because of the focus on inventing methods of collecting and analysing data. Examples include introducing software to gather lived experiences (Dow et al., 2016; Wilson & Tewdwr-Jones, 2019), centring user experience as a usability test tool (Vermeeren et al., 2010; Tullis & Albert, 2013), searching behavioural patterns for designing interactive products (Forlizzi & Ford, 2000; Forlizzi & Battarbee, 2004; Suh & Chang, 2006) and addressing user's non-instrumental needs in fragmented empirical research (Garcia & Hammond, 2016; Xu, 2012). Design driven user experience study takes a different approach, dissecting designers' thinking and empathic processes in product ideation (Kouprie & Visser, 2009; Visser et al., 2005), transferring user experiences into product prototyping origins (Buchenau & Suri, 2000) and considering different levels of cognitive reflections triggered by design (Desmet & Hekkert, 2007; Norman, 2005). The literature discusses designers stepping into users' experiences to gain knowledge valuable in the creation process and then stepping out to generate proposals. Design proposals are presented and discussed in design research project articles ranging from sketches to semi-finished prototypes to demos to final products (Buchenau & Suri, 2000; Bichard, 2015; Orth & Thurgood, 2018). Designers are involved in an iterative research process including observing users, generating design briefs (a design proposal 'lite'), repeating observations in more depth, visualising design proposals, user testing and finalising design proposals. Design proposals at different stages act as essential tools assisting with verification of designers' understanding of user experiences and should not only appear at the end of a research

project but throughout the entire research process. Design proposals should also serve as a part of the research process to incorporate new emerged insights. The value of generating these interim design proposals to demonstrate and visualise possible outcomes to users while collecting and analysing experience data has not been fully addressed.

1.2 User experience studies for vehicle design and services

This decade, user-vehicle interaction and experience design has been brought to the forefront of innovation in the automobile industry, mainly focusing on new mobility technologies and use cases. Several areas particularly attract research attention: autonomous vehicle design and enabling technologies, in-vehicle infotainment systems and user experience studies, and user interfaces for vehicles and connected devices. Mobility-as-a-Service (MaaS) has gained significant attention with great potential for service innovation integration with personal device applications and Vehicle-to-Everything (V2X) platforms. This trend opens research opportunities around individual vehicle user experiences and vehicle usage behavioural patterns for extended services and applications. Automotive concept design and research incorporates typical user experience studies for product design (Pettersson, 2017), envisioning future trends and design opportunities for technology innovation, typically with an emphasis on high end applications user experience. The following case study discusses how addressing common car owners' conundrums can result in relevant service solutions.

2. Case study – from vehicle user experiences to design proposals

Our vehicle experience study and design provide empirical examples for the design research community, looking at the research process from capturing existing user experiences to implementation of solution designs. We breakdown the research process into steps and analyse the methods, organisation and effectiveness.

2.1 Project introduction

Motoring Makeovers explores design opportunities for providing car owners with aftersales services to encourage keeping their beloved cars for longer. The aim is to investigate typical user behaviour when shopping for, maintaining and recycling private cars to explore alternative vehicle service designs. The design assumption is that if people want to change their cars years after purchase there must be motivations behind their decisions, partially because of desire for new things and partially due to marketing strategies encouraging purchasing new cars. This phenomenon is neither environmentally sustainable nor necessarily the best brand loyalty strategy for automotive companies.

We explored car ownership user experiences including defining scenarios such as getting to know the car, keeping it clean, personalising the interior, and sharing the vehicle with other family members. The team interviewed car owners to get to know them and their lifestyles, invited their participation in empathy workshops to recollect their habits and behaviours,

and conducted journey shadowing to observe their car use. The team also interviewed the client, an international automotive company, to ascertain its current vehicle sales and market position and identify potential near-term challenges, touring car showrooms to experience and investigate current approaches for selling products and services. These activities helped the designers develop their understanding of car ownership and immerse themselves in car owners' world. The experience data was analysed and transferred into ideas for designs for alternative car ownership products.

2.2 Research process and challenges

We follow our standard design and research process synthesised from the British Design Council's Double Diamond process (Design Council UK, 2005), the d. school's design thinking process (Institute of Design at Stanford, 2010) and Rampino's design driven innovation process (Rampino, 2011):

The British Design Council defines a typical design process as:

1. Discover: begins with an initial idea or inspiration based on identified user needs
2. Define: interpretation and alignment of these needs with business objectives
3. Develop: design-led solutions are developed, iterated and tested
4. Deliver: resulting product or service is finalised, approved and launched

d. school breaks down the five stages of the design thinking process as:

1. Empathise: gain empathic understanding of users within the context of the design challenge
2. Define: specify key problems users face based on analysis of user observations
3. Ideate: idea generation process encouraging 'going wide' in terms of concepts
4. Prototype: produce many inexpensive, scaled-down versions of products or features so users can walk through scenarios
5. Test: solicit feedback about prototypes created by target users and have another opportunity to gain empathy for the people the product is designed for

Rampino's design driven innovation process includes:

1. Idea creation: identify user challenges and define research problems
2. Idea selection: analyse user data and shape design hypothesis
3. Development: create design proposals and narrow down to deliver prototypes
4. Marketing: test prototypes with users, define appropriate marketing strategies

Our research process was structured as:

1. Definition: define research aims based on designers' initial understanding and experience data collection from users
2. Creation: construct scenarios where users and contexts are represented and create ideas for further design proposals
3. Iteration: refine design proposals by testing scenarios with users walking through

created solutions

4. Proposition: decide design proposal methods and implement concepts as tangible deliverables

There were challenges in almost every step for the team when identifying the most valuable experience data and translating it into tangible design proposals including:

- How to make judgements about which scenarios include valuable experience data that will lead to novel design opportunities
- How much experience data will be enough and what types of data are effective for making decisions about design proposals
- What types of design proposal appropriately reflect true user experiences

2.3 Research phases: translating experiences into design proposals

A picture of how design concepts were generated from investigations of user experiences is seen as we progress through our four research phases.

1. DEFINITION

This phase defined and explored key car ownership scenarios. Research methods included car owner telephone interviews, empathy workshops, journey shadowing and automotive client telephone interviews. Objectives when selecting research methods were:

- to go from basic to in-depth user experience investigation to help designers discover hidden users' needs at different levels
- combine text and visual summaries when organising collected experience data to ensure that the logic and intentions behind user behaviours drove initiation of design proposals

Telephone interviews were used for initial insights into individual car ownership. Fifteen people (six females and nine males) participated in twenty-minute interviews with questions including:

- How long have you had your car?
- When did you feel like you had built a relationship with your car?
- Do you have a name for your car?
- Can you tell us a story about your car and you?
- How do you see the relationship between you and your car?

Telephone interviews (Table 1) indicated that most people see their cars as an important friend, somebody they can rely on - one participant mentioned "he is like my rock". One participant said she built a relationship with her car once it stopped breaking down. She realised that once she learnt how it works, she started building trust between her and the car. Several male participants claimed they love the components of their cars and working on them - they enjoy the "machinery relationship". Most people said looking after their vehicles is important to them. One person mentioned having to change their car because of a new

child but they preferred their old car from a driver's perspective. A few people also saw their cars as tools, practical objects, and therefore felt they had a responsibility to look after them and ensure they function correctly.

Table 1 Telephone interview findings: initial understanding

Initial understanding	Key words
Vehicle user relationship	Friend; Reliable object; Tool
Moment of relationship build up	The car stopped breaking down; Learning how the car functions
What is important in the vehicle user relationship	Looking after the car; A good fit with the family

Empathy workshops were conducted to collect and investigate key car ownership scenarios. Five car owners (two males and three females) participated in the workshops, recounting a story about a journey with their car. They were asked to recall the journey and document it step-by-step using a Ritual Journey Map based on typical Journey Mapping tools. Ritual links repeated actions or habits during car journeys to the meaning of the relationship with their car. Participants were then asked to roleplay their journeys using cardboard props representing items they take with them or habitually keep in their cars such as mobile phones and amulets. Participants were asked to describe any key moments when they interacted with their cars and why these moments had significance for them.

During the workshops three major topics related to car ownership appeared (Table 2):

- car maintenance including cleanliness, tidiness and digital updates
- family needs when sharing a vehicle and journey
- personal vehicle settings and adaptations

We collected examples of experiences for each topic, documented with participant quotes.

Designers summarised their understanding based on the user experiences to create an initial design proposal. The proposal addressed ownership experiences that appeared repeatedly such as:

- seeing "looking after the car" as important, as it strongly impacts their driving experience and sense of belonging to the car
- having new family needs requiring that they either change the car or create a new way of using the current cars functions to address the needs
- people (especially men) had a strong desire to upgrade their car's technical functions

We therefore proposed an aftersales service allowing owners to upgrade their car components and functions.

Table 2 Empathy workshop findings: Summary of ownership topics with user quotes

Ownership topic	Supporting examples
Car maintenance	One owner mentioned ensuring his car is clean, tidy and equipped gives him a sense of pride, happiness and confidence that his vehicle will perform well. "I feel like the car is a part of my family. I enjoy the ride more when the car is clean."
Family needs	A mother described her daily routine when driving her daughter to nursery and their different preferences for playing podcasts. "I always wait listening to the podcast after I dropped my daughter off. It is time for me to reflect or switch off."
Personal vehicle settings	One driver described commuting habits and their connection with maintaining his car: he always cleans windscreen and side mirrors before switching on satellite navigation and dashcam before setting off. "I am a part time police officer so that is why I know how to check everything. We have a checklist for all the things need to be checked such as lights, miles, etc."

After initially understanding car ownership behaviours, we decided to interview our international automotive company research sponsor to gather insights about mobility trends and their impact on aftersales services. We interviewed the aftersales and marketing departments by telephone, asking about the core business of the aftersales market, aftersales and marketing strategies, and perceived future mobility trends challenges.

We learnt that the company's core European aftersales business is limited to dealership experiences - selling accessories, showroom design consultations and explaining offers to individual customers. Vehicle customisation and long-term customer loyalty still offer substantial opportunities for business innovation. Participants mentioned that aftersales service will face significant challenges once electric vehicles are a substantial proportion of the market as they need less maintenance resulting in an estimated fifty percent reduction in sales of car parts.

We discussed our initial thinking about designing a vehicle upgrade subscription service allowing users to change car components and accessories. They were very interested in supporting the idea by involving their customer community, encouraging user driven customisation, and providing fun activities to reinforce brand loyalty. This design direction potentially addresses the electrification challenge, providing additional sources of revenue (Table 3).

Table 3 Client interview summary: proof of initial idea

Challenge	Potential for innovation	Value of innovation	Initial design hypothesis
Limited aftersales services	Increase provision of alternative services such as part customisation, accessory designs, customer events	Reinforce brand loyalty, boost aftersales income	Design vehicle upgrade service providing parts, accessories and digital updates
Electric vehicles require less aftersales service			

Journey shadowing strengthened our understanding of our participants experiences owning and using cars, habits accumulated over years of experience, and expectations about what can be changed and what they wish to stay the same. Insights about buying a new car, current car likes and dislikes, and experiences with car maintenance were collected during the journey. To investigate a range of ownership scenarios, we needed regular drivers in different stages of relationships with their cars, for example, drivers who use the same car for years, users of family cars, and new car users. Four users had their daily commute journey shadowed. We observed drivers' behaviour and the implications of their relationships with their cars, the findings (Table 4) supporting the next phases ideation process.

Table 4 Journey shadowing findings

Topic	Users habits/behaviours/expectations	Value of design provision
Maintenance service	Always go to same car dealer; New owners worry about being cheated, need reassurance about where they can safely go	Trust the quality and pricing of the service
New car purchase	Every 3-4 years consider buying a new car; When buying a new car consider depreciation, technology upgrades, interior materials, whether it is suitable for life changes and trying something new	Keep the value of car for longer
Upgrades to consider for current car	Technology related items such as satnav, headlights, cruise control, dashboard, media player, etc.; exterior design; interior materials such as seating and steering wheel	Easy to replace or upgrade
Parts owner feels close connections with	Steering wheel; In-car mirrors	Keep the original function and customise the styling

2. CREATION

The research team now has a clear understanding about topics that car owners and service providers focus on. A design hypothesis has emerged from the first phase of car ownership experience investigations. "Good facts are only the starting point, good product design is actually built on the designers' interpretation of those facts." (Holtzblatt, 2016) Based on the design hypothesis, we conducted an ideation workshop looking at the experience data, emerging trends in mobility, and current vehicle sales models (Figure 1) to create visual

design proposals that people could look at, feel, judge and provide feedback. The main objectives when selecting research methods in this phase are:

- ensure designers are exposed to richly detailed experience data summarised from the *Definition* phase before and during the ideation process
- ensure designers' ideation is guided by the ethical, societal and technological status quo as well as the commercialisation environment

The current model for choosing the specification of your car happens in three stages. Pre purchase, In vehicle set up and after market.

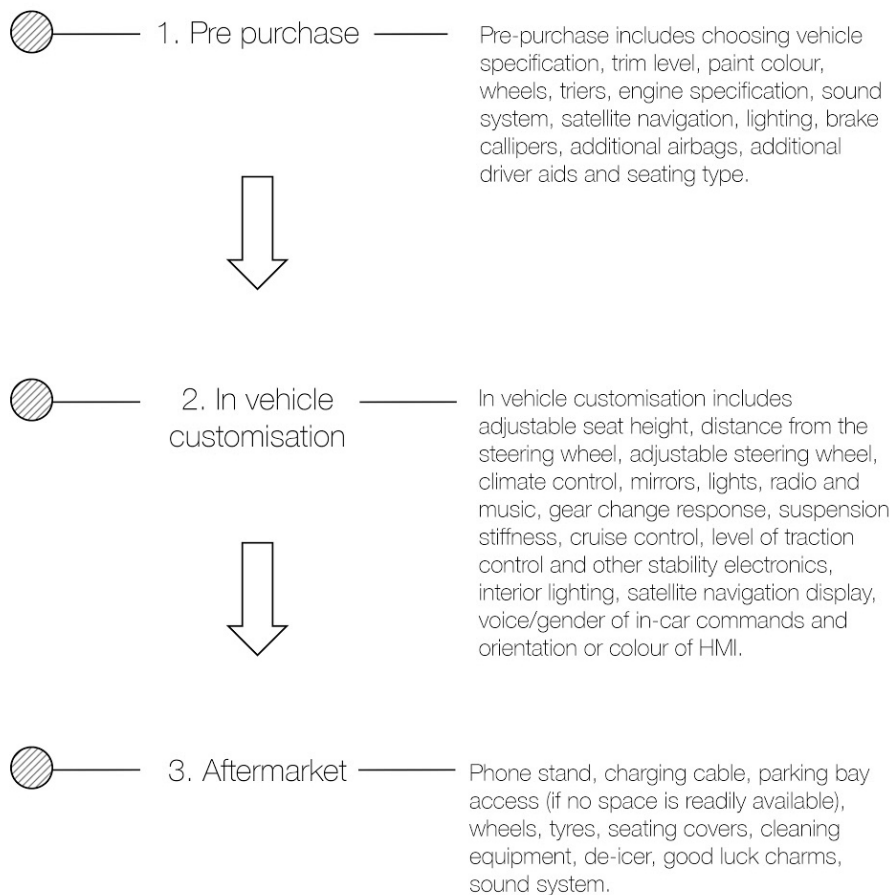


Figure 1 A designer tries to make sense of a current vehicle sales model in three steps

A contextual video (Figure 2) (Wu et al. 2019, March 19) was created to help designers construct a tangible scenario describing how car owners would use the proposed service. The video was designed to communicate “user expectations of situated use mainly concerned ease-of-use, trust building and previous experiences of related technology as well as stimulation” (Pettersson, 2017). The video shows users' situations, amplifying key

interactions needing to be designed, and provides a draft of potential design provisions while leaving the design of specific features to later development phases. This research step acts as a knowledge sharing platform with dual purpose: clarifying and communicating user experiences and expected solutions within the design team and creating a more tangible visualised design hypothesis for further user empathy and feedback sessions.

People are used to customising interior features such as seats, dashboards, and technology, and allowing such changes after the initial purchase opens opportunities for users to keep their cars longer and recycle components and materials they no longer need. With an engaging service model, customers could access and compare information about such options and be encouraged to make sustainable choices. The contextual video *Motoring Makeovers* incorporates findings from previous research phases to tell a story about Laura, a fifty-three-year-old whose youngest son has just left home. She no longer needs a car with six passenger seats and her business needs a car with a spacious boot. She goes to her car company's Design Lab to see how she can upgrade her current car to fit her requirements, where she is given a tablet to make modifications until she is satisfied. The service features described in this video include making the boot bigger and reducing passenger space; changing the cars' colour; changing car components such as the front lights, dashboard and drivers' seat; and selecting and changing the fabric of the seats.



Figure 2 Contextual video for *Motoring Makeovers*. Left to right: An owner decides to upgrade her car after recent life changes; Customising her car at the brand's Design Lab; Looking at vehicle material selection and information on a tablet

In order to explore the possible features of a *Motoring Makeovers* service in more detail, we created an interactive display on a tablet so car owners could experience our concepts and give feedback on specific designs. For example, when users hold the tablet over material samples and vehicle components, different levels of information about the item appear on the display (Figure 3). This way the design hypothesis becomes more concrete, demonstrating experiences that can be designed to become real vehicle products.

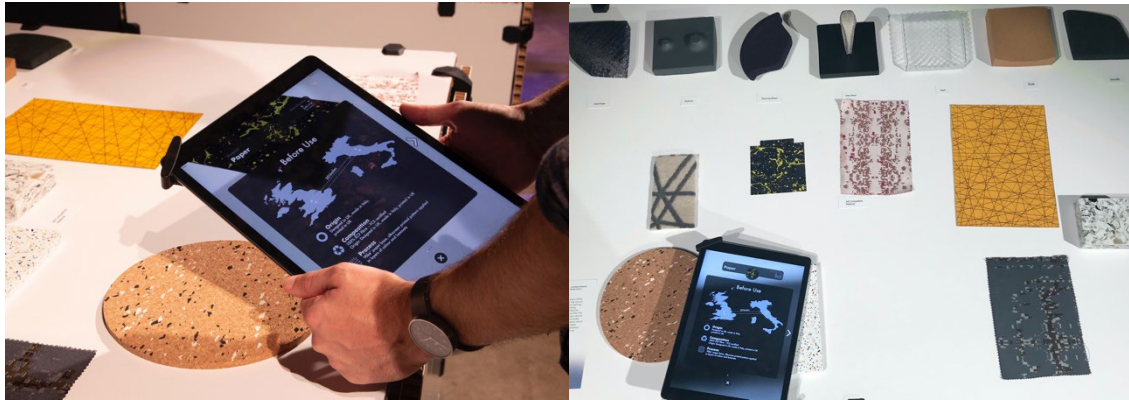


Figure 3 Left: *Motoring Makeovers* tablet interface; Right: *Customisable car parts and materials*

3. ITERATION

The iteration phase aims to user test and refine the design hypothesis. As Stanford d. school's Test stage suggests, this is another opportunity, in addition to Empathise at the beginning of the process, to return to scrutinise users' experiences. We collected feedback from randomly selected car owners who experienced our vehicle service design features at a workshop with five participants who represented different genders and age ranges (27-67), to test the design hypothesis and gain more information about the experience. A vehicle showroom tour was arranged for the designers to immerse themselves in typical car owners' experiences when purchasing and maintaining vehicles. These research methods were selected so user experiences could be investigated repeatedly and with more focus on expectations and assumptions of future visions so the design hypothesis could be developed into more detailed features for vehicle services and interfaces.

The design proposition is getting clearer for the research team - the key features that the *Motoring Makeovers* service will allow and support so that car owners can adjust and adapt their vehicle to their needs over time. We have investigated the main reasons why people want to change their car however we need more experience data to support the service design. Experience of expectations such as how they will keep beloved car parts and how they would like to access the service if they accept the idea will be perfect design evidence. At the workshop, as well as asking for reasons for changing their car, which parts they would like to change and keep, and watching the contextual video, we introduce a session to discuss their expectations. We provided a barometer with a list of "few things changed" to "many things changed" for their "old car" and asked them to build their own package to upgrade their car by placing provided cards on the barometer (Figure 4).

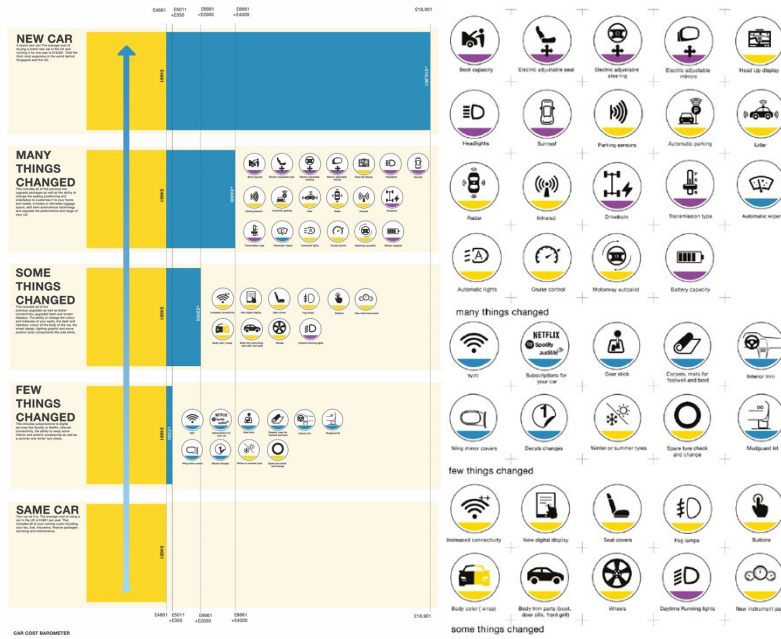


Figure 4 Left: Car upgrade cost barometer; Right: Vehicle component cards

When people discussed past and current experiences, we found they felt the same as we observed previously. For example, people want to dispose of an old car because of depreciation, the car reaching the end of its life, or new functionality being released. The parts of the car they wanted to keep varied: some mentioned functions, for example, cruise control; some mentioned components such as heated leather seats; some car size; one participant mentioned emission standards and government policy. When people discussed expectations for future services, their feelings were a mixture of being happy to try something new and being nostalgic about old functionality/components they enjoyed using. Table 5 summarises expectations and judgements when imagining a vehicle upgrade service.

Table 5 Experience expectations for future services

Potential design features	User expectations
Things to be changed	Functionality, safety and appearance
Number of upgrades	10 to 24
Popular upgrades	Electric seats and mirrors, automatic lighting, radar, parking sensors, Wi-Fi connectivity, carpets/ mats for footwells/boot
Acceptable price	~£4,000 (upgrade service)
Expected upgrade frequency	Dependent on items and existing features of car - some may be relevant after six months, others two years
Information to show with potential upgrades	Material durability; Ease of keeping clean; Environmentally friendly; Ethically sourced

To investigate vehicle customer experiences, the designers visited car showrooms (Figure 5)

of Hyundai, Land Rover and Tesla in London, and focused on looking at their customisation offers related to aesthetics and purchasing. All the showrooms were set up similarly: each had car models on display, a wall of material samples and colours, and large touch screens which customers could interact with to investigate customisation options and personalised payment plans. We found the brands offered much more limited customisation than we were expecting and saw potential for incorporating Virtual Reality or Augmented Reality, as well as introducing sensory elements, to connect customers with car models and provide more customisation experiences. Implementing these types of service as part of the aftersales business would offer a very different experience for potential car buyers.

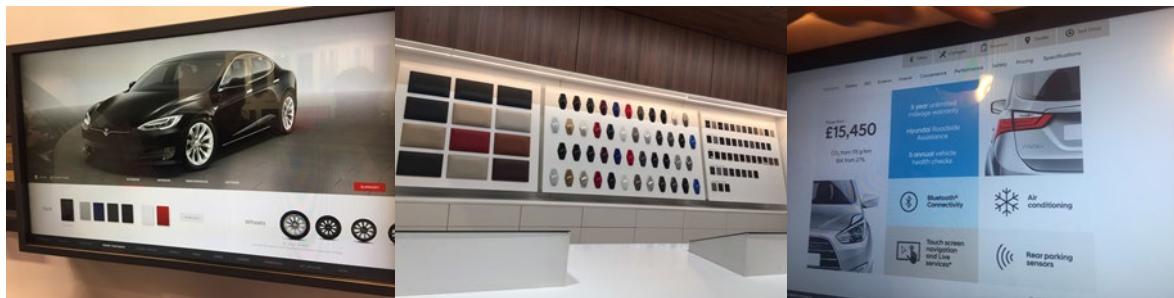


Figure 5 Vehicle showrooms: Left to right options - car accessories, car body colours and finance

4. PROPOSITION

Proposition is the concluding phase where experience data is turned into final design deliverables. The goal is to polish the design proposal and produce a tangible design visualisation, leaving space for discussions and decision making by clients or sponsors. The deliverable should indicate the specifics of the service design and business models including details such as subscription frequency, pricing models and commercial touch points.

We created a video (Figure 6) (Wu et al, 2019, March 14) showing service touch points via tablet to communicate the designed features for service options and the component customisation process. As we moved from contextual to concept video, we crystallised the ideas as comprehensive user interfaces for each scenario. The video starts with an owner in the brand's Design Lab holding a tablet to modify their current car. Design features are represented with detailed interfaces giving a concrete vision of how to use the service. Service packages can be established by choosing and changing multiple components, prices of the changes are calculated, and the results of adding or changing different types of components and their materials can be seen in a visualisation of their own car.

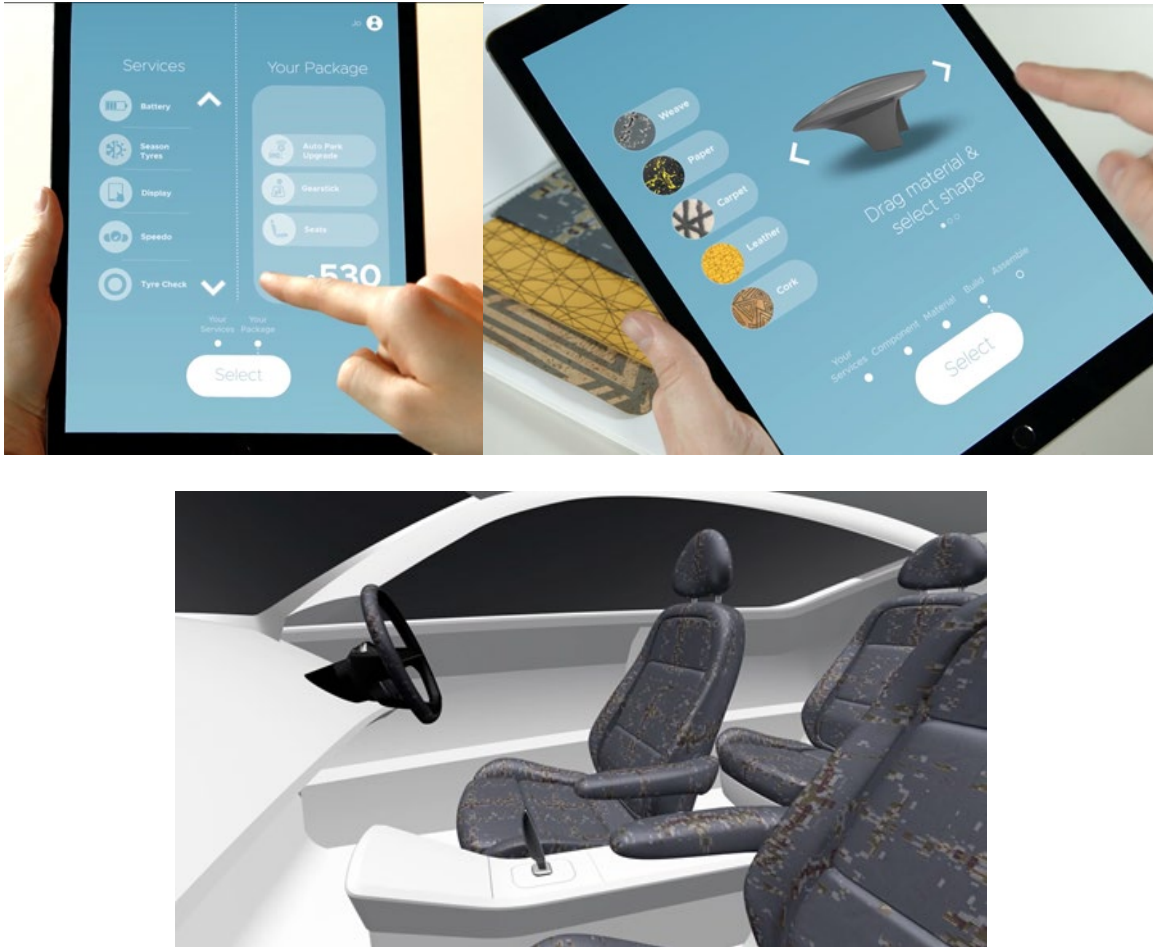


Figure 6 The final concept video showing how users can use the vehicle upgrade service. Clockwise from top left: choosing a service package and calculating the price; viewing and selecting types and materials of car components; viewing the upgrades in the user's own car

3. Discussion

By describing the process between analysing user experiences and creating design proposals using our vehicle ownership experience research as an example, we see the challenges - how to decide which scenarios include valuable experience data, how much experience data is enough for generating design proposals, and what types of proposal are appropriate.

Determining which scenarios to investigate is a critical step at the beginning of experience driven research. Defining useful scenarios is dependent on the projects problem statement, for example, *Motoring Makeovers* was intended to observe user habits and behaviours when owning cars so we could identify design opportunities for new vehicle services. We targeted looking at experiences of ownership for activities such as purchasing, maintaining and recycling cars. The decision on what to focus on is based on a complex judgement of whether potential design opportunities that the experiences point to can lead to mass or niche markets. We chose to focus on aftersales as it seems to be a neglected area.

How much experience data is enough and what types of data are effective for generating design proposals is the trickiest question. During research there should be several phases of experience data collection, each of which are followed by testing outputs generated by analysing the data. We started with telephone interviews and used the knowledge gained to design the empathy workshop. As we gained more understanding from workshops, we conducted more focused observations with journey shadowing. After creation of the design concept we conducted another empathy workshop to verify the idea and obtain more experiential insights for user interfaces and service designs. Experience data will only be valuable when looking for solutions relevant to the market with potential to be accepted by customers. The automotive client interview and showroom tours were vital for acquiring business insights necessary to validate the proposals.

Design proposal formats differ at each stage. The user experience collection and analysis phase design proposal can be a title and sentence. During ideation, design proposals can be sketches, visualising ideas quickly. A low-cost interactive prototype is suitable once the design direction is clearer. For the final research deliverable, a tangible demo/prototype accurately describing product features is appropriate.

Our four-step research process from user experience to design proposals presents a typical process of design driven concept proof research as applied in the automotive field. This research process is derived from a mix of academic study and business innovation and can be applied to a broad range of design fields such as product design, digital design and service design. The steps to unpack ownership into different topics and to evaluate potential concepts by summarising the value for end users and the client ensures that the designers look at design aspects that might be ignored by normal market research or when only focusing on designing forms. Breaking down ownership behaviours by identifying three steps – pre-purchase, the use of product and maintenance - helps designers immerse themselves in the context of the ownership lifecycle in order to find out what the current product can not provide. The car upgrade cost barometer was inspired by the Card Sorting method and can be useful for investigating what features end users expect to have and their priorities once a concept has been decided.

4. Conclusion

Most of the way we organised our research process successfully translated segmented user experiences into a design proposal. The combinations of selected research methods and design techniques were justified by each phase's objectives and the target for the ultimate research outcome. There are limitations for this type of research in terms of methods and final design proposals. Although the mixture of experience data analysis and design sketches, visualisations and briefs as written text helped the research as it moved smoothly from user experiences to design conclusions, a lack of specific knowledge of emerging vehicle technologies made our ideation development ungrounded.

Designing for advanced technological innovations is a challenge for experience designers.

People's current experiences can only say what works now, not what will work in the future. Even as we gathered user experiences and expectations, their future product insights might not be accurate or appropriate for real world implementations. Translating user experiences into design proposals for current markets and technologies might be feasible, but translating current user experiences into future facing design proposals is still to be explored.

There are many formats that are appropriate for each phase's design proposal with no absolute right way of doing it. Video demonstrations are constrained by time and budgets. A good storyboard together with two-dimensional product prototypes can be sufficient, with three-dimensional modelling showing every facet of the product more appropriate for others. The key is to set up a design hypothesis and continuously test it as research progresses with design proposals.

The paper authors hope to inspire a discussion to explore user experience research around the user led process and the approaches combining it with design processes. We believe further research development to reinforce the linkage between user led experience study and designers' interpretation and proposal is needed.

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Instructional Design for Non-specialist Beginners to Learn Chinese Semantic Radicals

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Abstract: The study investigates the effectiveness of instructional design for non-specialist beginners to learn Chinese Semantic Radicals (SRs). A Chinese SR is the smallest semantic component of a Chinese character. Research has shown that learning Chinese SR benefits the learning of Chinese characters by beginners. Research in this area is scarce with only a few studies investigating the application of related images to learn Chinese characters. This research investigates the performance and opinions of non-specialist beginners regarding four types of instructional designs: simply display, colour coding, illustration, and the combination of colour coding and illustration. The results confirmed that the combination of illustration and Chinese SR has the functions of visualisation, translation and memorisation. Colour coding has the function of position highlighting and memorisation. These research-based findings are an important contribution to knowledge and can inform future design and research when it comes to teaching Chinese SRs for non-specialist beginners.

Keywords: instructional design; illustration; colour coding; effectiveness

1. Introduction

Chinese is the second of the ten most important languages for the UK's economic, cultural and educational future (Tinsley & Board, 2017). Chinese characters play a vital and irreplaceable role in the acquisition of Chinese as a second language. Semantic Radicals (SRs) are the smallest semantic components in Chinese characters (Hoosain, 1991; Qian, 2009; Shen & Ke, 2007). For example, Figure 1 shows that the SR "Hand" is included in Hit, Pull and Push characters. It is obvious to see that characters which have the SR "Hand" are related to "Hand". Many researchers stated that Chinese-language beginners benefit from learning Chinese SR (Chan & Nunes, 1998; Packard et al., 2006; Su, 2010). The knowledge of Chinese SR includes its meaning and position (Shen & Ke, 2007; Su, 2010), which are regarded as learning tasks and instruction goals in this study.



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SR	Characters		
 Hand	 Hit	 Pull	 Push

Figure 1 An example of Chinese SR and related characters.

This study focuses on non-specialist beginners, which are defined as learners who are not taking a degree study in a language (Canning, 2011). Interviews with five Chinese language teachers revealed the difficulties of learning Chinese SRs for non-specialist beginners. Results from interviews showed that non-specialist beginners have very limited time to learn Chinese characters or Chinese SRs in class time, and they normally spend little time to learn it after class. This means non-specialist learners need more effective instructions for learning Chinese SRs. Cohen (2014) suggests that Western learners might need a variety of visual aids for learning Japanese kanji (original Chinese characters).

Chinese characters are logograms and some of them are iconic, which means that the way some Chinese characters and SRs are written makes them appear what they represent (Chen & Tzeng, 1992; Potowski, 2010). Some studies have provided evidence that the iconicity of Chinese characters benefits the acquisition of Chinese characters (Chan, Leung, Luo, & Lee, 2007; Luk & Bialystok, 2005; Shu, Chen, Anderson, Wu & Xuan, 2003). The iconicity of Chinese characters (including SRs) is their feature, which should be taken into consideration in instructional design.

2. Visual instructions for language learning

The research of visual presentations in instructional design for enhancing learning is not scarce in the field of language education. For instance, images are suggested as an effective tool for learning English (Akbari, 2008; Louie and Sierschynski, 2015), Arabic (Aldalalah et al., 2010) and Spanish languages (Snyder and Colon, 1988). Colour mark is recommended to increase the effectiveness of learning Russian language (Birzer and Zinsmeister, 2016). Moreover, images and graphic organisers bring a positive impact on learning English root words (Gill, 2007), which is similar to Chinese SRs to some extent.

In terms of learning Chinese characters, Wang and Thomas (1992) state that imagery-based mnemonics are beneficial to the short-term retention of Chinese characters compared with rote learning; though Kuo and Hooper (2004) argued such “a picture representing a concrete or abstract word” (p.26) approach does not yield to significant benefits. Wang (2014) stated that learning Chinese characters with animation is significantly more effective than learning Chinese characters with text-only.

Previous studies (Kuo & Hooper, 2004; A. Y. Wang & Thomas, 1992) support the potential effectiveness of instructional design for learning Chinese SRs.

However, few studies test the effectiveness of different static infographics for learning Chinese SRs. Moreover, the visual instructions for language learning in the previous studies were presented as extra and independent information for describing the content of targeting knowledge. For improving the effectiveness of the instructions, the theories and suggestions of infographic instructions are stated in Section 3.

3. Infographic instructions for effective learning

The main purpose of infographic design is to organise and present information via visual graphics in order to communicate with target audiences effectively (Pettersson, 2002; Smiciklas, 2012). Infographic instructions make the acquisition of knowledge more efficient and accessible (Merrill, Drake, Lacy, Pratt, & Group, 1996; Reiser & Dempsey, 2012). The theoretical basis and the effectiveness of different visual approaches will be explored next.

Dual Coding Theory proposes that both visual coding and verbal coding are independent cognitive systems for processing information (Paivio, 1986). The effectiveness of instructions in learning materials may be increased by stimulating with visual and verbal materials rather than only verbal representation (Clark & Paivio, 1991). Regarding infographic instructions, this theory has been used as theoretical support in many studies (Carney & Levin, 2002; Vekiri, 2002). Moreover, the Picture Superiority effect refers to the phenomenon that human memory is more sensitive to visual information than verbal information (Curran & Doyle, 2011; Defeyter, Russo & McPartlin, 2009). The cognitive load theory suggests that instructions should not split learners' attention from various sources of information and they should integrate multiple sources of information physically (Chandler and Sweller, 1991).

Different infographic instructions have different functions for effective learning. Images and colour are widely used in infographic instructions. Based on the targeting learning tasks, the potential functions of images have been explored and listed below by reviewing the studies conducted by Ainsworth, (1999, 2006), Levin & Mayer (1993) and Marsh and Domas White (2003).

- Visualise: images provide visible representations.
- Translate: images repeat the same content from verbal information.
- Memorise: images help to memorise information.

The potential functions of the colour application have been suggested and listed below (Ainsworth, 1999; Chandler & Sweller, 1992; Keller, Gerjets, Scheiter & Garsoffky, 2006; Smallman & Boynton, 1993).

- Relate: colour provides clear visual instructions to show relationships.
- Highlight: colour emphasises the important parts of the whole.
- Memorise: colour help to memorise information.

However, the instructions in the previous studies were presented as independent and separate information rather than physically integrated. Moreover, the functions and effectiveness of instructional design are not always universal and depend on the type of instructions, learners and learning tasks (Clark, Lyons & Hoover, 2010; Gyselinck & Tardieu, 1999; Kalyuga et al., 2004; Kalyuga & Sweller, 2014).

The aim of this study is to explore how instructions with illustration and colour coding affect the recognition behaviour for learning Chinese SRs. A performance task was designed to test non-specialist beginners' short-term memory. This was followed by a post-test questionnaire to explore the functions of different infographic instructions.

4. Methods

To investigate the effectiveness of different infographic instructions for non-specialist learners, a performance test and a post-test questionnaire have been conducted with 16 participants. The effectiveness was explored by measuring the accuracy. The instruction with illustration in this paper is defined as the combination of illustration and SR. The instruction materials in this study include: (i) illustration which integrates graphics presentation and SR, and (ii) colour coding which a different and chromatic colour is applied to part of the character for denoting the position of the Chinese SR.

The research hypotheses have been formulated as below:

- Hypothesis 1: Instruction with illustration increases memorising the meanings of Chinese SRs.
- Hypothesis 2: Instruction with colour coding increases memorising the positions of Chinese SRs.

4.1 Participants

A total of 16 participants (8 female and 8 male) were recruited with a mean age of 21 years old. All the participants were non-specialist beginners from non-Chinese speaking countries (India, Ireland, Mexico, Pakistan, Poland, Saudi Arabia, Spain and UK).

4.2 Instruction materials

The instruction materials used in this study consist of four types of learning instructions with sixteen Chinese SRs. Each instruction has four SRs, and each has specific and concrete meanings. The difficulty level of SRs is determined by the number of strokes. The total number of strokes for each group has been determined in the range of 13-15 strokes. Figure 2 shows the 16 SRs with an English translation and stroke numbers.

β city	扌 hand	宀 cave	马 horse	刂 knife	禾 grain	艹 grass	灬 fire
2	3	5	3	2	5	3	4
讠 talk	宀 house	女 female	衤 clothe	冫 ice	彳 slow-walk	火 fire	𦵏 bamboo
2	3	3	5	2	3	4	6

Figure 2 Sixteen SRs and their corresponding meaning and stroke number.

Figure 3 shows examples of the four types of learning instructions. Each SR was displayed with three characters which share the same SR. Participants were asked to memorise the Chinese SRs rather than characters; the characters were displayed to help participants to understand the relationship between the targeting SR and the related characters. Type one is a simple display with black position highlight. Type two instructs radicals with colour coding for learning position. Different Chinese SRs have different positions. Normally, SR has the top, bottom, right and left position. The different position shows with different colours: green for left, orange for right, blue for top and brown for bottom. Type three instructs radicals with an illustration integrated with SR. The illustration visualised the meaning and followed the shape of the radical. Type four is a combination of type two and type three.

Figure 3 illustrates four types of learning instructions for Chinese radicals. Each type shows a radical, its meaning, and three example characters that share the radical.

- Type 1:** Shows the radical '扌' (Hand Radical) and '打' (hit). Example characters: 打 (hit), 拉 (pull), 抓 (catch).
- Type 2:** Shows the radical '衤' (Clothes Radical) and '袖' (sleeve). Example characters: 袖 (sleeve), 袜 (socks), 裤 (trousers).
- Type 3:** Shows the radical '火' (Fire Radical) and '煮' (cook). Example characters: 煮 (cook), 照 (shine), 焦 (burnt).
- Type 4:** Shows the radical '彳' (Slow-walk Radical) and '徘' (wander). Example characters: 徐 (slowly), 徘 (wander), 往 (go).

Figure 3 The 4 types of learning instructions: (1) Simply display, (2) Colour coding, (3) Illustration, (4) Illustration and colour coding.

4.3 Procedure

The whole procedure of the experiment has three main parts:

- Learning task
- Memorisation task
- Post-test questionnaire

Participants were provided written explanatory materials, to learn about what Chinese SRs refer to and their relationship to Chinese characters, before they started the learning task. For the learning task, the participants were given 20 seconds to study each of the 16 SRs (i.e. 4 types of learning instructions x 4 SRs under each type).

Once the learning task was completed, the participants were required to take on the memorisation task. The memorisation task was set in form of a multiple-choice quiz with 3 questions for each of the SRs and only one answer should be given out of the 4 possible options in each question:

- Meaning Recall (MR): To choose the meaning when offering the SR.
- Radical Recall (RR): To choose the SR when offering the meaning.
- Position Recall (PR): To choose the position when offering the SR.

All the questions were randomised to minimise any bias. The participants were allowed an unlimited amount of time to answer all the questions. After the memorisation task was completed, the participants were asked to fill in a five-point Likert scale questionnaire. The questionnaire was set to attempt confirming the functions the functions of illustration and colour coding.

4.4 Analysis

All the data have been tested for normality with the Shapiro-Wilk test. All the p-values¹ of the data are smaller than 0.05, therefore, all the data are non-normal distribution (Royston, 1992). The Wilcoxon signed-rank test (Woolson, 2008) is a non-parametric statistical test to compare the differences between two matched samples. The descriptive statistical data of all groups was to compare the means of different groups. The Wilcoxon signed-rank test was conducted to compare the accuracy of the four groups. If the p-value of the Wilcoxon signed-test is greater than 0.05, the two groups have no significant difference. If the p-value is less than 0.05, the two groups have a significant difference. If the p-value is less than 0.01, the two groups have a highly significant difference.

1 The p-value is the probability value in statistical hypothesis testing (Wasserstein & Lazar, 2016).

5. Results

5.1 Memory test accuracy

The descriptive statistic result of the memory test accuracy is shown in Table 1. Figure 4 illustrates the p-value of the Wilcoxon signed-test for the four different types. The result shows obvious trends of different questions among Type one (T1), Type two (T2), Type three (T3) and Type four (T4).

For the MR question, Table 1 shows the means of four types: T1 (M=69%) < T2 (M=72%) < T4 (M=89%) < T3 (M=95%). The result of statistical test (Figure 5) reveals that T1 (M=69%) and T2 (M=72%) do not have a significant difference ($p > 0.05$). T3 (M=89%) and T4 (M=95%) do not have a substantial difference ($p > 0.05$). The MR accuracy for T1 (M=69%) is highly significantly lower ($p < 0.01$) than T3 (M=89%), and significantly lower ($p < 0.05$) than T4 (M=95%). The MR accuracy for T2 (M=72%) is highly significantly lower ($p < 0.01$) than T3 (M=89%), and significantly lower ($p < 0.05$) than T4 (M=95%).

For the RR question, the means of the four types could be ordered as T1 (M=63%) < T2 (M=77%) < T4 (M=88%) < T3 (M=98%). The accuracy of T1 (M=63%) is significantly lower ($p < 0.05$) than T2 (M=77%), highly significantly lower ($p < 0.01$) than T3 (M=98%), and significantly lower ($p < 0.05$) than T4 (M=88%). T3 (M=98%) is highly significantly higher ($p < 0.01$) than T2 (M=77%), and significantly higher ($p < 0.05$) than T4 (M=88%). The accuracy of T2 (M=77%) and T4 (M=88%) does not have a large difference ($p > 0.05$) (Figure 4).

For the PR question, T2 (M=81%, SD=14%) \approx T3 (M=81%, SD=27%) > T4 (M=67%) > T1 (M=45%). The statistical result (Figure 4) shows that the accuracy of T1 (M=45%) is highly significantly lower than T2 (M=81, $p < 0.01$), T3 (M=81%, $p < 0.01$) and significantly lower than T4 (M=67%, $p < 0.05$). T2 (M=81%) does not have great difference with T3 (M=81%, $p > 0.05$) and T4 (M=67%, $p > 0.05$). The accuracy of T3 (M=81%) is noticeable higher ($p < 0.05$) than T3 (M=67%).

In summary, instructional design with colour coding only (T2) shows great higher accuracy for answering the PR question. Instructional design with illustration only (T3) has significant higher accuracy for learning Chinese SR in terms of answering all the three questions (MR, RR and PR). Instructional design with the combination of colour-coding and illustration (T4) shows obvious higher accuracy for answering MR and RR questions, however, T4 shows significant lower accuracy than T3 in terms of the PR question.

Table 1 The result of the memory test accuracy.

Accuracy	Type	Mean	SD	N
MR Question	T1	69%	25%	16
	T2	72%	29%	16
	T3	95%	10%	16
	T4	89%	22%	16
RR Question	T1	63%	24%	16
	T2	77%	14%	16
	T3	98%	6%	16
	T4	88%	22%	16
PR Question	T1	45%	28%	16
	T2	81%	14%	16
	T3	81%	27%	16
	T4	67%	33%	16

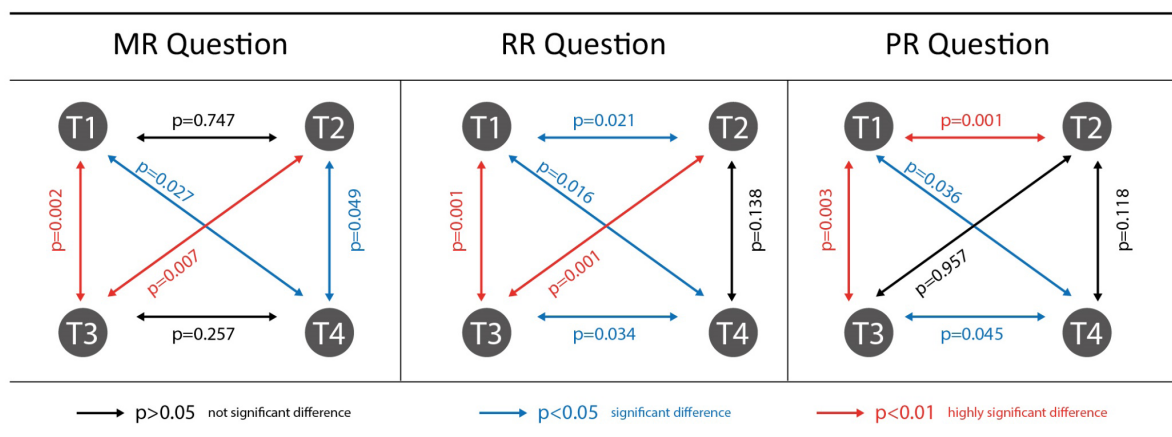


Figure 4 Wilcoxon Signed Ranks Test p-value for Memory test Accuracy.

5.2 Questionnaire

The questionnaire helps to explore the various functions of illustration and colour coding. The five-point Likert scale was developed to measure the agreement of different functions: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree. Table 2 displays the results, 87.5% (31.25% agree and 56.25% strongly agree) of participants confirm the function of visualisation; all participants (18.75% agree and 81.25% strongly agree) believe illustration has the function of translation. The majority of participants (93.75% from which 12.50% agree and 81.25% strongly agree) think illustration helps to memorise radicals' meaning.

Most participants (81.35% from which 25% agree and 56.35% strongly agree) agree that illustration helps to highlight the shape of radicals.

Table 2 *The Results of illustration functions from Likert scale questionnaire.*

Illustration functions	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Visualisation	0.00%	6.25%	6.25%	31.25%	56.25%
Translation	0.00%	0.00%	0.00%	18.75%	81.25%
Meaning					
Memorisation	0.00%	0.00%	6.25%	12.50%	81.25%
Shaping					
Highlighting	0.00%	6.25%	12.50%	25.00%	56.25%

Table 3 presents the results of functions of colour coding for learning Chinese SR. Majority of participants (25% agree and 50% strongly agree) believe that colour coding highlights the position of each SR. Many participants agree with the function of position memorisation (68.75% from which 31.25% agree and 37.5% strongly agree). More than half of participants (68.75%) approve that colour coding breaks down the whole characters into components. More than three quarters of participants (12.25% agree and 68.75% strongly agree) found the colour-coding helps to know the structural relationship between Chinese SR and complete characters.

Table 3 *Results of colour coding functions from Likert scale questionnaire.*

Colour-coding Functions	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Position highlighting	0.00%	6.25%	18.75%	25.00%	50.00%
Position memorisation	6.25%	6.25%	18.75%	31.25%	37.50%
Breaking down	0.00%	12.50%	18.75%	25.00%	43.75%
Relate	0.00%	0.00%	18.75%	12.50%	68.75%

In summary, the majority of participants agreed that the combination of illustration and Chinese SR visualises and translates the meaning of radicals. Moreover, it helps to memorise the meanings of SRs and highlights the shapes of SRs. In terms of colour coding, most participants agreed that colour coding has functions of position highlighting and position memorisation. In addition, many participants agreed that colour coding helps to break down the whole character into components and it helps to understand the structural relationship between Chinese SR and complete characters.

6. Discussion

This study investigated different instructional designs for non-specialist beginners to learn Chinese SRs. The memory test task ascertains the effectiveness (measured by accuracy) of different instructional designs. The questionnaire confirmed various functions of illustration and colour coding. The study is using an experimental approach to examine the impact of illustration (integrated with radicals) and colour coding for learning Chinese radicals.

The findings of the memorisation task align with previous studies (Kuo & Hooper, 2004; Wang & Thomas, 1992) and further develop the theories of instructional design for learning Chinese SRs. In the memory test, the results are in line with Dual coding theory (Paivio, 1986) and Picture Superiority effect showing that instructional design facilitates the acquisition of knowledge (Clark & Paivio, 1991). Specifically, the results of memory test accuracy for answering Meaning-Recall questions and Radical-Recall questions confirm Hypothesis 1 that instruction with illustration increases memorising the meaning of Chinese SR. The results not only prove that illustration helps to recall from radical to meaning (MR question), but also the other way around, from meaning to radical (RR question). This is in agreement with the visualising, translation and memorising functions with illustration (Ainsworth, 1999; Ainsworth, 2006; Levin & Mayer, 1993; Marsh & White, 2003). All the above functions have been confirmed with participants.

As colour has been identified as important in enhancing memory (Chandler & Sweller, 1992; Keller et al., 2006; Smallman & Boynton, 1993), this result of memory test accuracy (G1 and G2 for PR question) and the result of post-test questionnaire confirm the efficiency of colour-coding (Hypothesis 2). These experimental results confirm the efficiency of colour-coding, specifically on memorising SRs' positions, which can be further popularised in the instructional design for learning Chinese Radicals. The results expose the highlight and relate function (Ainsworth, 1999; Chandler & Sweller, 1992; Keller et al., 2006; Smallman & Boynton, 1993), which emphasises the position and the relationship between Chinese characters and SRs. Moreover, a new function of colour coding as an instructional design approach when learning Chinese SRs is break down, which means the colour split SRs from complete Chinese Characters. Learners also confirmed that colour coding facilitates knowing the relationship between Chinese SRs and the whole characters. This help learners to know an SR is a part of Chinese Characters by colour coding.

Based on the result of the study, illustration and colour coding have different functions in terms of different learning tasks. The data reveals a decrease in accuracy when applying illustration and colour coding together; this might be because of too many instructional information, such as too many colours. For future research, reducing the number of different colours for the instructional design might be a solution.

This study supports and suggest (Clark et al., 2010; Kalyuga & Sweller, 2014) the effectiveness of different instructional design approaches is different in various learning tasks. The results suggest that instructional design should be approached more directly for specific problems when learning Chinese SRs. The questionnaire further supports the various functions

for illustration and colour coding separately, as confirmed by participants. Additionally, governments of many countries increasingly emphasise the great importance of the acquisition of the Chinese language. For example, it is noted Saudi Arabia started to take the Chinese language into its educational curriculum in 2019 (“Saudi Arabia plans”, 2019). This means that the research of instructional design for learning Chinese SR is of significant importance to help meet such demand. Since the target audience of this study is general Chinese learners, special conditions like colour blindness or dyslexia were not considered, which is a limitation of this study and a topic to be addressed in the future.

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Graphic design studies: what can it be? Following in Victor Margolin's footsteps for possible answers

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Abstract: Graphic design studies is proposed as a new way to differentiate practice in graphic design from reflection on that practice. Previous attempts to link design studies and graphic design have fallen short of arguing for graphic design studies, and consequently has not been explicit about how graphic design studies may contribute to better understanding the nature of graphic design practice. This has not been helped by the abstruse nomenclature that confuses graphic design's relationship to and distinction from other visual practices. Victor Margolin called this 'narrative problems.' This paper explores the potential to differentiate graphic design practice from graphic design studies. Building on Margolin's longstanding work and dissatisfaction with perpetuating the term 'design research' in favour of adopting 'design' and 'design studies,' the potential for recognising a new field of graphic design studies is introduced and explored for the benefit of emerging interdisciplinary design research agendas.

Keywords: graphic design; narrative problems; interdisciplinarity; process

1. Introduction

What can graphic design studies be? This paper follows Victor Margolin's interest in developing design studies as a useful way to differentiate design practice from reflection on design practice and attempts to adopt this approach for the benefit of graphic design research, past, present and future. The aim is to present the idea of graphic design studies as a possible remedy to the perceived lack of credible research in graphic design. The paper speculates on a future for graphic design studies and the aspiration for more coherence, consensus, stability, and standards in graphic design research. First, it will consider Margolin's argument for design studies before exploring this for the benefit of graphic design scholarship. Through further focusing on portrayals of graphic design practice, the objective is to make a comprehensible case for graphic design studies. The credence in Margolin's argument will serve to hypothesise what graphic design studies already is and what it can be.



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2. The argument for design studies

At the Design Research Society's 50th anniversary conference in Brighton in 2016, Dennis Doordan presented a paper on behalf of Victor Margolin, who had been unable to attend. Entitled 'Design Research: What is it? What is it for?', the paper questioned the use of the term 'design research' in preference for adopting *design* and *design studies* 'to delineate more precisely the nature of the knowledge or capabilities they signify' (Margolin 2016: 5). In essence, Margolin argued that when scholars call what they do 'design research', this suggests a secure and clear domain, but his belief was that this is not the case. In his view, so-called 'design research' does not have a distinctive character, is somewhat illusory, and 'does not designate a specific body of knowledge or a particular methodology' (2016: 9). Hence, and in its place, design should denote 'producing design' whilst design studies should concentrate on 'reflecting on design as it has been practiced, is currently practiced, and how it might be practiced' (2016: 8). Margolin is unsure about what design research is and what it is for.

This clearly questions the nature of design research since it has evolved from the 1960s onwards, when there were no design research journals, conferences, societies, PhD programmes, or disciplinary concepts of design (Cross 2018: 706). During this time, design research is said to have transformed through a series of waves that, in brief: (1) explored its methods and theories whilst becoming a credible discipline at degree level; (2) attracted funding and grew internationally through conferences, journals and interdisciplinarity; (3) impacted on industry and the economy through innovation; and, (4) became more people orientated, absorbing theories from other disciplines, impacted on competitiveness and influenced other non-design disciplines (Cooper 2019). This fourth and most recent wave resembles design research as a transdisciplinary field.

Throughout this same period, established design practices are typically identified as 'product design, graphic design, fashion design, transportation design, interior design, design management, and the related activities of engineering and architecture (Margolin 2013: 403). To these Margolin adds an abundance of new design activities such as 'service design, interaction design, human-computer interface design, universal design, participatory design, ecological design, social design, feminist design, medical design, organization design and numerous others'. However, this latter group is said to have been established in a 'haphazard fashion with no attention given to the theories, principles or arguments that should identify any shared assumptions, purposes or methods among these diverse activities' (2013: 403). If Margolin is right, these newer conceptions of design do not appear to have advanced design research and reinforce his view that design research has evolved without a precise identity as an intellectual field (2016). Hence, Margolin calls for the adoption of design studies as 'a framework that can most effectively integrate the multiple voices, theories, arguments and claims that have design as their subject into a course of action that can make the most productive use of them' (2013: 405). In this pursuit, Margolin's ideas align design studies with the fourth wave of design research noted earlier.

Margolin has explored the possibility for adopting ‘design studies’ since the mid-1990s. In 2013, he argued that the tasks and challenges associated with the idea of design studies should emphasise, above all, a need to ‘find its own subject matter, topics of investigation and methods’ as well as convincing established researchers to contribute to and clarify a chaotic domain, and lead the shaping of design’s future (Margolin 2013: 400–401). Accordingly, the broad domain of design should encompass practice, research, discourse and education, with design studies providing the place for transformation in these sub-domains at the interface between design and non-design domains, these being those disciplines outside of design that can and do provide useful insights on design. Going back further still, he posited design studies as an alternative to design history because advances made in that field had made it difficult to pin down a fixed identity due to the fact that design as an activity constantly changed (Margolin 1995: 10). Recognising the breadth of subject matter that the study of design had evolved into, Margolin then proposed a definition of design studies as ‘the field of inquiry which addresses questions of how we make and use products in our daily lives and how we have done so in the past’ (1995: 14). This affirmed the idea of design studies as an inclusive, interdisciplinary or transdisciplinary field of inquiry. Margolin concluded his argument by proposing a central focus for design studies as the social, technological, cultural, transformative, exploratory and educational potential of design, with a particular emphasis on improving and transforming practice in a global context.

At a time when there is considerable interest in how design research can facilitate collaboration and co-creation, celebrate the uniqueness of disciplinary knowledge as well as interdisciplinary ways of working, meet the challenges in design education, understand roles, experience and expertise, as well as include multiple voices, amongst other concerns, this paper explores the potential for graphic design’s contribution to these debates by exploring its possible contribution to design studies in readiness for the next wave of design research and its ‘potential to change the world at all levels’ (Cooper 2019: 10). In essence, it explores the usefulness of design studies as an approach to establish what can be learned for the benefit of graphic design research.

3. The argument for graphic design studies

The need for research in graphic design is not new. Research has been recognised as an important addition to the education of graphic designers, and in 2006 was considered ‘the next big academic challenge’ (Heller 2006: 13). This came after concerns about graphic design research at the end of the last century when it had been argued that the research culture in graphic design was beset by ‘narrative problems’ in the form of abstruse nomenclature that confuses graphic design’s relationship to and distinction from other visual practices (Margolin 1994). Twenty years on this had not changed. For example, in the United Kingdom, the most recent national review of research suggested research in ‘graphic and communication design’ is weak intellectually and theoretically (Anon 2014). That said, in the United Kingdom a modest graphic design research culture is said to be emerging, and ‘thriving, if you know where to look’ (Walker 2017). This view emerges from on a broad

definition of the field, a random set of sub-disciplines, and alternative name suggestions that extend the narrative problems, either by narrowing or broadening its scope from information design, graphic communication, to communication design. In the same vein, there are said to be a few 'graphic design academic journals' such as *Communication Design*, *Journal of Design History*, *Information Design*, and *Visible Language*. However, none of these are known by name as graphic design research (a minor concession being the short-lived *Communication Design*, which carried the sub-heading *Interdisciplinary and Graphic Design Research*).

Conversely, there is clear evidence of scholarship that diminishes the potential for confusing narrative and directly aligns with the term graphic design. Numerous publications are available that account for the depth of practice and how it continues to:

- evolve as a practice (Dziobczenski and Person 2017; Roberts, Wright, and Price 2015; van der Waarde 2009);
- build on a significant documented histories that are both short- and farsighted (Müller and Wiedermann 2019a; 2019b; Drucker and McVarish 2013; Eskilson 2012; Cramsie 2010; Jubert 2006; Hollis 2001; Heller and Balance 2001; Meggs 1983);
- examine theory (Hongmin Kim 2018; Bestley and Noble 2018; Davis 2012; Armstrong 2009; Bennett 2006);
- explore critical perspectives (Triggs and Atzmon 2019; Lees-Maffei and Maffei 2019; Drucker 2014; Blauvelt and Lupton 2011; Bierut, Drentell, and Heller 2006; Barnard 2005).

This sample of references access the knowledge of other disciplines to help structure thinking about graphic design, leading to an understanding that it is fundamentally interdisciplinary (Davis 2012: 234). Margolin's definition of design studies as a field of inquiry that 'addresses questions of how we make and use products in our daily lives and how we have done so in the past' is useful here for what can be referred to as graphic design studies, as distinct from graphic design practice. If research in graphic design needs to discover its own subject matter, topics of investigation, and methods, by reflecting on graphic design practice, past, present and future, what could its focus be?

4. The focus of graphic design studies

If the main objective of design studies is to reflect on design as it has been practiced, is currently practiced, and how it might be practiced, and the same applies to the aim of graphic design studies, it is essential to understand the nature of graphic design practice. It has been suggested that specialist graphic design sub-disciplines now include, but are not limited to, typography, typeface design, wayfinding, book and periodical design, interaction design, illustration, exhibition design, branding and corporate identity (Walker 2017). Whereas, in his historical account of design, Margolin (2015) implies graphic design emerged as a profession at the end of the nineteenth century from the work of commercial artists in five kinds of business: printing and engraving houses; book, periodical and newspaper

publishing; lithography and poster houses; advertising agencies; and commercial art studios (2015: 387). This involved a range of activities, or sub-disciplines, including lettering, type design and typography, layout, poster art, illustration, the design of books and periodicals, even writing.

In discussion about the formation of graphic design as a profession, Margolin (Margolin 2015: 387) does not say much about the adoption of the term graphic design by those working at the turn of the nineteenth-twentieth century (leaving this to a later discussion about the Dwiggin), even though graphic design has been identified in use as early as 1908 related to the design of charts and graphs (Shaw 2014). However, there is a clue about the origin of the practice as a design activity when Margolin refers to the activity of Chicago based freelance independent 'designers' such as Fred Goudy and Will Bradley who in the 1890s 'managed to establish patterns of practice that enabled them to move between various activities such as typography, layout, poster art, and the design of books and periodicals', both being 'part of an active design scene in Chicago' (Margolin 2015: 387).

The scope and scale of activities listed in portrayals of the discipline since suggest this pattern has continued. During the second half of the twentieth century the unification of a disparate but clearly related set of practices as graphic design eventually crystallised in a definition in the first *Dictionary of Graphic Design and Designers* (Livingston and Livingston 1992) as 'Generic term for the activity of combining typography, illustration, photography and printing for purposes of persuasion, information or instruction'. This short description did not reflect the full extent of practice in the early 1990s, when computers had already integrated with graphic design process and its practitioners had made significant impact in non-print applications such as broadcast media and environmental signage. However, it did capture the integrative nature of the practice.

Graphic design in the early twentieth century, considering the various trades, techniques, and technologies, clearly crossed and integrated many sub-disciplines, and the situation is similar a century later, with some notable similarities and differences forged by an understanding of the basics (for example, type design, illustration, printing) as well as some newer areas of practice (branding, information design, digital design).

In design scholarship, graphic design has recently been described as a 'broad and multidisciplinary' profession for print, screen and environmental (physical rather than ecological) applications that include various modes of representation such as photography, illustration, typography, diagrams, and animation (Ramirez 2016: 107–109). It is still acknowledged as often being combined with other disciplines and its 'specialities' are said to include: editorial design; visual identity design; packaging design; web design; alphabet design or typography (adapted from Ramirez 2016: 108–109).

However, this partial indication of graphic design as a practice in the early twenty-first century is insufficient. It excludes a number of specialist interests such as illustration or photography, advertising, or writing, and preoccupations already known from accounts of graphic design by its practitioners and critics. See Table 1.

Table 1 *What is graphic design is and what it is for?*

What is graphic design? (Newark 2002)	What is graphic design for? (Twemlow 2006)
Alphabets	Experimental typography
Modules	Movie titles
Typefaces	Visualising music
Digital typefaces	Broadcast design
Full character set	Sound design
Languages	Games design
Typography	Signage
The grid	Editorial design
Hierarchy	Book design
Rules and other devices	Information design
Images	Interactive design
Illustration	Identity design
Photography	Advertising
Using photography	Type design
Word and image	Writing
Tools	Software design
Pencil	Mise-en-scène
Materials	
Paper	
Computer	
Disciplines	
Logos	
Identity	
Print –publicity	
Print – information	
Packaging	
Books	
Magazines	
Exhibitions	
Signs	
Web and film	

Building on this early twenty-first century indication of graphic design practice, investigating graphic design from a research perspective is further revealing new insights into the practice. Through an extensive research programme of interviews with graphic design practices in the city of Breda in The Netherlands, the full extent of what graphic designers actually do (see van der Waarde 2009) provides a much more nuanced indication beyond the various attempts at definition and the many books that show the products of the practice. Organised into three basic components of visual elements, visual goals and effects, there is clear evidence that links recent practice to how it was a century ago. See Table 2. For example, typography, illustration, font design, publishing, graphic art, and advertising clearly provide a constant thread back to then. Activities such as photography and animation have since been added as they became established in the twentieth century. In the first decade of the twenty-first century, programming, website design, spatial design, end user research and communication strategy, to name a few, provide a more contemporary indicator of what practitioners do, providing a picture of a sophisticated practice capable of supporting other disciplinary perspectives beyond those who have had training and education in art and design.

Table 2 What graphic designers say they do (adapted from van der Waarde, 2009).

Visual Elements	Visual Goals	Effects
Illustration	Film production	Marketing
Photography	Website design	Communication strategy
Typography	Graphic Art	Usability
Copywriting	Spatial design	End user research
Image processing	Advertising	Visual research
Animation	House style design	Visual strategy
Audio-video		Concept development
Programming		House style management
Author		Project organisation
Infographics		
Font design		
Desktop publishing		

In a similar vein, Dziobczenski & Person (2017) have identified what employers look for when appointing graphic designers, implying a similar alignment to the core capabilities of practitioners working across the various graphic disciplines a century ago. Essentially, the core competence areas cover the spectrum of activity that the contemporary graphic design professional must demonstrate, as well as personal characteristics of acumen, aesthetic and creative sensitivity, self-motivation and a passion for design. See Table 3.

Table 3 Graphic Design Competencies, Knowledge, Skills and Personal Characteristics, listed in order of importance (Dziobczenski and Person 2017)

What competence areas UK [graphic design] industry says it needs	
Competence areas	
Print and Advertising	
Digital Design	
Packaging and Point of Sale	
Brand Visual Identity	
Retail and Environmental Design	
Film and Animation	
What knowledge and skills UK [graphic design] industry says it needs	
Process management skills	Conceptual design skills
Interpersonal (teamwork)	Idea generation and concept development
Project planning and administration	Business orientation
Presentation and communication	Design research
Team management	Process understanding
Client relationship	Briefing
	Problem solving
Technical design skills	
Detailing and production	Software skills
Coding and platform management	2D software
Visual coordination	Office software
Layout and composition	Web development software
Typography	Animation/video software
Photography	3D software
Digital photo manipulation	
Illustration	
Motion design	
3D modelling	
Personal characteristics	
Acumen	
Aesthetic and creative sensitivity	
Self-driven	
Design passion	

These portrayals of graphic design as a professional practice indicate the range of different activities undertaken in the name of graphic design. Although still overlooking some aspects

of practice that one might expect to see, such as 'App' design, they considerably extend the way graphic design practitioners and critics have previously portrayed the practice in terms of what it is and what it is for. However, it remains the case that many of these sub-disciplines are activities in their own right, with independent associations, exhibitions and publications, as was the case in the twentieth century (Margolin 1994: 239).

What is clear from this is that graphic design has stood as a unifying term, first to integrate a disparate set of practices, then throughout the twentieth century serving a more descriptive purpose. Clearly, what graphic designers say they do and what employers require from graphic designers is not represented by the way the practice was defined in the early 1990s. It has evolved in the same way that many fields and academic disciplines do (e.g. Geography). Now, based on recent research into the field, any attempt to describe the field of graphic design would conform with the need to recognise the complexity of practice, but still recognise its synthesising capability.

As implied earlier, if graphic design studies should reflect on the practice of graphic design, it must stay abreast of the field of activity. As shown in Table 1 and 2, this benefits from empirical research into what graphic designers and graphic design employers say they do and should not be reliant on single disciplinary perspectives. For example, it should be clear from the examples cited above that graphic design is more than editorial design, visual identity design, web design, alphabet design or typography. Research into graphic design, rather than self-declaring statements about graphic design, reveals the nuanced dimensions associated with the visual elements, visual goals and effects, or the competencies, knowledge, skills and personal characteristics that are necessary to practice. Such approaches, as Margolin suggests, will provide distinction between graphic design and other practices that produce 'visual communication' and enable deeper analysis of 'the distinctive discourses within each practice such as advertising, illustration and typography and understand better how they are contextualized and recontextualized into new narratives' (Margolin 1994: 237).

5. Discussion

Prominent design researchers, cited earlier in this paper, argue that design research today has evolved over the past 50 years into an established academic subject. It has also been suggested that this has been through a series of 'waves', the most recent confirming how design not only benefits from but adds to non-design disciplines. What has been called the fourth wave in design research resembles design as a transdisciplinary field and aligns with Margolin's argument for design studies as 'a framework that can most effectively integrate the multiple voices, theories, arguments and claims that have design as their subject into a course of action that can make the most productive use of them' (2013: 405). This has been part of a longer trajectory that sees design as having evolved from 'craft, to sophisticated professional practice and academic discipline,' along the way finding 'novel ways of dealing with the ever-increasing complexity of the problems it needed to address' (Dorst 2019: 118). Conversely, Victor Margolin has argued that design research has not yet developed a

distinctive body of knowledge. Both established and newer design practices are implicated in Margolin's suggestion that design is yet to establish clear theories, principles, arguments and methodologies.

To some extent, this resembles the objectives of the already established notion of design studies as outlined in the relatively long-established research journal of the same name. *Design Studies*, established in 1979, has as its stated focus design processes and the study of design activity – a shorthand version of what Margolin argues as reflection on design as it has been practiced, is currently practiced, and how it might be practiced. Design Studies' website home page states:

Design Studies is a leading international academic journal focused on developing understanding of **design processes**. It studies design activity across all domains of application, including engineering and product design, architectural and urban design, computer artefacts and systems design. It therefore provides an interdisciplinary forum for the analysis, development and discussion of fundamental aspects of **design** activity, from cognition and methodology to values and philosophy. (<https://www.journals.elsevier.com/design-studies>)

As the journal representative of the Design Research Society (a learned society committed to promoting and developing design research, founded in 1966), Margolin believed that those who contribute to Design Studies as so-called 'design researchers' did not constitute an established discipline or field in the same way historians, philosophers, anthropologists or sociologists may contribute to journals in their disciplines. There is an obvious contention in this delineation between design, design studies and design research. However, Margolin's differentiation between design and design studies offers a useful approach for established design practices that have struggled to establish a widespread research culture that is clearly defined. Graphic design is such a case.

Since the 1970s, graphic design has been singled out for its limited grasp of theory, even though there is a considerable amount of scholarship in the field and glimpses of research capability have recently come to the fore. Margolin's call for his interpretation of design studies – to provide the space for reflection on design (note that this is different to the kind of reflection-in-action associated Donald Schön) – may also be adopted for graphic design. From an historical perspective, there is an abundance of sources about graphic design that continue to emerge since the 1980s. Theoretical perspectives are more recent and tend to draw more from other disciplines such as art, design, communication, language studies, to name a few. Meredith Davis' book *Graphic Design Theory* cited earlier, is a good example of this in that it draws from not only design theorists such as Christopher Alexander, or J. Christopher Jones, but also from humanities and social science through often cited models of communication, for example, Shannon and Weaver, gestalt psychology, and semiotics, to mention a few. To some extent, this satisfies Margolin's early argument for a broad domain of design, or 'design world', based on observations made about the 'art world' (Margolin 2013: 402) where 'different disciplines come together to teach, do research and disseminate it.' Graphic design theory, in the way it is characterised by Davis, does exactly this and may be usefully deemed *graphic design studies* within a larger design studies framework.

Furthermore, the examples given above of research into what graphic designers actually do, compared to what graphic design practitioners and critics say it is and who it is for, necessarily provides a more detailed portrayal of the evolving nature of practice in the field. It is clearly much more than the integration of typography, illustration, photography and printing, and a closer reading of scholarship in the field reveals its functions, for example, as information, persuasion, decoration, magic, metalinguistic and phatic (Barnard 2005: 13–18).

Although some argue that there are graphic design academic journals, there are none that claim graphic design as their core concern. For example, *Visible Language* started in 1967 as *The Journal of Typographic Research*, but now speaks to the research and practice of visual communication, and the development of communication design. There is no mention of graphic design in its stated ‘publication history’ (<http://visiblelanguagejournal.com/>). The more recent *Dialectic* follows a similar path in its alignment with visual communication design (<https://quod.lib.umich.edu/d/dialectic/past-issues>). There has been occasional reference to graphic design in the aims of research journals. For example, Information Design Journal was founded in 1979 with several clearly stated aims published in its second issue. These initially made no mention of graphic design, but emphasised information, communication and information design. In response to one correspondent, who suggested the basic aim of the journal was to establish a connection ‘between graphic design practice and information design theory and technique’ the editor Bryan Smith agreed an additional aim as ‘to establish a link between graphic design theory and practice’ (Smith 1979). This link with information design has been reinforced on several occasions since. For example, based on the suggestion that graphic design had strong ties to printing and visualisation, Gui Bonsieppe (1994) sought to reinvent graphic design to include the special activity of the of ‘information designer,’ or ‘info-designer’ to reflect less concern for ‘communication’ but ‘effective action’. Per Mollerup (2015: 148) also reinforces this with the suggestion that ‘information graphics’ as a sub-category of information design’, is a ‘special type of graphic design that deals with visual explanation’. In all, these links reflect the same narrative problems noted earlier.

There are occasional special editions of existing design research journals about graphic design (for example, see Design Issues Volume XXVII Issue 1, 2011), but conferences are few and far between, there are no societies of graphic design research, nor are there PhD programmes of research, even though there is an increasing pool of PhD qualified academics. If compared to the waves of design research noted earlier, although graphic design has been a credible degree programme since the 1960s, first at undergraduate and then postgraduate level, it is not a field of funded research. International networks of scholars have formed, but their singular commitment to advancing scholarship in the field of graphic design can be undermined by similar problems of nomenclature and an uncertainty about where to place their research.

Yet, in the context of various international mapping and measuring exercises of the so-called creative industries, graphic design is said to be the majority design practice since the mid-1980s (Julier 2014: 25). This substantiates graphic design as a significant part of the global

design network, not least because it is a subject taught in schools and universities, but also because it has been the foremost creative industries design practice for the past three decades at least. It is clearly a sophisticated professional practice, but it is clearly under-researched.

Finally, at a time when graphic design scholarship ponders its future and acknowledges that graphic design is 'co-produced with other disciplines, such as geography, biology or physics' (Triggs and Atzmon 2019: 776), the argument for graphic design studies as a domain where interdisciplinary knowledge and expertise about the conceiving, planning and making of graphic form can co-exist seems timely. However, this relationship between design studies and graphic design is not new. In 2006, a range of interdisciplinary perspectives on graphic design were assembled in the reader *Design studies: theory and research in graphic design* (Bennett 2006). This considered visionary perspectives, design inquiry, designing culture, and human-centred design, importing and exporting a range of design perspectives for graphic design scholars. The book could have been more appropriately called 'Graphic Design Studies' in that it achieves much of what is argued in this paper, but with more emphasis on design studies and mostly from a North American perspective.

6. Conclusion

This paper has speculated on what graphic design studies can be. In doing so it has further exposed what some interpret contentiously that over five decades design research has not yet established a clear identity in terms of its knowledge base and methodologies. During this time graphic design practice has been shown to have grown significantly through periods of significant change, aligning with design's longer-term trajectory from craft to professional practice and academic discipline. But its research credentials come under constant scrutiny, not helped by the narrative problems it has faced and must be overcome.

Suggestions that graphic design is bereft of research have been highlighted, but it has also been shown that it is not devoid altogether if considered from a design studies perspective. In fact, in the United Kingdom, history and complementary studies are part of the foundation of approximately a third of curriculum since degree level study was introduced in the late 1960s. For most of that time this has generally been taught by non-design educated academics, meaning graphic design graduates are aware of the interdisciplinary nature of design. There is not enough room here to debate the various domains where graphic design studies might be relevant, such as design history, but it is hope that this is implicit in the fact that Victor Margolin was, primarily, a design historian who argued for design studies as a more suitable way to frame design research .

To further enhance the idea that design studies as a field of inquiry should address questions of how we make and use every day products in our daily lives past and present, the nature of graphic design practice has been explored to substantiate the kind of graphic products that facilitate the relationship between people and the world. In particular, it has been shown how research into graphic design compares with approaches from graphic design

practitioners and critics. The former paints a more nuanced picture and provides some indication into how the graphic designers engage with some of the challenges said to be facing design research in the future.

Within graphic design practice, notions of co-creation are implicit, as are the interdisciplinary ways the practice has evolved in close collaboration with a professional client base. It would not have prospered otherwise. Margolin's arguments for design studies provides a useful framework for graphic design educators, researchers and practitioners to coalesce and contribute more to the future of design research and the complexity of problems in need of address in a changing world, or so-called fifth wave of design research.

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The Social Aspects of Companion Robots

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Abstract: Advanced technologies, including automation, Artificial Intelligence, ubiquitous computing, and smart products are influencing our everyday lives. Their complex nature brings new challenges and opportunities for all users, especially the older generations. This paper presents an ongoing PhD project that investigates the social context of older users (aged 65+) interacting with new emerging smart products using an emotional design theoretical perspective. The data is multimodal user research consisting of pre-interaction interviews, observation of first-time interactions, extended user experience of ten participants interacting with social robots in their home environments, and post-interaction interviews. In this paper, we present and discuss some of the patterns revealed by our investigations, including tactile experiences, the notion of realness, and privacy and trust around emerging technologies. We argue that the study of the affective dimensions of advanced technologies offers an actionable emotional categorisation of users' experiences with practical applications for the design of future smart products.

Keywords: human-robot interaction; social robots; extended user research

1. Introduction

For the last two years, we have been studying the experience of older users interacting with social robots as an instance of emerging smart products. The study has led to a set of findings that allow us to better understand some of the social aspects of human-robot interaction (HRI), which we summarise in this paper. The paper centres around the opportunities, challenges, and limitations of using robots as companions (Broekens, Heerink, & Rosendal, 2009). The study of user experience with social robots is relevant today because we are still at the early stages of the interaction with automata with whom we share our homes. The study of the affective dimensions of users interacting with advanced technologies can inform designers and businesses in the design of future products that can trigger meaningful experiences. These investigations also have the potential to inform the emotional and



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social dimensions for the design of future user experiences with robots and other advanced technologies.

In this paper, we first discuss what constitutes the affective aspects of emerging technologies and smart products, and the challenges that they present for designers using an emotional design theoretical perspective. Then we present the methods used to conduct a comprehensive user research study in this area. We then summarise some of the initial results of our ongoing research. Lastly, we discuss how this research informs the design research community of the significance of multimodal user research and how it can inform future HRI design practitioners.

2. Smart products and the emerging design of social robots

The study and the market for social robotics have grown rapidly over the last two decades. However, research in human-robot interactions (HRI) that investigate the emotional experience of interacting with robots is still limited (Greenfield, 2017; McStay, 2018; Tallapragada, Rao, & Kanapala, 2017; Tonkin et al., 2018). Lyardet and Aitenbichler (2007) define “smart products” as everyday products embedded with computational power, information and sensing capabilities with three levels of knowledge –about themselves, their environment and users. These sensing and processing abilities allow these “smart products” to interact, cooperate, and adapt autonomously. We study the user experience with social robots as an instance of smart products.

Social robots are autonomous technologies with a physical presence that work collaboratively with people in human environments and open contexts. This distinguishes them from industrial and space robots that operate in predictable spaces and under controlled conditions. Social robots have mostly been used for a narrow set of menial tasks, such as vacuuming, and have yet to find their way into more meaningful daily experiences. Social robots have the potential to re-shape how people interact, communicate, talk, live, and even how they experience ageing in the future (Consortium, 2007; Greengard, 2015; Kim & Mauborgne, 2014). Smart technologies are rapidly integrating into most everyday activities (Coughlin, D’Ambrosio, Reimer, & Pratt, 2007) and they are affecting how we book services and transport, order food, monitor our health, and adjust our behaviour patterns such as sleeping time and daily exercise.

Faced with an increase influence of advanced technologies in daily life, the effects that these technologies might have on our future raise serious social and ethical concerns (Greenfield, 2017). Technologies such as robotics and AI are often developed and deployed without considering people’s emotional responses to usage, aesthetic elements, and social expectations (S. Lee, Ha, & Widdows, 2011; Schifferstein & Desmet, 2010). Therefore, businesses and designers need to assess evidence on how these technologies may influence future users in transitioning from conventional products to smart devices.

2.1 Older users' interaction with technology

Populations are getting older worldwide (Fisk, Rogers, Charness, & Sharit, 2009; Lloyd-Sherlock, 2000) and the next generation of older users, unlike their previous generations, are healthy, active, and have experienced significant technological changes. So-called “baby boomers” had access to education, wealth, leisure, and have witnessed radical changes with technologies both at work and home environments (Brophy, Blackler, & Popovic, 2015). Paradoxically, research on the ability of this generation to interact with technological innovations has often been neglected (J. A. Lee, 2017). Following the terminology used in most inclusive design and HRI studies (Goddard & Nicolle, 2012; Pripfl et al., 2016; Wu, Thomas, Drobina, Mitzner, & Beer, 2017), this research refers and identifies our active ageing population as older users versus the other terms commonly used in health and science related studies such as senior citizens or elderly people.

The shift towards integrating technologies into everyday activities has caused great difficulties and frustration for older users (Pattison & Stedmon, 2006). These challenges can reduce motivation and create a sense of social isolation, and even depression for older users (Lawry, Popovic, Blackler, & Thompson, 2019). The complex nature of emerging technologies can cause some frustrations among users that are accustomed to simpler processes with the ability to manually control their products (Yang & Coughlin, 2014). Social issues such as accessibility, isolation and a loss of independence associated with age can influence the ways older people interact with technologies.

Studies suggest that a combination of cognitive, physical, sensory, and attitudinal changes that occur as a result of aging also impact older users' interaction with technology (Rogers, O'Brien, & Fisk, 2013). Research related to the design of technology for older users distinguishes age-related changes as essential factors (Bouma, Fozard, Bouwhuis, & Taipale, 2007; M. T. Braun, 2013; Miller, Gagnon, Talbot, & Messier, 2012). Brophy et al. (2015) argues that smart products should not only be useful and usable by the next generation of older users but appropriate, engaging, and meaningful. They suggest that the design of future products has to extend beyond the narrow focus of age-related decline.

The design community needs to have a broader perspective for the envisioned future of technologies designed for older users. It is essential to understand the relationship that this diverse group of people have with technology. Research needs to move beyond measures of performance, functionality and adoption and towards a deeper understanding of this user-technology relationship (Blackler, Popovic, & Mahar, 2010; Fisk et al., 2009).

2.2 Design for emotions

It is our goal to study the ways in which older demographic of users interact with smart products on an emotional level. Research has long established that by designing for emotion, we can make users' experiences safe, pleasurable, effective, and fruitful rather than complicated (Desmet, 2018; Hirschman & Holbrook, 1982; Lloveras, Molokwane, & Montoya, 2004; Thoring et al., 2016; Wakefield & Baker, 1998). A design that connects with

people on an very emotional level results in better performance, a richness of the interactive experience and a sense of enjoyment (Gill, 2012).

Technologies designed with a lack of empathy for their users can lead to a failure in delivering pleasurable experiences and result in a sense of isolation (Rama Murthy & Mani, 2013) that can negatively impact on user's self-esteem. New technologies are often aimed at removing the human touch for the purpose of preciseness and efficiency. While new technologies such as AI (Artificial Intelligence) and IoT (Internet of things) can bring advantages to the field of design by making products "smart", they should not be applied blindly and without consideration of the users' needs for emotional attachment and bonding. Advanced technological products should be human centred and consider how products will be used for delivering meaningful and pleasurable experiences (Hanington, 2017).

Research suggests that the complex nature of smart products and their ability to performing a wide range of tasks to assist people in the real world, means that studies needs to go beyond the laboratory settings, mock homes or office environments (Cesta, Cortellessa, Orlandini, & Tiberio, 2016; de Graaf, Allouch, & van Dijk, 2017; Tonkin et al., 2018). We see an opportunity to overcome the complex nature of the human-robot interaction through a systematic evidence-based study, which is the aim of this research. This study can help designers create more pleasurable and safer experiences with smart products by providing a better understanding of the emotional transitioning process that users are going through to adapt to new technologies. The results can also provide a better understanding of the way older users emotionally feel about robots emotionally. Lastly, this research can demonstrate how to study social robots from a design and emotional user experience perspective.

3. Multimodal user research

Our study takes an interaction-centred perspective (Forlizzi & Battarbee, 2004) to explore users' engagement process with social robots. Studying users' emotional responses towards social robots enables us to capture users' expectations around what constitutes a meaningful experience, relationship, and interaction with robots. We look at different stages of users' behaviour towards social robots to understand different factors such as trends, self-image, thoughts, doubts, presumptions, and interaction behaviours that might affect the users' choices. Our aim is to investigate the elements of meaningful emotional experiences in detail.

We focus on the emotional influences of social robots on the user experience by applying an interpretivist paradigm (Cohen, Manion, & Morrison, 2002, p. 21). To analyse the phenomena associated with the users' experiences, a user research approach is used as the methodology of this research (Schumacher, 2009). User Research has been defined as a type of "ethnographic approach" to gather information about users through interviews and studying their behaviour in everyday context (Schumacher, 2009). Therefore, we study participants in their homes and the context of their everyday lived experiences over an extended period. The enquiry opens the opportunity to explore the behaviour and emotions

of the users from their perspectives. This enables us to immerse in the participants' experiences, which can assist a better interpretation Hunting (2014).

We apply multimodal methods of data collection (Chen et al., 2016) to collect both qualitative and quantitative data, allowing us to understand the users' emotional needs and experiences deeply. Our multimodal user research starts with pre-interaction interviews to capture users' worldview and the way they perceive interactions with smart products and changes and challenges that they have faced through the years. It then proceeds with multimodal field observations of users interacting with the robot that we introduced to them for the first time at their home environments. Next, extended user experience is analysed by leaving the robot with them over a two-week period. Users are asked to maintain a journal documenting their experience. The final stage of the study is a post-interaction interview to capture their final thoughts and feelings of their experience and ask questions around their lifestyle and lived experiences.

3.1 Pre-interaction interviews

We conducted semi-structured interviews to identify the semantic value of the smart products and users' perceptions of social robots before interaction. Participants were asked to describe their favourite products and express their thoughts on emerging technologies and what they imagine the experience of interacting with robots to be like. These interviews enabled us to understand users' personal relationships and experiences with technology, the effect users think robots and emerging technologies might have on their life, and what they expect from them. Each interview took between 1 to 2 hours.

3.2 Multimodal observational study of social robots in home environments

In the second part of data collection, multimodal usability and interaction observation was conducted. The aim was to capture the first-time interaction with the selected robot. Each session took about 15 to 30 minutes. Sonderegger and Sauer (2010) recommend that usability testing is an appropriate method for evaluating the design of products by stimulating the user experience.

The focus of this part was to monitor and understand user interaction with robots in a natural environment. We explored the way users tend to understand and interact with the selected robot based on the form, signals and symbols of the designs. Gonzalez, Val, Justel, and Iriarte (2017) argue that observing every single participants' interactions with a product offers a comprehensive and intuitive understanding of the experience. This facilitates the chance to perceive the user-product interaction as it is, without the researcher getting involved or affect in the process by implying their perceptions.

We studied users' emotions toward the technology based on Jacob-Dazarola, Nicolás, and Bayona (2016) Nicolás, and Bayona (2016) categories of emotions. We reflected on a combination of cognitive processing, how users made sense of the product, their behaviours, and what they said about the process, their' attitudes, expressions, gestures, and subjective

experiences, as well as measuring their physiological responses using a wearable device to capture their heart rates¹. Participants were asked to interact with the selected robot in vocal-work approach, which allowed them to explain their feelings while interacting with the product.

Collecting data was based on the UTAUT theory (Venkatesh, Thong, & Xu, 2016) to understand the process of how people make sense of the products. Factors such as understanding technologies involved in the available robots, the level of curiosity and creativity of users in the process of interacting with a new device without prior knowledge were considered as well. Participants' physiological responses were observed, such as facial expressions, body language and heart rate using MCLM techniques (Chen et al., 2016). Incorporating quantitative measurement in the observation process can authenticate the data collection process by comparing people's attitudes and verbal responses with their physiological responses. The participants' comments about how they feel, and the researcher's perspective, based on this relationship between human and products, were collected as well.

3.3 Extended user experience

We also analysed how users interact with the robot over an extended period in their homes. We asked participants to journal their interaction and emotions during this time. One of the essential elements of user-product interaction is the temporality of the experience (Karapanos, 2013). An extended user experience test can measure the level of excitement and overall evaluative judgement of users across time Karapanos, Zimmerman, Forlizzi, and Martens (2010). Therefore, in this stage we used a longitudinal approach to investigate a user's attitude and behavioural changes in interacting with the product over a two-weeks period in their home environments. Our pilot studies suggested that two-weeks' time was enough to our users to familiarise themselves with the robot and form an opinion towards it. Furthermore, requesting participants to journal their daily interactions with a robot over a month would have been an unnecessarily laborious process.

A journaling technique was selected to capture users' reflection on the interaction process. While journaling requires a good level of commitment from participants, it is a valuable resource for capturing their personal experiences comprehensively (Kenten, 2010). Inspired by the framework of MacKerron and Mourato (2013), traditional solicited diaries of participants recording expressions, emotions, feelings, and values were used. It is important to note that we designed the journals specifically for this experience and provided them to participants. They reported daily interactions with the robots at the end of each day explaining the amount of time, the experience and their feelings. They were invited to reflect on the setting in which they are interacting with the robots.

1 Apple Watch Series 4, 44mm model and Cardiogram application were used to capture users' heart rate. Further information about the watch: <https://www.apple.com/nz/watch/>

The focus was to collect users' stories, thoughts and emotional experiences that they might have encountered while interacting with the given robot.

3.4 Post-interaction interviews

We finished the data collection stage with post-interaction interviews. This stage was designed to compare the information that the users mentioned in the pre-interaction with what they actually experienced during the extended user experience stage. It allowed us to obtain a better understanding of their emotions after the interaction. Furthermore, we conducted our demographic questions during this stage to allow enough time to build trust between the researchers and participants.

3.5 Participants

We followed Howe and Strauss (1991) argument that generational categorisation offers a more comprehensive personality generalisation than any other social categories such as race, religion, or gender. A generation's peer personality can represent the collective stances of lifestyle, politics, gender roles, and social attitudes (Sandein, 2008). Therefore, we investigated the emotional behaviour of two different older generations, those aged between 50 to 65 years old (prior to retirement) and those 65+ years old, retired, and living independently. The reason for this was to understand the experience of the users that are not living in retirement homes and social caring facilities that have an inbuilt community of social support.

Participants were invited to take part in the research through various platforms, including word of mouth, sending out digital advertisement on social media and placing advertisement posters in local shops. At the time of writing, ten participants had taken part in this research. Seven of them are aged between 50 to 65 years old and three are 65+ years old. Since then we have added four more participants in the second age category for a better comparison of the results. It is important to note that our study suggests that the younger group of users (aged between 50 to 65) seems much more accepting and interested to take part in this type of studies, and it has been more difficult to recruit older participants.

4. Findings

A reflexive Thematic analysis (V. Braun & Clarke, 2006) is used for analysing and interpreting the captured data. Thematic analysis is taking the dataset and highlighting the patterned meaning using a clustering method. Through meticulous processing of data familiarisation, coding, and theme generation, these patterns can be identified. So far, we have found some interesting themes that can assist designers in better understanding some of the concerns and challenges of older users interacting with social robots. We managed to understand better what technology means to our participants, the influence it has on their daily activities, and how their experiences of interacting with technology have changed over the years. We also captured our participants' emotions towards emerging technologies and

smart products, and the impacts of such technologies on their relationships, conversations, medical and health-related activities, and privacy. This section covers the main themes that have emerged so far.

4.1 Tactile Experiences

The comparison between digital and analogue experiences appeared to be one of the main limitations of emerging technologies for our participants. While they all perceive technology as an enabler, they also acknowledge the lack of tactile experience when using digital technologies. For example, the experience of analogue photography was given to illustrate the idea of crafting and art creation. The waiting time of processing photographic film in the darkroom to see the final results was contrasted to the current ability of taking thousands of photos with mobile phones and saving them in our digital library without ever looking at them or remembering the event. The experience of events themselves has also changed for our participants as they mentioned that people are quite occupied with taking photos and videos on their phone to share on Snapchat or Instagram without real interaction.

Other comparisons were made between the experience of listening to music on vinyl records or CDs and music streaming. Our participants value the tactile experience of touching the records and the record player, looking at the album's artworks, reading the lyrics, remembering the song names as rich and immersive. On the other hand, while digital music libraries make millions of songs available, they notice a change in how they listen to music mostly in the background without really noticing or experiencing the music as before. Few of our participants compared e-books with physical books. They acknowledged the benefits of having access to many books on tablets or e-readers. However, they still identified as much richer the experiences of touching the paper, smelling the book and being able to visually perceive the volume of pages read and even the experience of going to a library and interacting with other people.

In terms of interacting with the robot, our participants expected more natural conversation. This included them expecting the robot to be ready to interact or provide the option for greeting when the sensors picked up the presence of the users and not only when an explicit command is spoken. They also desired receiving a confirmation about a question or a given task. They expected the robot to acknowledge that it is on to it and not make the user wait around to guess if the command was picked up or not. Furthermore, as a companion robot, the conversation was expected to go beyond simple commands by giving several options to the users or asking follow-up questions to hold up a more natural conversation.

Lastly, our participants mentioned that the "cuteness" of the robot, its eyes, facial expressions when answering questions constituted a unique and differentiating element. Surprisingly, the participants mentioned that this made them feel guilty when the robot looked at them eating food. Participants also missed the chirping sound when the robot was switched off. The physical features and mobility of the robot made participants more engaged with it compared to conversational agents on their mobile devices. Furthermore, it

was interesting that the robot also interacted and responded to non-human organic beings, i.e., pets. According to one of our participants the robot reacted to the dog's barking as if it got scared. In turn, the dog got scared as well by the unexpected movements of the robot. This example was quite a unique surprise as the experience of the robot expressing confusion or fear by the sudden movements or when perceiving an unknown object was not expected by our participants.

The captured data around tactile experiences suggest that emotional and gestural responses in technology are appreciated by users. However, the cuteness or fun elements of their design need to be balanced, as over time it could become annoying as the novelty of the experience wears off. A majority of our participants concluded that after two weeks the novelty of the robot faded out and some of the characteristics starting to become perceived as toy-like or limiting.

4.2 Realness

Our study suggests that users may see benefits in robots mimicking behaviours and characteristics of organic beings based on different contexts. For example, a participant working at a retirement village mentioned that one of the residents has a robot cat as a companion. She suffers from dementia and acknowledges the robot as a real cat, asking nurses to feed the cat for her and to take care of it. Contrary to this, some of the nurses feel the need to inform her that the robot is not a real cat since they feel it would be cruel to mislead the patient. According to this participant, such conversation causes the patient some discomfort for a while until she forgets the event. The notion of the realness and to what extent we need to differentiate between organic and non-organic beings deserves further attention in future studies. Another participant expressed that how they would prefer to recognise when they are interacting with an AI or a human for getting a service. They would prefer it to be as human and as real possible but to also allow the user to be aware that it is not a real human as they interact with a human differently.

Our study suggests that users are concerned or at least aware that social robots are going to resemble organic livings. Several studies have addressed issues around making humanoid robots mimic a real human presence (Magnenat-Thalmann, Yuan, Thalmann, & You, 2016). We are interested to investigate further on why users may expect robots to possess human capabilities and characteristics but still want them to be different from us. It is also interesting that our level of politeness and social norms would possibly change when expressing our feelings to non-organic beings. Studies on the *uncanny valley* in this area deserve more attention from designers as they will help identify the steps and strategies for designing future social robots.

Our female participants seemed more open to the idea of having a robot companion or a social robot present at their home. They acknowledged that people that might have limited socialising opportunity to interact with other people might benefit from having such technology. On the other hand, most of our male participants felt quite hesitant and

reluctant toward having a robot as a companion. They referred to the issue of a lack of soul and real communication in social robots. They mentioned there is some value in social robots to help older people stay active as an entertainment and assistive technology rather than replacing “real” companionship. For example, one of the participants mentioned the following statement:

“Robot companions don’t have a soul and have been programmed by a person. They are, therefore, non-organic, and it is a cruel act to replace them with real companions. Humans and animals’ behaviour are genuine and not programmed. Even, if they annoy us or hurt us, these are real responses.”

This suggests opportunities to further investigate the role that gender plays on the user experience of interacting with emerging smart technologies.

4.3 Privacy and Trust

A prominent theme in our analysis was about user privacy. Most participants during the pre-interaction interview session responded positively towards having their information available for businesses and governments in exchange for the benefits that technology provides for them. They argued that since they don’t have anything to hide, they are not worried about sharing their information. Some mentioned that it also helps them to remember and track their activities. Two of the participants though mentioned that their trust toward sharing their privacy might change based on their location and the context that they live in.

However, it was interesting that a majority of the participants were not happy with the robot sensors picking up their movements walking around the home and waking up without the command. They referred to the experience as spooky, weird, or annoying as if the device is constantly listening to them or watching them. Such spookiness included the robot looking at users when asked to go to sleep making them feel they are being watched. A comparison of these perceptions against other everyday uses of sensors such as electric doors, escalators sensors, or lightings is worth addressing in the future. It is also worth noting that our participants were aware that such examples can be connected to a server and track activities. Perhaps the trust in such sensors depends on the absence of a face or a humanoid character.

We propose these observations provide useful information about the complexity of the emotions involved in human-robot interaction. The emotions involved in interacting with social robots go beyond everyday objects that are not possible to capture through traditional usability tests. It requires a change in both research and design practices in order to deeply empathise and emerge with such complex experiences.

5. Conclusion

In this paper we presented a four-stage multimodal user research study to capture older users’ emotions toward emerging technologies. Social robots were selected as an instance of emerging technologies with embedded conversational agents in them. The study was a combination of pre-interaction interviews, observational study, extended user experience,

and post-interaction interviews. The preliminary results of this study have led to insights about the users' expectations and challenges. The findings enabled us to think and reflect on our participants concerns and emotions beyond basic user-product interactions. One of the main insights was about the importance of conducting a multimodal and mixed user research that goes beyond lab-based practices when it comes to understanding our users' emotions. We find our users were able to identify the given robot's capabilities and limitations in the two-weeks period of time and formed a strong point of view toward it. We are aware that based on the complexity of the given product this timeframe might need to be altered.

Our research on emotional aspects of human-robot interaction had led us to some interesting insight about usability and functionality of the social robot. All of our participants at the end identified the given robot as a fun and cute device but not practical. They all mentioned that at the end of the day if a new technology is not useful and does not add a new value to their lives, they would not consider it. They considered the robot as another toy that will end up in their storage room. This is an interesting insight because beside the robots embedded CA (conversational agent) it had Alexa included as well. A few of our participants were familiar with the technology and had smart homes but they preferred to use their mobile phones voice command instead of adding another device with similar capabilities. This is quite important within the current context of robotic designs as it is crucial that designers pay attention to the fundamental elements of the design, usability and functionality. With the current competitive market of technology, people will not consider a design without a strong usability point of difference (Moradi, 2015, p. 4). It is crucial to identify what are the values and point of differences of new designs we are introducing to the market and not to simply embed them with current technologies that users already have at hand.

We conclude that in the field of user-product interaction it is important to go beyond capturing a snapshot of users' emotions and conduct extensive user research that can identify lived experiences and challenges of our users in depth. We believe that the identified information can be used as a guide for design practices of emerging technology. The identified themes so far will shape the final co-design stage of our study. We are proposing to conduct a design session with designers and participants to co-create their desired future together, while introducing some other categories of social robots such as Aldebaran Nao to them. We are still considering whether this session should be technology based itself or perhaps it would be better to focus on activities such as scenario planning, role playing, and rough prototyping to create a more open space for creative practices.

6. References

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Supporting people with dementia - Understanding their interactions with Mixed Reality Technologies

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Abstract: Emerging technologies such as Mixed Reality Technologies (MRTs) could offer possibilities to support People with Dementia (PWD). This study examined interactions of PWD with two MRTs - HoloLens and Osmo. Ten participants (MoCA = 18 to 23, Age= 63 to 88 years) played a game of Tangram on Osmo. Six of these participants played Young Conker on HoloLens. The study found that PWD used gestural actions in the physical world more correctly than speech. Audio prompts in human voice were more correctly perceived than visual prompts. Physical affordances, embodied actions and familiarity to verbal instructions contribute to this success. Visual prompts such as text present promising opportunities to complement with audio prompts. Interaction with MRTs require prompts to direct PWD towards physical or virtual worlds. The research outcomes are significant as the focus on interactions of PWD could open up avenues for further research on actions and perceptions with emerging technologies.

Keywords: mixed reality; assistive technologies; dementia

1. Introduction

Assistive prompting technologies could support people with dementia (PwD) to continue instrumental activities of daily living (IADL) such as cooking, laundry and making a phone call. There is huge potential for technology-based prompting to support PwD through the sequences required to complete activities. Mihailidis, Boger, Craig, & Hoey (2008) and Pigot, Mayers, & Giroux (2003) developed intelligent systems using textual and auditory prompts, utilising sensors, computer vision and artificial intelligence. In a real-world deployment, Orpwood, Adlam, Evans, Chadd, & Self (2008) created a smart apartment equipped with passive sensors and light controls, bed occupancy monitor, tap and cooker monitors and



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voice prompting devices. Their trial with a single user with quite severe dementia, revealed that the technology helped the user retain a lot of independence, regain urinary continence and improved his hours of sleep and reduced night-time wanderings. To translate these promising results into scalable solutions for PwD to continue independent activities, Mixed Reality Technologies (MRTs) could offer affordable, adaptable solutions that can be easily adopted and deployed.

On a physical virtual continuum, MRTs are anything in between physical interfaces at one extreme end of the continuum and virtual interfaces at the other extreme end (Desai, Blackler, & Popovic, 2016). MRTs can either consist of augmentation of the physical world with virtual objects, as in Augmented Reality (AR) (Azuma et al., 2001) or the virtual world augmented with physical objects, as in Augmented Virtuality (AV) (Regenbrecht et al., 2004). AR and AV technologies could offer new technological solutions for PwD by generating prompts in response to their behaviour and actions. For example, AR technology, HoloLens is capable of tracking the gaze of people and can be programmed to generate prompts in response to their gaze and actions. This could be used to detect when people have become derailed during an activity and are searching for cues to get back on track. Similarly, AV technologies, Kinect and Osmo could track the behaviour of people through a network of sensors to determine when the person has derailed during the activity.

For MRTs to be able to deliver prompts that are effective and perceivable for PwD, firstly requires developing an understanding of their interactions with MRTs. This study thus investigates actions (e.g. gestures, speech, etc.) that are most suitable for PwD and forms of prompts that should be administered to PwD (e.g. such as auditory, visual, pictorial, etc.) in MR environments.

2. Background

MRTs could provide an adaptive and scalable solution that can be easily deployed in different applications. Chang, Chou, Wang, & Chen (2013) reported that a Kinect-based prompting system in a vocational setting improved task completion in two participants, one with early onset dementia and one with an acquired brain injury. In this study the prompts were delivered on a computer screen. Since HoloLens' launch in 2016, AR has been explored as a therapeutic tool for PwD. Ro, Park, & Han (2019) developed a projection based AR robot with 360 degrees of space for PwD, some of the applications targeted are therapy, entertainment, spatial art and mental care aids. Vovk, Chan, & Patel (2019) developed an AR HoloLens game as a memory assessment tool for early Alzheimers diagnosis. Aruanno, Garzotto, & Rodriguez (2017), Aruanno, Garzotto, Torelli, & Vona (2018) and Garzotto, Torelli, Vona, & Aruanno (2019) developed three holographic activities using HoloLens in cooperation with neurologists to stimulate memory functions affected by Alzheimers disease, with the goal of delaying the cognitive decline. PwD did not have problems using the technology, however the success with which they completed the holographic activities depended on the design features that they interacted with. Although, AR and VR have been explored in research to

support manual tasks such as maintenance, assembly and surgery for over five decades, there is a need to research interaction requirements of PwD.

2.1 Actions and prompts

Perception and action are inseparable processes which form the basis of any interaction. Perception is about recovering information about the interface such as shape, colour, motion and materiality through the use of sensory systems of vision, touch, auditory, taste and smell and the prompts presented in the interface (Gibson, 1979a). This information is processed by reasoning and decision-making to determine actions to be carried out on the interfaces. These actions could change the features and behaviour of the interface, communicating feedback, status or/and attention to the user, ready to be perceived again for subsequent actions (Maier, 2015). An interaction comprises of several such perception action loops. If for some reason there is a failure to understand the prompts or to act on the interface, the perception action loop is broken, people could find it difficult to get back on track. Desai, Blackler, & Popovic (2019) refer to interfaces that facilitate continuous perception action loops as intuitive in nature.

Tangible interactions have been explored for reminiscence in PwD. Huber, Berner, Uhlig, Klein, & Hurtienne (2019) using contextual design process identified needs of PwD and developed three tangible prototypes – a pyramid, set of drawers and a juke box. All three prototypes used object manipulation for gestural interaction. Their study found that the tangibles were intuitive to use where the form was familiar to the participants. Even though when the memory of PwD slipped away, they were still exploring the contents of the tangibles in their hands.

Natural User Interfaces (NUIs) have been successfully used in reminiscence therapy for PwD (Loureiro & Rodrigues, 2011). NUIs use natural interactions of humans such as touch, speech, gestures, gaze, facial expressions to interact with interfaces. Older adults find interactions with mouse and keyboard difficult (Czaja, 1997). On the other hand touchscreen gestures have found to be easy to use for PwD (Barban et al., 2016; Buiza et al., 2009; Gamberini et al., 2006). Gündogdu, Bejan, Kunze, & Wölfel (2017) evaluated use of NUIs in interactive multimedia systems as means of reminiscence therapy in PwD. The study found that while touch gestures and tangible interactions were successful in generating positive feelings and activating mental states, the interactions with NUIs depends on the person's stage of cognitive impairment and the individual form on the day.

Carlomagno, Pandolfi, Marini, Di Iasi, & Cristilli (2005) studied gestures of PwD in their daily communications with other people and they found that irrespective of the level of impairment, people were using gestures without any trouble. Bewernitz, Mann, Dasler, & Belchior (2009) compared machine administered verbal and visual prompts in PwD carrying out three tasks, drinking water, brushing and eating. Visual cues were not effective during the brushing activity. This was due to the placement of the screen at the sink level height which made it difficult to look at while looking into the mirror. But they were able to complete

the task of brushing which is an indication that the prompts were probably not needed for that activity. The audio cues were equally effective for all the three activities. These studies are limited in terms of exploration of types of prompts and actions for PwD because the focus is on the design of systems followed with user evaluations to test the designed systems rather than understanding the interactions with different types of modalities. Also, MR environments pose an additional challenge of dealing with the transition between the physical and virtual environments. A focussed study on understanding actions and prompts that work for PwD interacting with MR environments is thus required.

3. Method

3.1 Research design

This research was an observational study conducted at Memory and Company, a memory health club for seniors with dementia. Game play was used as a probe to elicit natural behaviour in the participants. Games are part of daily day programs at Memory and Company to engage PwD in hands on activities that simulate their mind and challenge their mental, functional and physical abilities. Thus, play-based research design allowed us to integrate the study as part of the day program at Memory and Company. It also acted as an ice breaker and made the participants feel more comfortable around technologies. The study was approved by the Research Ethics Board. Informed written consent was obtained from all participants and their care givers.

Ten people in their early stages of dementia with low cognitive impairment (MoCA = 18 to 24, Age= 63 to 88 years) participated in the study. The Montreal Cognitive Assessment (MoCA) is a rapid screening tool to detect cognitive dysfunction for early diagnosis of Alzheimers disease. It consists of 30 questions targeting attention, concentration, executive functions, memory, language, visuo-constructional skills, conceptual thinking, calculations, and orientation. Each question is scored as per the MoCA scoring guidelines. The total possible score is 30 points. A score of 26 or above means that there is no cognitive impairment. As the score gets lower, the level of impairment increases.

We used two off the shelf MRTs – HoloLens from Microsoft and Osmo from Tangible Play as case studies to study interactions of PwD with MRTs. Using off the shelf existing technologies is an effective way to understand technology needs of people and their perception action behaviour (Blackler, Popovic, & Mahar, 2010; Desai et al., 2019; Lawry, Popovic, Blackler, & Thompson, 2019). The two technologies represented AR (HoloLens) and AV (Osmo) types of MRT and were easily available for the study off the shelf. Participants played Tangram on Osmo and Young Conker on HoloLens. These games were chosen after exploring several games available on these technologies. The criteria for the selection was that they should present different forms of prompts (visual, audio, animations, text) and opportunities to carry out various actions (gestural and speech interactions).

Pilot studies with 2 older adults in their early stages of dementia (MoCA = 18 and 22) were carried out before the actual study to determine the suitability of the technologies and games for the study.

OSMO AND TANGRAM

Osmo, AV technology, with distinct physical and virtual environments to interact with separately, allows physical play with a virtual environment on a tablet. It comes with a reflector, a stand to place the tablet on, and games (Figure 1).

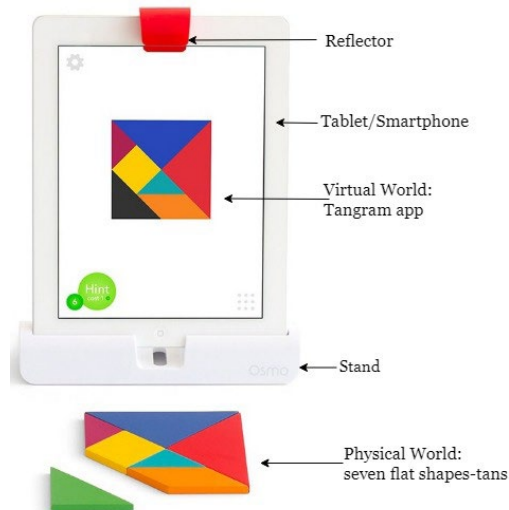


Figure 1 Osmo Setup and Tangram

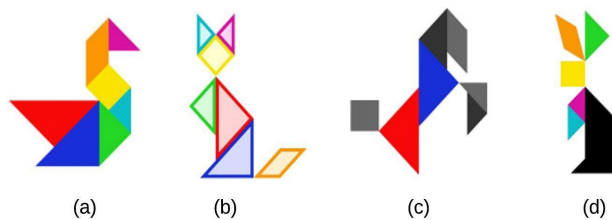


Figure 2 Tangram pieces arranged in shapes. (a) Seven tans arranged in the shape of a swan. (b) Easy level shape presented in the app (virtual world) consists of shape and colour information. (c) Medium level shape presented in the app (virtual world) consists of shape and colour tone information. (d) Hard level shape presented in the app (virtual world) consists of partial shape information

The camera on the tablet captures any physical activity performed in front of the tablet. The captured information is fed back into the virtual world on the tablet, and integrated with added virtual elements in an app. Tangram is played with seven flat shapes, called tans, which are put together to form shapes (Figure 2). The objective of the game is to form a specific shape using all seven pieces, without overlapping each other. A shape is presented to

the player on the tablet screen through the Tangram app. The player is expected to arrange the seven flat shapes in physical space to match the shape on the tablet. When the correct flat shape is placed in the right place in the physical space, the corresponding flat shape in the app on the screen is filled with the corresponding colour. This is an indication that the placement of the shape in the physical space is correct. The app provides visual and audio prompts to the player, as shown in Table 4. PwD are familiar with solving puzzles and thus tangram was an ideal choice amongst the games available with Osmo.

HOLOLENS AND YOUNG CONKER

HoloLens, AR technology with overlapped physical and virtual spaces is a holographic computer in the form of a headset (Figure 3). HoloLens uses the physical world to overlay holograms for the user (who wears the headset) to interact with them, see and hear them within their environment.

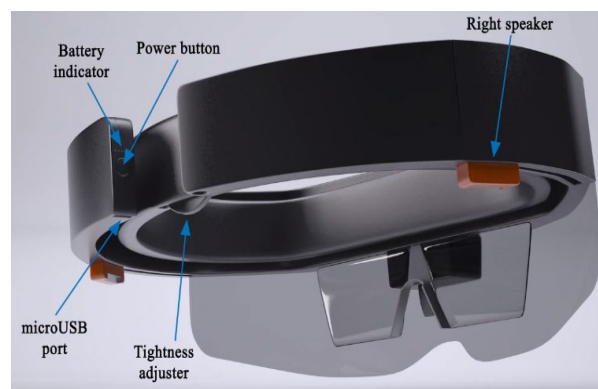


Figure 3 HoloLens - AR technology

Young Conker transforms existing real-world setting into a platform to go on a mystery adventure. The game starts with a scan of the physical space to detect walls and other objects. The game consists of different levels referred in the game as missions. Each mission involves looking for generated holograms in the space. A holographic squirrel character, Conker interacts with the user through speech. The player is required to guide Conker through their gaze movements to the holograms in each mission. The game prompts the player through visual texts, graphics, animations and Conker's speech to accomplish a set mission in the game.

3.2 Data Collection

Ten participants consented for the study who played Tangram on Osmo. Of these, six also played Young Conker on HoloLens. Four participants did not show up for the play session with HoloLens. The study was conducted in three sessions on three different days of the day program. Cognitive impairment of the participant was recorded using MoCA assessment tool in the first session followed by game play with Osmo (Figure 4) and HoloLens (Figure 5) in each of the next two sessions. On the day of the game play with MRT, participants were

explained how each technology works and how to play the games on the MRT. Participants were prompted by the researcher when they were unable to proceed with the game play or/ and when they asked for help. Each play session lasted for maximum 60 minutes. Although this was a small sample observation study, a 60-minute game play allowed us to collect enough interactions (actions and prompts) to compare types of prompts and gestures.

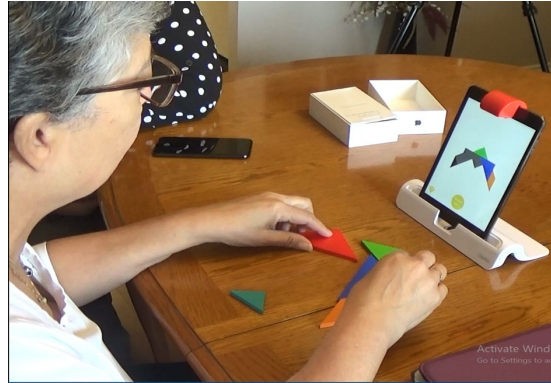


Figure 4 Participant P1_2000 playing a game of Tangram on Osmo

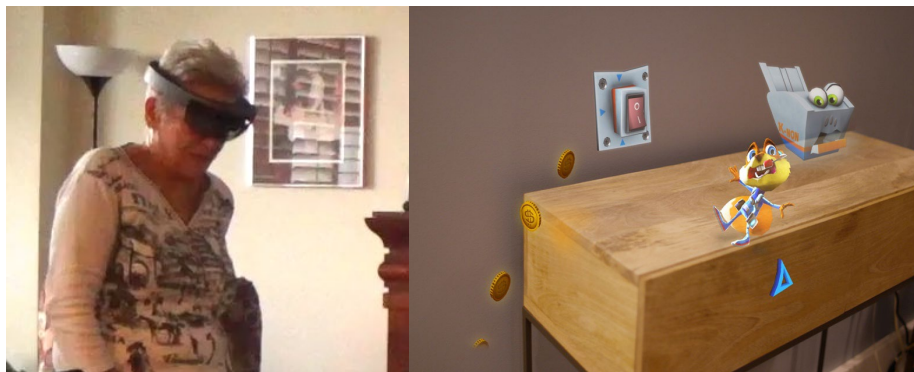


Figure 5a, 5b Participant P9_2009 playing a game of Young Conker on HoloLens (a) using gaze to move young Conker, the squirrel from one place to another in the game (b) Screen capture of what participant sees through the headset.

3.3 Analysis

The video recordings were analysed in Noldus Observer XT 14.0, a software for analysis of observational data that facilitates coding and description of participant behaviour. The videos were coded for two events: prompts presented by technology, opportunities to perform actions on the technology. These coded events were assigned a sub-code. The coding heuristics for the codes and sub-codes is shown in (Table 1). The coded data was exported to Microsoft Excel and analysed in SPSS. Nonparametric statistical methods were used as small-n data does not comply with the normality tests. Nonparametric methods also do not rely on the estimation of statistical parameters such as mean and standard deviation which

makes them suitable for small-n data analysis (Gibbons & Chakraborti, 2011).

Table 1 Coding Heuristics

Codes for an event	Sub-codes for a coded event	Description
Prompts presented		Instant when a prompt is presented to the participant.
	Type of prompts	The coded event, Prompts presented was coded for the type of prompts – <i>Visual, Audio</i> .
	Correct use	The coded event, Prompts presented was coded as <i>Correct use</i> when the prompt was correctly perceived. This was determined through a combination of verbal protocols and participant behaviour in the videos.
	Incorrect use	The coded event, Prompts presented was coded as <i>Incorrect use</i> when the prompt was incorrectly perceived. This was determined through a combination of verbal protocols and participant behaviour in the videos.
	Undetected prompt	The coded event, Prompts presented was coded as <i>Undetected prompt</i> when the prompt was presented by the technology but not detected by the participant. This was determined through a combination of verbal protocols and participant behaviour in the videos.
Opportunity for Actions		Instant when the technology presents an opportunity for the user to perform an action is coded as <i>Opportunity for Action</i> .
	Correct action	When the user performs a correct action in response to <i>Opportunity for Action</i> by the technology, it is coded as <i>Correct action</i> .
	Incorrect action	When the user performs a incorrect action in response to <i>Opportunity for Action</i> by the technology, it is coded as <i>Correct action</i> .
	Type of actions	When the user performed a <i>Correct action</i> , the type of action was coded – <i>Gestural, Speech</i> .

The Independent Variables (IVs) for the analysis were Type of prompts and Type of actions. The total prompts presented by both the technologies, total opportunities to perform actions with each of the technologies, total correct actions performed and total prompts correctly perceived were computed from the coded events. We also coded for incorrect use of prompts and actions and undetected prompts, but only included correct use of prompts





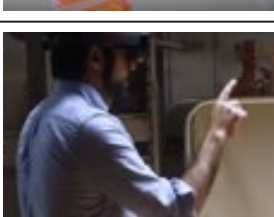
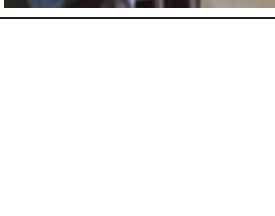
and actions in the analysis to compare the gestures and prompts. The dependent variables for the analysis were: Percentage of prompts correctly perceived and Percentage of actions correctly performed.




4. Results

4.1 HoloLens

HoloLens allows two Types of actions – Gestural and Speech. Two types of prompts were presented to the participants by the AR technology, HoloLens – Audio and Visual (Table 2).

Table 2 Types of action and prompts in HoloLens

Interaction/Type	Interaction	Description
Prompt/Visual - Graphic		Visual Graphic prompt, a tap icon, prompting to select an object in the virtual world
Prompt/Visual - Text		Visual Text prompt, a tap icon, prompting to select an object in the virtual world
Prompt/Visual Graphic		Visual Graphic prompt (microphone) to use speech as an action.
Prompt/Audio – Animated voice		An Audio prompt in the form of the squirrel's animated voice.
Prompt/Visual Graphic		Visual Graphic prompt (arrows) indicate the direction in which to look for the objects in each of the game missions.
Action/Gestural – Air tap		Gestural action, air tap to select an object in the virtual world. This is derived from the familiar gesture of tapping on a mouse to select in a desktop computer.

Interaction/Type	Interaction	Description
Action/Gestural - Bloom	 <p data-bbox="485 521 560 548">Step 1</p>  <p data-bbox="485 804 560 831">Step 2</p>	A bloom gesture is used to reset HoloLens to Home screen.
Action/Gestural - Gaze		Gaze is used to guide (move) the squirrel, Young Conker in the direction of the object which is being searched in the individual missions.

A comparison between the Types of actions - Gestural and Speech and the Types of prompts – Audio and Visual in HoloLens was first carried out using nonparametric statistical methods. Of the 6 participants who played Young Conker with HoloLens, all showed high percentage of correct use of gestural actions as compared to speech to interact with the technology. A Wilcoxon signed-rank test determined that there was a statistically significant increase in percentage of correct use of actions when subjects were using Gestural actions (Mdn = 80.31%) compared to Speech actions (Mdn = 23.61%), $z = -2.201$, $p = 0.028$, $p < 0.050$.

Similarly, analysis for Type of prompts perceived correctly using HoloLens found that out of 6 participants, there was higher percentage of correct perception of audio prompts as compared to visual prompts in 5 participants whereas 1 participant used visual prompts more effectively than audio prompts. A Wilcoxon signed-rank test determined that there was a statistically significant increase in percentage of correct perceptions of prompts when subjects were using Audio prompts (Mdn = 60%) compared to Visual prompts (Mdn = 19.52%), $z = -1.992$, $p = 0.046$, $p < 0.050$.

Further comparative analysis of types of gestural actions and types of visual prompts in HoloLens was carried out. Although audio prompts were more effective than visual prompts, we wanted to know the effectiveness of various visual prompts.

Descriptive statistics for these gestures and visual prompts are shown in Table 3.

Table 3 Descriptive statistics for Types of gestural actions and visual prompts

Type of Gestures and Visual Prompts in HoloLens	Percentage of correct actions and perceptions		
	Mean (%)	Median (%)	Standard Deviation (%)
Gestural - Gaze	76.52	74.50	6.43
Gestural - Bloom	18.33	0.0	28.57
Gestural - Air tap	76.47	92.96	37.85
Visual Prompts - text	36.48	44.43	18.75
Visual Prompts - Graphics	14.17	16.25	8.60




Gestural – Air tap was most effective while Gestural – Bloom was most ineffective with PwD. Visual text prompts were more effective in terms of correct perception than visual graphic prompts. A Friedman test was run to determine if there were differences in percentage of correct actions with the following types of gestures: Gestural-Gaze, Gestural-Bloom and Gestural-Air tap. Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons (SPSS Statistics, 2016). Percentage of correct actions were statistically significantly different for the types of gestures, $\chi^2(2) = 8.96$, $p = 0.011$ ($p < .050$). Post hoc analysis revealed statistically significant differences in percentage of correct gestures from Gestural-Bloom (Mdn = 0.0%) to Gestural-Air tap (Mdn = 92.96%) ($p = 0.012$, $p < 0.05$), but not Gestural-Bloom & Gestural-Gaze and Gestural-Gaze & Gestural-Air tap.



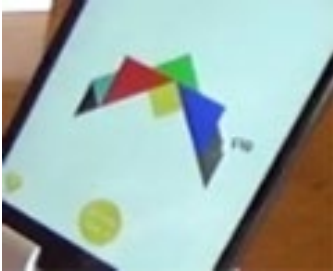
A comparison between the two types of visual prompts – Text and Graphic revealed that out of the 6 participants who played Young Conker with HoloLens, 5 participants showed high percentage of correct perception of visual text prompts as compared to visual graphic prompts. One participant used visual graphic prompts more effectively than the text prompts. A Wilcoxon signed-rank test determined that there was a statistically significant increase in percentage of correct perception when participants were using visual text prompts (Mdn = 44.43%) compared to graphic prompts (Mdn = 16.25%), $z = -1.992$, $p = 0.046$, $p < 0.050$.

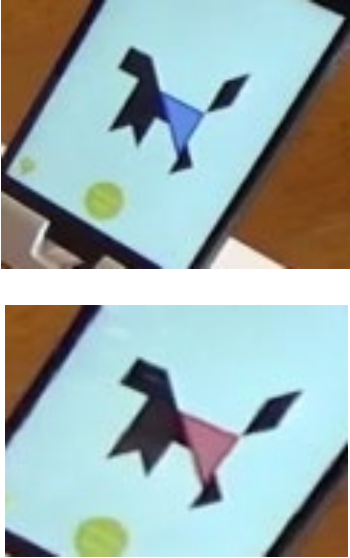
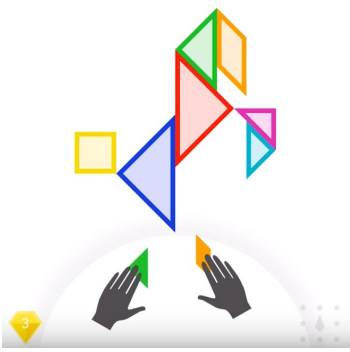
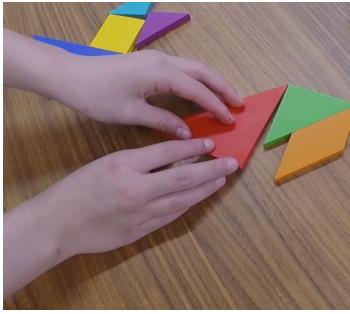
4.2 Osmo

Osmo offered only Gestural actions as a modality to interact with Osmo (Percentage of correct Gestural actions: Mean = 70.06%, Median = 69.13%, Std Deviation = 5.53). Two types of prompts were presented to the participants – Audio and Visual (Table 4).

Table 4 Types of action and prompts in Osmo

Interaction/Type	Interaction	Description
Prompt/Visual		<p>Visual properties of the blocks – shape and size were used to put the pieces together in a puzzle.</p>
Prompt/Visual – Animation		<p>A Visual - animation of coins emerging from a gem on completing a puzzle indicate to the players that they have earned coins. These coins could be used by the players to release more prompts in the game.</p>
Prompt/ Visual - Graphic		<p>A Visual – graphic (symbolic) prompt of a tick metaphorically relates to a tick on a list of things to do meaning ‘it is done’. In the game, the tick means that the player has successfully completed the level.</p>

Interaction/Type	Interaction	Description
Prompt/ Audio Prompt/ Visual – Text Prompt/ Visual - Graphical		<p>Audio prompt in the form of an owl in a female voice, prompts the player to use the gems collected during the game play to release a prompt.</p> <p>This audio prompt is complemented with a Visual – Text prompt in a speech bubble.</p>
Prompt/ Visual - Graphical		<p>Visual – Graphical prompt with a text prompt in the form of a number inside a gem, indicates number of gems available to the player.</p> <p>Visual – Graphical prompt complemented with a Visual – Text prompt in the form of a yellow circle with a text “Use Gems Cost #”, where # is the number of gems required to release a prompt for the current game, prompts the player to use gems to release more prompts to solve the Tangram puzzle.</p>
Prompt/ Visual – Text Prompt/Visual - shapes		<p>Visual – Graphical prompt in the form of yellow, orange and red ellipses representing easy, medium and hard levels respectively. Purple represents the highest level, which the participants did not play in the study.</p> <p>Visual – Text ‘flip’ prompts players to turn over the physical orange tangram piece when it is not aligned correctly with the rest of the pieces.</p> <p>Visual – shapes represent prompts that include shapes filled with colour, shapes with coloured outlines.</p>

Interaction/Type	Interaction	Description
Prompt/ Audio	Music	Audio prompt in the form of a tone prompts players about the progress of the puzzle solving task as they put the pieces together.
Prompt/ Visual – Flickering		Visual – Flickering prompt in the form of flickering red and blue colour for a block prompts the players to use either of the two colours for the same shape in that position.
Prompt/Visual - Animations		Visual – Animation prompt shows how to complete the puzzle. Two hands emerge from the bottom of the screen showing how to place each piece in the puzzle.
Action/Gestural		Gestural actions performed through manipulations of the Tangram pieces.

A comparison between the two Types of prompts – Audio and Visual in Osmo was first carried out using nonparametric statistical methods. Of the 10 participants who played Tangram, there was higher percentage of correct perception of audio prompts as compared to visual prompts in 8 participants whereas 2 participants used visual prompts more effectively than audio prompts. A Wilcoxon signed-rank test determined that there was

a statistically significant increase in percentage of correct perceptions of prompts when subjects were using Audio prompts (Mdn = 20.68%) compared to Visual prompts (Mdn = 10.76%), $z = -2.090$, $p = 0.037$, $p < 0.050$.

Further comparative analysis of types of Gestural actions, Audio prompts and Visual prompts in Osmo was carried out. Descriptive statistics for these gestures and prompts are shown in Table 5.

Table 5 Descriptive statistics for Types of gestural actions and prompts

Type of Gestures and Prompts in Osmo	Percentage of correct actions and perceptions		
	Mean (%)	Median (%)	Standard Deviation (%)
Gestural – Object Manipulation	90.0	90.51	3.00
Gestural – Touchscreen swipe	54.3	63.33	29.47
Gestural – Touchscreen tap	39.53	40.0	3.90
Audio Prompts – Human voice	82.40	91.15	29.50
Audio Prompts – Music tone	11.64	10.14	7.23
Visual Prompts - Animations	15.92	16.10	1.70
Visual Prompts - Shapes	38.14	38.63	2.19
Visual Prompts – Shapes flickering	3.27	3.27	0.53
Visual Prompts - Text	25.80	25.17	2.48
Visual Prompts - Graphic	5.14	5.36	1.02

A Friedman test was run to determine if there were differences in percentage of correct actions with the following types of gestures: Gestural-Object manipulation, Gestural-Touchscreen swipe and Gestural-Touchscreen tap. Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons (SPSS Statistics, 2016). Percentage of correct actions were statistically significantly different for the types of gestures, $\chi^2(2) = 16.80$, $p = 0.0$ ($p < .050$). Post hoc analysis revealed statistically significant differences in percentage of correct gestures between Gestural-Object manipulation (Mdn = 90.51%) and Gestural-Touchscreen swipe (Mdn = 63.33%) ($p = 0.022$, $p < 0.05$) and Gestural-Touchscreen tap (Mdn = 40.0%) ($p = 0.0$, $p < 0.05$), but not Gestural-Touchscreen swipe & Gestural-Touchscreen tap.

A comparison between the two types of audio prompts – human voice and music tone, revealed that out of the 10 participants who played Tangram with Osmo, 9 participants showed high percentage of correct perception of human voice as compared to music tone prompts. One participant used music tones more effectively than the human voice prompts. A Wilcoxon signed-rank test determined that there was a statistically significant increase in percentage of correct perception when participants were using human voice prompts (Mdn = 91.15%) as compared to music tones (Mdn = 10.14%), $z = -2.7$, $p = 0.007$, $p < 0.050$.

A Friedman test was run to determine if there were differences in percentage of correct perception with the visual prompts- animations, shapes, flickering shapes, graphic and text. Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons (SPSS Statistics, 2016). Percentage of correct perceptions were statistically significantly different for the types of visual prompts, $\chi^2(4) = 39.28$, $p = 0.0$ ($p < .050$). Post hoc analysis revealed statistically significant differences in percentage of correct perceptions between Visual-animations (Mdn = 16.10%) and Visual-shapes (Mdn = 38.63%) ($p = 0.047$, $p < 0.05$), Visual-flickering shapes (Mdn = 3.27%) and Visual-shapes (Mdn = 38.63%) ($p = 0.0$, $p < 0.05$), Visual-flickering shapes (Mdn = 3.27%) and Visual-text (Mdn = 25.17%) ($p = 0.0$, $p < 0.05$), Visual- shapes (Mdn = 38.63%) and Visual-graphic (Mdn = 5.36%) ($p = 0.0$, $p < 0.05$), Visual-text (Mdn = 25.17%) and Visual-graphic (Mdn = 5.36%) ($p = 0.03$, $p < 0.05$), but not between Visual-animations and Visual-flickering shapes, Visual-graphic and Visual-flickering shapes, Visual-graphic and Visual-animations, Visual-animations and Visual-text, Visual-shapes and Visual-text.

5. Discussion

The study found that PwD can use gestural actions correctly and successfully. These gestures could range from the ones that are familiar (e.g. touchscreen tap) to others that are completely unfamiliar (e.g. air tap). Participants found the game of Tangram on Osmo easy to use, one participant expressed that the game was for children and wanted to play a game for grownups.

“this game looks like for children, I want to play a game for grownups”. P10

Participant P10 went on to play longer than the maximum allocated play time for the study. This suggests that the participant found the game easy to use and was engaged in the game.

The air tap gesture was most effective in HoloLens, while PwD used object manipulation effectively with Osmo. Dementia can affect parts of the brain that control language (Bayles, 1982) which supports effectiveness of non-verbal forms of responses such as gestures. Communicative functions are impaired, specifically in semantic systems. The semantic capacities are dissociated from the systems of syntax and phonology. This means that PwD have difficulties in forming complete sentences which acts as a barrier in using speech as a modality to perform actions on the technology. HoloLens employs single word commands for speech interaction such as ‘select’, ‘stop’, etc. It can be programmed for specific commands to be used in an application. However, this means that PwD are expected to learn new commands and remember them short term as well as long term for ongoing use. Dementia is associated with decline and/or loss of memory and reasoning and this is due to both an impairment in the short term memory and additional difficulty in creating new memories in long term memory (Miller, 1973). This means that PwD would find it difficult to remember the commands resulting in them abandoning the technology altogether.

The participants used air tap gesture in HoloLens to select virtual holograms in the

application. The technology requires the index finger to be within the line of view of the headset cameras for the gesture to be tracked by the technology. Participants had to be verbally prompted by the researcher to keep the index finger in front of their face. The gaze gesture in HoloLens is used to move virtual holographic young conker from one place to another. This is embodied in the act of looking around for something in the physical environment. In the virtual environment, it in turn results in the act of looking for virtual objects and in turn move the cursor for object selection. Embodied interactions are intuitive in nature and result in successful interactions (Desai et al., 2019). Beaudouin-Lafon (2000) suggested that if the extent of similarity between the user actions on a domain object and the resulting response (degree of conformance) are kept higher, it could result in successful and correct interactions. With the gaze gesture in HoloLens, the movement of the head and the eye gaze results in the movement of the virtual object in the same direction in the virtual world.

PwD used three gestures with Osmo, object manipulation and touchscreen tap and swipe gestures. In object manipulation, people were using the natural and material properties of the physical objects, shape, size and colour, as prompts to put the puzzle pieces together. In other words, they were using physical affordances of the objects to determine how they may interact with it and what manipulations may be possible with the objects. People use their sensorimotor knowledge to decide on these actions and manipulations, which is the most accessible form of knowledge in humans and is established early in life (Blackler, Desai, McEwan, Dieffenbach, & Popovic, 2019). Gibson (1979b) emphasized that affordances depend on an individual's ability to perform actions in the environment. This means that although people will unconsciously look for physical affordances to interact with the objects, the interactions with the same objects could lead to different actions and manipulations in children, older adults and PwD depending on their abilities and sensorimotor knowledge.

The touch interactions were effective, contributing to 40 - 65% of the total presented opportunities. Touch screens allow more than one person to interact with the interface, both visually as well as by touch. Instead of limiting the interaction to one person through single control device such as a mouse, PwD become equal partners in the interaction with the researcher in the study but with their care givers in the larger context (Jodrell & Astell, 2019). The touch screen tap was the least effective, but this was due to lack of affordances in coloured circles in the app to tap on them to select the level of game. This prompt either went unnoticed or PwD used incorrect gesture with it. PwD could not interpret the expectation to shift their attention from the physical world of object manipulation to the virtual world and tap on the circles. MRTs should offer affordances to shift attention between the virtual and physical worlds. Since people are expected to interact with the physical and virtual elements, both at the same time, participants often were unable to determine when they should interact with the virtual elements and when with the physical objects.

The study found that audio prompts were more effective in correct perception of the prompts in comparison to the visual prompts for both technologies, despite of the fact that the total number of visual prompts presented by the technologies were much higher than

the audio prompts. PwD were unable to understand the visual prompts. Many visual prompts remained unnoticed. Visual cognition which involves ability to determine on the basis of the retinal input, the presence of particular shapes, configurations of shapes, objects, scenes, and their properties are before us, is impaired in PwD (Pinker, 1984). This supports our observation that some visual prompts were not noticed by PwD.

Animated audio prompts were most effective in HoloLens, followed by visual text and then visual graphics. Audio prompts in human voice were most effective in Osmo followed by music tones and then with animated voice. Participants expressed their dislike towards the animated voice of Young Conker in HoloLens,

“I don’t like to talk to this guy [young conker]?” P3

“I don’t like this voice...it is too much for my ears” P6.

Participants preferred the human voice in Osmo but had no problems with the visual character of an owl in Osmo. Effectiveness of audio prompts and specific preference to human voice could be due to familiarity of receiving instructions from their care givers at home and in day programs. All participants in the study attended day programs for varying lengths.

Shapes with coloured outline, filled with colour and filled with black and grey colours, were most successfully perceived followed by text prompts. This is despite impairments in visual cognition that make it difficult for PwD to recognize shapes and colours and reason and remember their properties to inform decision making process. We believe that this success is credited to the action of object manipulation that accompanies visual perception process in Osmo Tangram game. It was also observed that participants would often not look up at the tablet for the visual cues but rely on the object manipulation to figure out the right arrangement. Animations and flickering shapes were most ineffective in HoloLens. Dementia affects attention, working memory and visual-perceptual ability to varying extents depending on the type of dementia (Calderon et al., 2001). People with certain types of dementia are also prone to visual hallucinations. This could explain participants’ lack of attention to visual animations and flickering shapes.

Participants read all text prompts presented to them by both technologies. One participant said while playing Young Conker in HoloLens,

“They should write what we have to do.” P5

However, words and language when using text prompts or audio prompts should be simple, that does not require PwD to reason the meaning. Use of population stereotypes, idioms and metaphors requiring access to past experience and knowledge are difficult to perceive for PwD due to decline or loss of memory and reasoning. The use of word ‘Flip’ to turn over the orange piece in the tangram puzzle was confusing for all the participants. The researcher had to intervene with the word ‘Turn Over’ which the participants immediately understood the meaning and translate it into a correct object manipulation. Similarly, colour coded circles representing level of the puzzle could not be deciphered by PwD.

5.1 Design Implications

The findings from this study have defined use of interaction modalities in the design and development of MRTs for PwDs, resulting in a design framework shown in Figure 6.

ACTIONS

The Actions layer (at the bottom of Interaction Modalities) represents actions that should be used in MRTs for PwDs. Gestures, including those that PwD are unfamiliar with, are effective in generating correct actions. The actions should demonstrate high degree of conformance, that is the action in the physical world should result in the same functionality in the virtual world as in the physical world. Embodied actions such as object manipulations are effective with PwD. Other forms of embodied actions such as full body interactions (e.g. bowling) should be explored in future studies. In the context of IADL, effective correct actions mean that PwDs have control and independence in carrying out the activities instead of them following instructions from the technology.

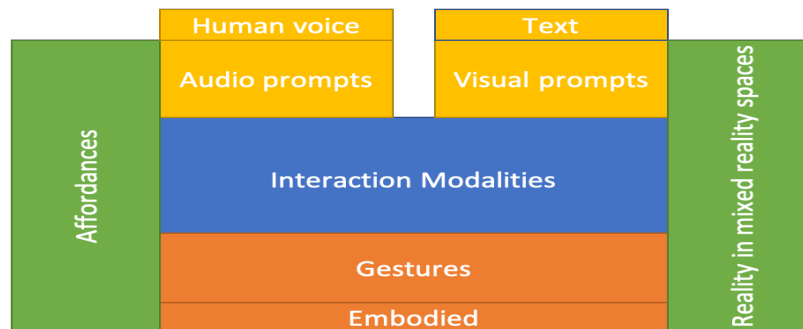


Figure 6 Framework for interaction modalities in MRTs for PwDs

PROMPTS

The prompts layer (at the top of Interaction Modalities) represents modalities of prompts that should be generated in MRTs to provide clues to PwDs to generate appropriate actions. Audio prompts in human voice are more effective over visual prompts of all forms. Amongst visual prompts, text prompts were desirable and preferred by PwD. Visual prompts and possibility of complementing visual with audio prompts needs to be investigated in future research. In the context of IADL, correct perception and interpretation of prompts means that PwD remain on track in executing tasks in an activity. This in turn would ensure that PwD adopt and accept these technologies in their everyday use. The effectiveness of the prompts and the actions depend on the sense of reality in physical and virtual worlds and affordances.

REALITY

In AV technologies, specific prompts or affordances may be required to shift attention between physical and virtual worlds. In general, PwDs should be aware of the world in which they are acting and perceiving, irrespective of the coupling mechanism, whether AR or AV (Desai, Fels, & Astell, 2020). This ensures that PwD respond to the correct prompts that are

presented to them and in turn respond with the correct actions. Segregating reality from virtuality in IADL activities is important for the safety of PwD in some activities, but also to determine in which world they should be executing actions and perceiving.

AFFORDANCES

Affordances play an important role in execution of actions as well as perception of prompts. Metaphors or idioms or population stereotypes are difficult for PwD to process and reason the meaning out of them. Physical affordances on the other hand offer natural and intuitive form of interaction for PwD (Blackler, Li-Hao, Desai, & Astell, 2020). The speed at which prompts are perceived and actions executed, will determine ongoing engagement of PwDs in IADL.

6. Conclusions

The study has found that PwD interact with MRT effectively through gestural interactions and audio prompts in human voice. Affordances and embodied actions contribute to the success of these actions and prompts. Text prompts that used simple and direct language were the most effective prompts amongst visual prompts. MRTs should incorporate affordances that allow PwD to differentiate interactions with virtual and physical elements. These findings are significant as they will drive further human centred studies into understanding prompting mechanisms for technology development for PwD. The outcomes could be applied to other interactive systems for PwD. Future research will investigate audio and visual prompts, specifically how to complement these prompts with gestural actions for effective interactions for PwD with MRTs.

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A Health Care Platform Design: Applying Novel Machine Learning Methods to Predict Chronic Cardiac Disease

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Abstract: With the aging of the global population, the number of people with chronic diseases is also increasing, and cardiac disease has become the main cause of human deaths worldwide. In this study, we propose an integrated detection system for measuring the blood pressure (BP), blood glucose (BG), blood lipids (BL), and heart rate (HR). Next, we employ five commonly used machine-learning-based (ML-based) data classification methods, namely, support vector machine (SVM), random forests (RF), k-nearest neighbors (KNN), XGBoost, and LightGBM, for predicting chronic cardiac disease. These five classification methods use the data of BP, BG, BL, and HR, to predict the chronic cardiac disease, whose result shows that RF and KNN have the highest prediction accuracy (88.52%) as compared to the new ML methods, such as XGBoost and LightGBM. In addition, the proposed system should serve as a platform for the long-term detection and tracking of users' physical health.

Keywords: chronic disease; cardiac disease; machine learning; data analysis

1. Introduction

With the rapid aging of the global population, the incidence of chronic diseases in the elderly population has also increased (Prince et al., 2015). Some of the common chronic diseases include hypertension, diabetes, cardiac disease, gastropathy, and arthritis. Of these, both hypertension and diabetes increase the risk of cardiac-related diseases (Ettehad et al., 2016). According to the World Health Organization, cardiac disease is the leading cause of death worldwide (Anderson et al., 2016). Cardiac-related chronic diseases require long-term observation and tracking. Therefore, it is very important to reduce the incidence and mortality of chronic diseases through health check-ups and regular blood pressure and blood glucose monitoring. These not only allow for the early detection and control of chronic



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diseases but can also help prevent and delay the occurrence of these diseases.

In recent years, with the growth of the elderly population and the related increase in the demand for medical resources as well as owing to various government medical policies, such as those related to long-term care, the use of information technology in the medical field has been increasing. The application of artificial intelligence in the medical field can not only help clinicians in improving their workflows and reducing medical errors but also aid in the analysis of patient data for promoting their health (Topol, 2019).

On the other hand, the medical data has accumulated to a great amount since the national health insurance implementation. Integrating Health Insurance Information and artificial intelligence not only makes good medical diagnostic but also undertakes the complicated medical document arrangement and integration (Verghese et al., 2018). Therefore, due to the solid foundation of information technology and the increasing demand for medical care, the application of artificial intelligence medical technology has become a niche for nowadays development.

Given the trends of an aging society and the increasing demand for medical care, current medical equipment available in the market mostly measures only a single parameter, such as monitors of blood pressure (BP), blood glucose (BG), heart rate (HR), and other related devices. This may reduce users' willingness of long-term use, resulting that they should not use autonomously. In this study, we integrate four major detection systems for measuring BP, BG, HR, and blood lipids (BL), providing a design platform for the long-term detection and tracking of their physical health. This platform combines machine learning methods to explore the commonly used computing methods in cardiology- such as support vector machines (SVM), random forests (RF), K-nearest neighbors (KNN) (Johnson et al., 2018), and new types, LightGBM and XGBoost. By comparing the accuracy of five algorithms for predicting chronic diseases, we aim to improve the accuracy of chronic disease prediction and provide the best medical product and service for the home-based self-test. The better prediction leads to lower risk because individuals will take a prediction of future health problems as a warning and change their behavior accordingly. Even, it will reduce the proportion of future deaths due to cardiac-related diseases. The proposed home-based self-test medical product will reduce the unnecessary use of medical resources and improve the quality of medical care. The goals of this study are listed as follows:

1. Design and develop a software prototype with a platform that provides users for the long-term detection and tracking of their health status.
2. Compare regular machine-learning-based data analysis methods with the latest ones, such as LightGBM and XGBoost.
3. Serve as a reference for the development of machine-learning-based platforms regarding the detection of cardiac disease.

2. Literature review

2.1 *Global status and analysis*

In Taiwan, the elderly, that is, those over 65 years, account for 14.05% of the total population. It is estimated that in a very short period, approximately 8 to 9 years, the percentage of the elder population in Taiwan will reach 20%, making Taiwan become a “super-aged society”. In 2060, it may exceed 40%, making Taiwan the second aging country in the world. The National Development Council (2019) shows that countries such as Japan, South Korea, European countries, and the United States are also facing the increasingly aging society and low child birth rate, which is now an irreversible global trend. In the next 30 years, the proportion of Taiwan’s elderly population will increase rapidly and surpass many countries. Thus, it was officially announced that the country had transitioned from a 7% “aged society” to a 14% “aged society” (Department of Statistics, Ministry of the Interior, 2019). A report from the World Health Organization stated that, with the aging of the global population, chronic diseases have become the world’s major disease type (WTO, 2018). These diseases include cardiovascular diseases, diabetes, and other common chronic diseases. Approximately half of the adults in the United States have at least one chronic disease, while another 117 million are threatened by one (Ward, 2014). Eighty percent of Taiwan’s middle-aged and elderly populations suffer from more than one chronic disease, with the proportion of women (90.7%) being higher than that of men (88.7%). Chronic diseases are the main cause of death among the elderly population over 65 (Hong, 2015). One quarter of the diseases in those over 60 years of age are cardiovascular or respiratory diseases (Chatterji et al., 2015). Cardiovascular-related chronic diseases increase the risk factors for cardiac disease as well as the risk of death. According to Anderson (2016), cardiac disease is the leading cause of death all over the world. Therefore, cardiac-related chronic diseases are not to be neglected. Hence, it is of great importance to be able to detect and control the incidence of chronic diseases and reduce the mortality related to them.

Therefore, most people face the threat of a decline in their physical and mental functions along with the occurrence of chronic diseases as they age. This will not only increase the consumption of medical resources but also the risk of death in elderly people. Thus, platforms such as those proposed in this study will prove to be indispensable in the coming years.

2.2 *Application of machine learning in medical field*

In the era of big data, which is the result of recent advancements in information technology, several highly useful machine learning techniques have been developed. Along with advances in medical science, the use of machine learning methods in the medical field for analyzing the relationship between preventive and treatment technologies and disease prediction (Yu et al., 2018) has resulted in significant improvements in clinical outcomes. Big data and machine learning tools provide clinical assistance to doctors and promote the continuous development of medical transformation by the application of machine learning

to large-scale healthcare data (Beam & Kohane, 2017). At present, the application of artificial intelligence tools in the prevention and treatment of cardiac disease mainly includes the use of training, monitoring, and prediction technologies. Machine learning and, in particular, the development of accurate prediction models for the latency characteristics of chronic diseases has resulted in significant progress in actual medical practice (Miller & Brown, 2018).

According to Shameer et al. (2018), various machine learning methods such as supervised learning, cognitive learning, and unsupervised learning can discover hidden structures in the data related to cardiac disease and can thus help prevent and treat common chronic cardiovascular diseases. Such insights may also lead to the discovery of new treatments and help improve specific cardiovascular care. In recent years, machine learning has been used in the field of cardiology for electrocardiography, myocardial perfusion imaging, and heart failure as well as for integrating clinical and imaging data using algorithms such as artificial neural networks (RNN), support vector machines (SVM), random forests (RF), and K-nearest neighbor (KNN) (Al' Aref et al., 2019). Motwani et al. (2017) showed that machine learning is a more effective way of predicting cardiac disease than using only clinical and conventional detection methods.

Therefore, in the era of big data, artificial intelligence has become a development trend in various fields and has resulted in significant progress in the medical field as well. With the prevalence of chronic diseases and given the significant changes occurring in the population, the demand for medical resources is also increasing. Using machine learning technologies for preventing and predicting the possibility of disease can not only solve the problem of limited medical resources but also offers an important auxiliary tool to assist clinicians in diagnosis.

2.3 Application of machine learning in predicting cardiac disease

In cardiology, the most commonly used machine learning algorithms are the support vector machines (SVM), random forests (RF), and K-nearest neighbour (KNN), (Johnson et al., 2018). We discuss these algorithms in brief next.

The SVM algorithm is a classification algorithm and is used to find a decision boundary to maximize the margins between two classes so that they can be distinguished perfectly. This linear classifier can transform the slope of a classification line to find the range with the largest width and determine the point closest to the line for the two classes. The distance between a given point and the classification is represented by a vector, which is called a support vector. Some of the common classification methods used with This algorithm include linear functions, the Gaussian radial basis function, and polynomial functions. Among these, the Gaussian radial basis function is the best classification function (Manavalan et al., 2018) (Figure 2.1 (a)).

RF consist of multiple decision trees, with there being no correlation between each decision tree. When inputting new information, one repeatedly and randomly draws K samples from the original training set to generate a new training sample set. Next, each decision tree is made to judge separately. This generates K classification trees based on the sample set,

resulting in a random forest. The classification results for the new data are based on the scores assigned by voting by the classification tree. RF classification has the advantage of being able to deal with data with many characteristics. Further, in the case of unbalanced datasets, it can effectively balance the errors in the data (Wager & Athey, 2017) (Figure 2.1 (b)).

The KNN method is a supervised learning classification algorithm. It uses the feature distance between the sample points to determine the type of the new data. The training data for the KNN method must be labelled, that is, the training data must be categorized. The main application area of this classification algorithm is the classification of unknown data. An advantage of the KNN method is that it does not have to be retrained. Further, its prediction error rate can be reduced effectively (Liao & Vemuri, 2002) (Figure 2.1 (c)).

(a) Support Vector Machine

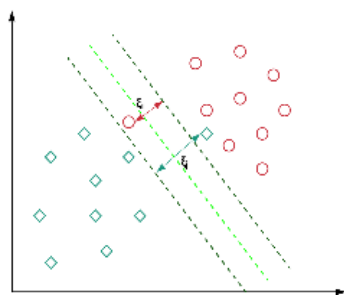


Image Source:
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(b) Random Forests

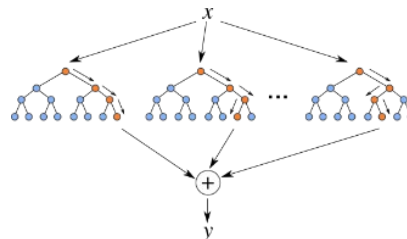


Image Source:
<https://reurl.cc/e5pM7R>

(c) K-Nearest Neighbor

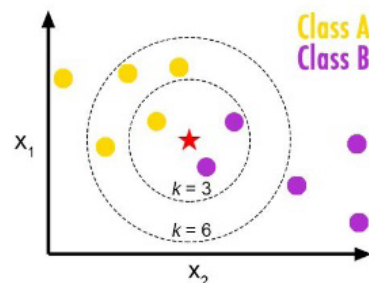


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<https://reurl.cc/M723VX>

Figure 2.1 Machine learning methods for data classification.

3. Research methods

The health status detection platform proposed in this study, a database similar to the Cleveland database with 76 attributes was established based on the study by Janosi et al. (2018). A total of 13 impact attributes related to heart disease based on the existing literature were included in the database. Then, 313 samples were evaluated the performances of the latest machine learning algorithms (i.e. XGBoost and LightGBM), and compared with those of SVM, RF, and KNN in order to improve the accuracy of cardiac disease prediction.

3.1 Design of health care platform

An inspection of the medical testing equipment available in the market showed that the products for monitoring BP, BG, HR, and other related parameters mostly measure only a single parameter. This may reduce users' willingness to have multiple medical signals detected simultaneously. Therefore, we attempted to integrate four detection devices, i.e.

BP, BG, BL, and HR, in a single platform to facilitate the simultaneous collection of multiple medical data. This was done so that the data could be used to effectively predict the user's risk of cardiac-related chronic diseases using machine learning techniques (Figure 3.1).

Steps of using this device: First, the user logs in the basic information of gender, age, and gender. Second, uses a fine needle to prick a needle on his fingertip to take blood, squeeze out a few drops of blood, drop it on a sensor test paper, and place a device to measure the blood glucose. Third, after measuring blood glucose, put your arm into a circular hole that detects blood pressure and heart rate. After pressing the button on the top of the device, the device starts that the data could be used to effectively predict the user's risk of cardiac-related chronic diseases (Figure 3.2-3.4).

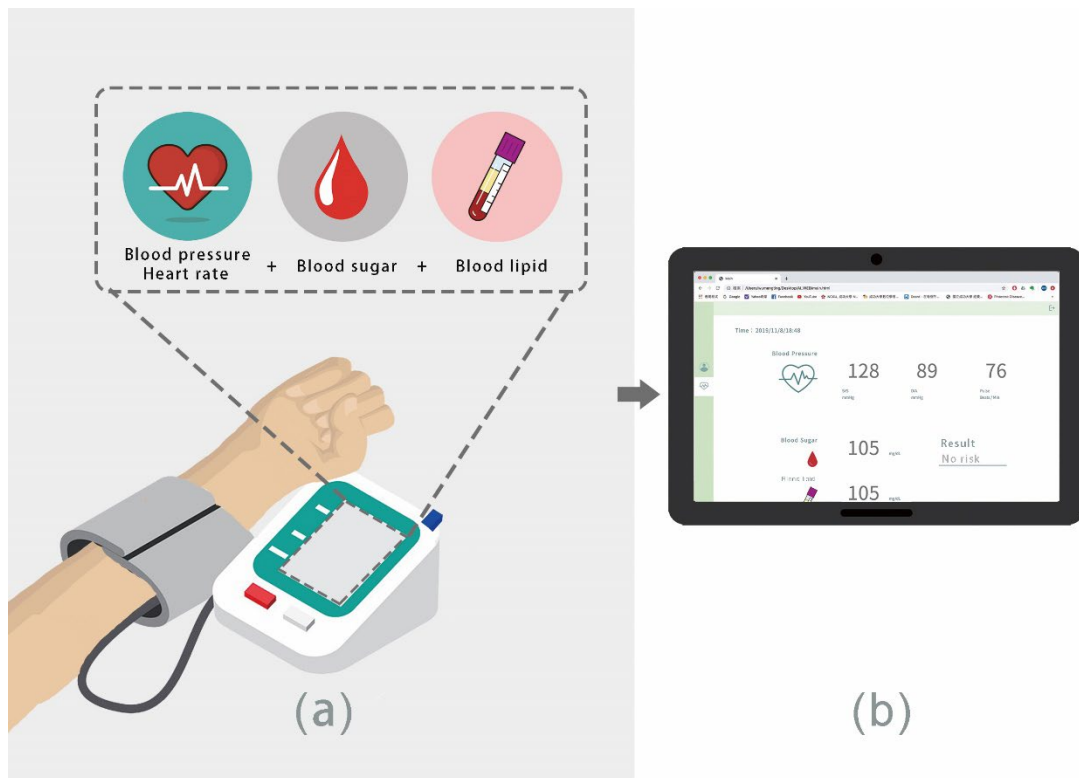


Figure 3.1 (a) Intelligent health care platform developed in this study integrates four detection systems for measuring blood pressure (BP), blood glucose (BG), blood lipids (BL), and heart rate (HR). (b) After performing measurements, system predicts probability of cardiac disease using machine learning.

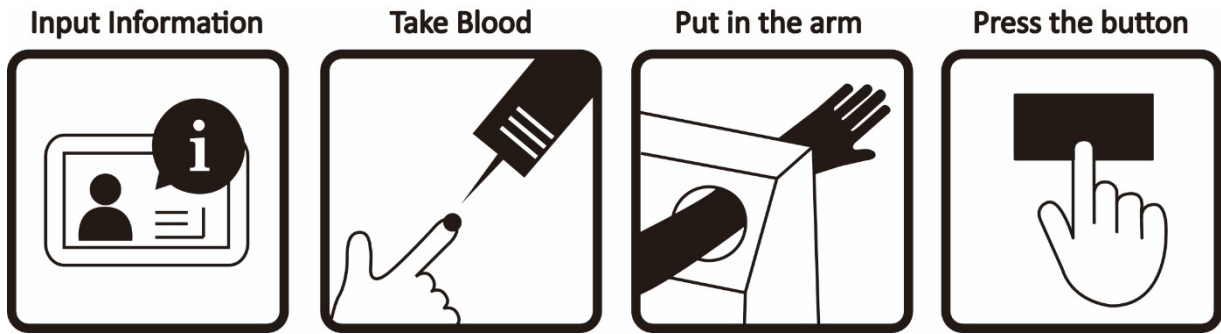


Figure 3.2 Intelligent health care platform use steps.



Figure 3.3 Intelligent health care platform 3D model design.



Figure 3.4 The prototype of intelligent healthcare platform and the scenario diagram.

3.2 Data classification using XGBoost

XGBoost is based on the boosting algorithm and improves the training speed and prediction accuracy of the boosting tree model (Chen & Guestrin, 2016). In other words, XGBoost is an improved tree model and can be considered as a collection of many tree models. It continuously performs feature splitting to generate a tree. When the tree is generated, a new function is also generated. This function will fit the previously predicted loss function (Fan et al., 2018). After training, k trees are obtained. The classification method is based on the characteristics of the samples; the predicted values of the corresponding leaf nodes in the k trees are summed to obtain the predicted values for the test sample. The objective function is generated as given in Eq. (1):

$$\hat{y} = \Phi(x_i) = \sum_{k=1}^K f_k(x_i)$$

$$\text{where } F = \{f(x) = \omega_{q(x)}\} = (q : R^m \rightarrow T, \omega \in R^R) \quad (1)$$

3.3 Data classification using LightGBM

LightGBM is based on the histogram calculation method and speeds up training by using continuous features. Its calculation of the maximum split gain is needed to reduce the amount of calculation of the segmentation gain, and the method speeds up the calculations by subtracting the maximum value of the histogram from the minimum value. Only the leaf nodes of a single tree are required to establish a histogram, and the histogram of the adjacent nodes can be obtained by subtraction (Chen et al., 2019); this increases the calculation speed (Figure 3.5).

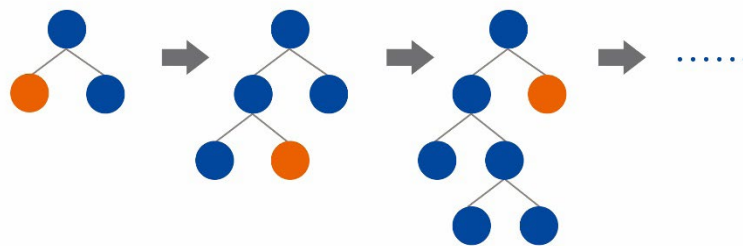


Figure 3.5 Concept of data classification using LightGBM.

4. Results and discussion

The database used is similar to the Cleveland database (Janosi et al., 2018), which contained 313 samples, and we assessed the possibility of predicting chronic cardiac disease. The data corresponded to 165 people without cardiovascular disease and 138 people with the disease. In this study, we use three commonly used classification algorithms (i.e. SVM, RF and KNN), and compare two latest algorithms: XGBoost and LightGBM, in order to determine the best data classification method. This result can increase the accuracy of chronic disease

prediction, achieve the goal of self-testing and prevention, and reduce the risk of death caused by chronic disease.

4.1 Dataset for SVM, RF, and KNN methods

We used 313 samples with attributes related to chronic cardiac disease. Before the data analysis, normalization was performed to effectively eliminate the occurrence of heterogeneous states in the attributes and transform the original data into intervals ([0, 1]). The expression used for this was the following: (original data – minimum value) / (maximum value – minimum value). We performed one-hot encoding for the data features, such as the maximum heart rate and the occurrence of myocardial infarction and thalassemia, and divided these categories into multiple rows; 1 indicated that the data for this category existed, while 0 indicated that it did not. This was a categorical variable that could handle discontinuities (Table 4.1). With respect to the four levels for the maximum heart rate, cp_0 indicated no heartache, cp_1 indicates mild pain with a pain index of 1–3 points, cp_02 indicated moderate pain with a pain index of 4–6 points, and cp_03 indicated intense pain corresponding to 7–10 points. Further, with respect to the four levels for myocardial infarction, Thal_0 indicated the first type in the Killip classification system with no complications and no signs of heart failure; Thal_1 indicated the second type in Killip—mild to moderate heart failure; Thal_2 was the third type in Killip—severe left heart failure or pulmonary edema; and Thal_3 was the fourth type in Killip—psychogenic shock or systolic blood pressure below 90 mm Hg. Finally, in the case of the three levels of thalassemia, Slop_0 indicated normalcy, Slop_1 indicated fixed defects, and Slop_2 indicated reversible defects.

Table 4.1 Conversion of maximum heart rhythm, myocardial infarction, and rare disease data using one-hot encoding.

No	Cp_0	Cp_1	Cp_2	Cp_3	Thal_0	Thal_1	Thal_2	Thal_3	Slope_0	Slope_1	Slope_2
0	0	0	0	1	0	1	0	0	1	0	0
1	0	0	1	0	0	0	1	0	1	0	0
2	0	1	0	0	0	0	1	0	0	0	1
3	0	1	0	0	0	0	1	0	0	0	1
4	1	0	0	0	0	0	1	0	0	0	1

4.2 Dataset for XGBoost and LightGBM

For classification using XGBoost and LightGBM, we used a dataset with categorical features to perform data segmentation and created dummy variables. The classification of categorical features involves dividing the dataset into two subsets based on the categories. If there are k categories, the number of categories obtained would be $2^{(k-1)}-1$, which can then be used for data classification (LightGBM, 2019). The feature importance measure represents the importance of the attributes with respect to the final goal based on the metric used. The data used in this study had 13 attributes, and a total of 19 attributes were obtained

through category classification. The histogram was sorted based on the cumulative metric of importance. The top three features based on the importance measure as per LightGBM were the maximum heart rate (178), cholesterol (170), and age (162) (Figure 4.1), while those as per XGBoost were thalassemia intermedia (0.29), myocardial infarction (0.24), and major vessels (0.07) (Figure 4.2).

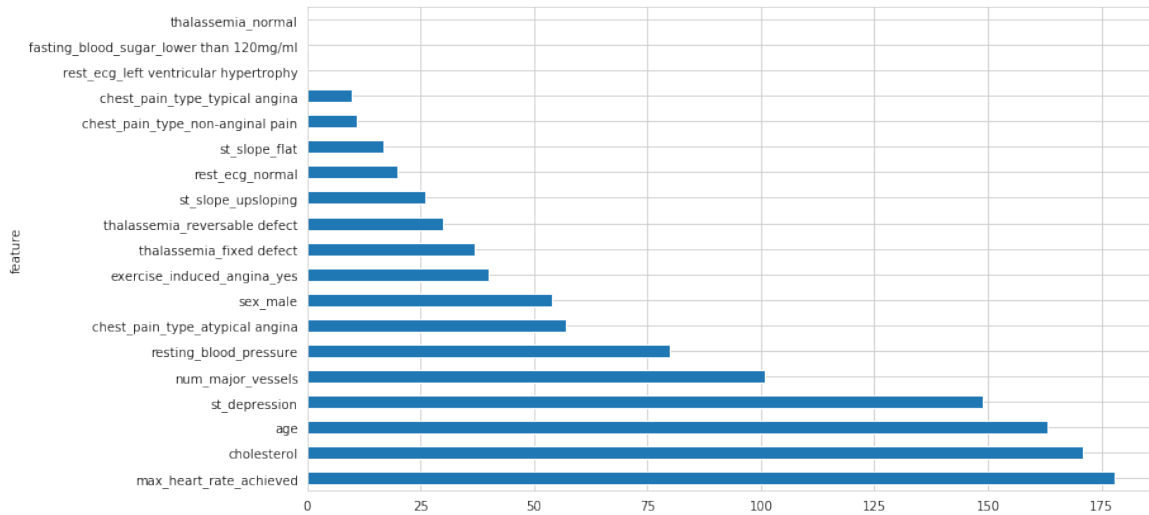


Figure 4.1 Feature map for LightGBM.

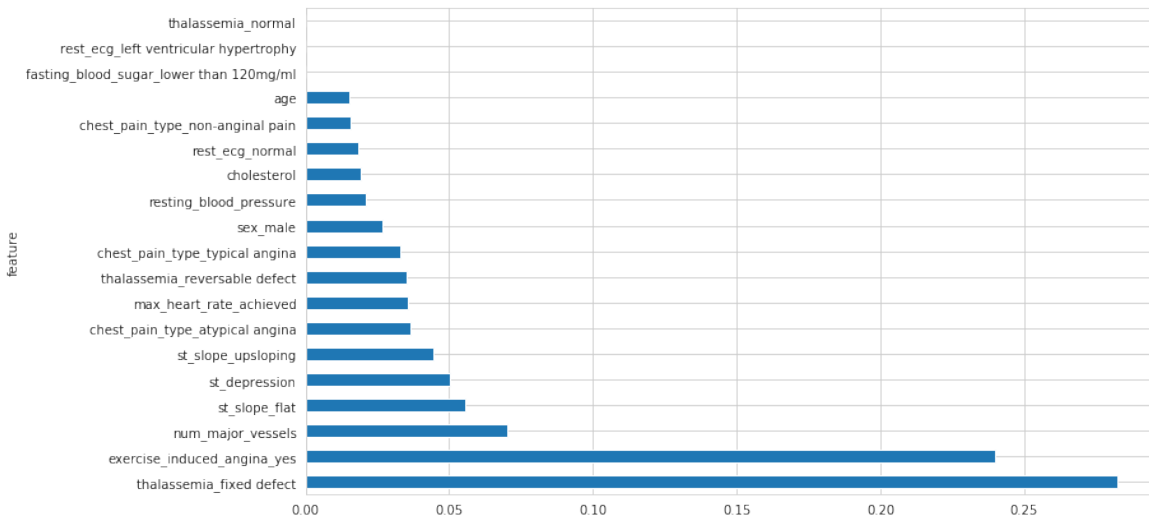


Figure 4.2 Feature map for XGBoost.

4.3. Results

As stated previously, three commonly used classification algorithms, i.e. SVM, RF, and KNN (the value of k was set to 3) were used for classification. In addition, two new algorithms (i.e. XGBoost and LightGBM) were also used for binary classification. In order to increase the accuracy and reduce the overfitting conditions, we unified the following fixed parameters

used in these algorithms: “learning rate” was set to 0.05 while “max depth” was set to 7. In the case of LightGBM, “max bin” was set to 200 and “num leaves” was set to 150. Further, of the 313 samples in the dataset related to cardiac disease, 80% were used as the training set, and the remaining 20% were used for the test set. The performances of the five algorithms were compared. We found that SVM exhibited the best performance in terms of speed at 0.007 ms, followed by XGBoost and LightGBM; With respect to prediction, the accuracies of RF and KNN were the highest at 88.52% (Table 4.2). XGBoost and lightGBM classification algorithms were based on the calculation of large-scale data, which has faster training efficiency and higher accuracy (Chen & Guestrin, 2016; LightGBM,2020). Thus, for the small dataset (313 samples) used in this study, the new algorithms (i.e. XGBoost and LightGBM) did not perform better than the existing ones in terms of speed and prediction accuracy.

Table 4.2 Comparison of efficiencies and accuracies of various machine learning classification methods.

	Efficacy	Accuracy	
SVM	0.007/ms	Train	84.71%
		Test	86.89%
RF	1.513/ms	Train	99.89%
		Test	88.52%
KNN	1.11/ms	Train	87.19%
		Test	88.52%
XGBoost	0.029/ms	Train	82.89%
		Test	82.89%
LightGBM	0.026/ms	Train	80.26%
		Test	80.45%

5. Conclusions

The rapid aging of the global population and the resulting increase in the rate of chronic cardiac disease not only increase the risk of mortality but also pose significant challenges to national health policies. Artificial intelligence can have a significant effect on the medical field. Focusing of cardiac disease, in this study, we have compared the performances of five classification methods, i.e. SVM, RF, KNN, XGBoost, and LightGBM, in predicting chronic cardiac disease. A dataset consisting of 313 samples is used, and the result shows that the latest algorithms (XGBoost and LightGBM) are inferior to SVM in terms of the calculation speed. In addition, the prediction accuracy of RF and KNN is the highest (88.52%). For further discussion, the XGBoost and lightGBM classification algorithms are based on the calculation of large-scale data, which has faster training efficiency and higher accuracy. In this study, only 313 samples (small-scale data) have been used for testing and analysis, as such XGBoost and lightGBM have not yet obtained the best results. In the era of big data, whether the novel calculation method is suitable to be used for the small-scale data will can be further explored in future research.

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**Objects, Practices,
Experiences, and Networks
SIG**

Overview of papers in the Objects, Practices, Experiences, and Networks SIG highlights

Editorial 652
Tom FISHER

222. Identifying and addressing unintended values when designing (with) Artificial Intelligence 654
Niya STOIMENOVA, Maaïke KLEINSMANN

271. Design prototyping for policymaking 667
Diana Pamela VILLA ALVAREZ, Valentina AURICCHIO, Marzia MORTATI

265. Social Media Research and the Impact of Graphic Design: a case study examining an Indonesian political campaign 686
Fanny SUHENDRA, Nicole WRAGG, Carolyn BARNES



DRS2020
BRISBANE, 11–14 AUG
SYNERGY



Editorial: OPEN Sig

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The mission of OPEN is to facilitate and explore Design's connections beyond the areas of practice and research that characterised it after the middle of the C20, connecting it to networks of theory and method that can elucidate design practices, and experiences of the designed world. This is answering a situation where the definition of design is getting broader, from machines, to services, to policies, to politics. In academic discussion this broadening is allied to the goal of making better futures – Design retains its progressive mission of addressing futures, even though challenges and controversies await. The papers in this section address the ways in which design can work with these challenges to create opportunities for future designs. They are linked by the principle of trying something out before you commit to it - a principle deeply embedded in the DNA of Design practice. In two of them this is through prototypes, of policy or AI interaction, and in the third through engaging with political campaigns through social media. Stoimenova and Kleinsmann's paper, 'Identifying and addressing unintended values when designing (with) Artificial Intelligence' (paper 222) draws attention to unexpected and oftentimes not favourable side-effects of designed systems, drawing on the philosophy of technology to engage with the ethics of designing with AI, in the face of its independence of action. They show that prototyping, as well as testing the potential functioning of the products in use, also uncovers unforeseen actors that can come into play in the valuation of designs. In other words, by enabling a demo-run of the product in real life, prototyping provides designers to identify different and unforeseen stakeholders that can result from designs and their outcomes. Alvarez, Auricchio and Mortati's paper, 'Design prototyping for policymaking' (paper 271) presents a typological analysis to comprehensively review prototyping methods relevant to policy and outline approaches to prototyping. They direct our focus towards the use of prototyping for policy making and provide a method to approach "policymaking as designing" by locating recent moves to adopt design-process thinking in government policy development to precedents in design practice. Design connected to political campaigning is a fruitful avenue to engage



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with questions that point to the ethical validity, or otherwise, of design and Suhendra, Wragg and Barnes' paper 'Social Media Research and the Impact of Graphic Design: a case study examining an Indonesian political campaign' (paper 265) shows the ways in which graphical elements of a political campaign were helpful to provide a campaign brand that attracted attention and allowed large scale publicity. This paper showcases how politics, and this can be extended to policy makers, can make use of design. The relevance of the three papers to OPENSIG is nicely summed up by the quotation with which Stoimenova and Kleinsmann end theirs, offering a valid challenge to Design research:

"...do we hide behind the notion of technology we don't understand, or do we take full responsibility for all the unintended values we create?"

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For more information on the Objects, Practices, Experiences, and Networks SIG, please visit the SIG's webpage at <https://www.designresearchsociety.org/cpages/open-sig>. To find out whether the SIG is organising a satellite event to the DRS2020 conference, or just to get in touch with members and see news on the SIG, please visit the SIG webpage.



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Identifying and addressing unintended values when designing (with) Artificial Intelligence

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Abstract: A fundamental shift in the way society operates is approaching due to the prevalent adoption of self-learning technology like Artificial Intelligence (AI). Defined by the well-pronounced incongruence between their initial purpose and the values delivered to their multifaceted users, AI-powered systems are already being deployed in crucial social institutions such as hospitals, banks and courtrooms. To solve this tension, we first identify design practices that are suitable for the context of AI. Then we introduce a framework of three logical inferences that could aid designers to deliberately and continuously identify and address unintended values AI-powered solutions produce. The paper is concluded by three directions for future research.

Keywords: artificial intelligence; unintended values; purpose

1. Introduction

In the past few years we have witnessed impressive achievements of artificial intelligence (AI) ¹ in variety domains such as speech recognition, visual object recognition, object detection, drug discovery, physics and genomics (LeCun et al., 2015; Ching et al., 2018). However, multiple cases exist in which an AI-powered solution perpetuated biases and behaved in unintended, and possibly unanticipated², ways (Caliskan et al., 2017). For instance, in August 2019, Apple officially released a new type of credit card that “represents all things Apple stands for. Like simplicity, transparency and privacy.” (Apple, 2019). In November, however, a

1 While the whole field of AI is particularly interesting and there are multiple speculations about the level of consciousness an artificial agent can attain (see e.g. Shulman and Bostrom (2012)), in this article we focus on the type of AI that is currently making the biggest strides and affecting people’s lives the most – machine learning (ML). However, in the remainder of this article, we liberally use the terms model and algorithm, as well as AI and ML interchangeably for ease of explanation.

2 The word unanticipated implies that a behaviour was not foreseen and unintended is used to mean that while the consequence might have been anticipated, it was never intended. For the sake of simplicity, however, in this paper we consider unintended and unanticipated consequences to be the same.



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series of Twitter posts detailing a flaw with the AI behind the card became viral. It all started with a tweet from David Hansson (co-founder of Basecamp) who claimed that the algorithm gave him 20 times the credit limit his wife was afforded, despite the fact that she has a better credit score than him (Natarajan & Nasiripour, 2019). Even Apple's co-founder, Steve Wozniak, tweeted the following:

The same thing happened to us. I got 10x the credit limit. We have no separate bank or credit card accounts or any separate assets. Hard to get to a human for a correction though. It's big tech in 2019. — Steve Wozniak (@stevewoz) November 10, 2019

Yet, such AI-powered systems are already being deployed in crucial social institutions such as hospitals, banks and courtrooms (Crawford & Calo, 2016). Due to their extreme diversity, ubiquity and complexity, however, anticipating their behaviour remains challenging (Rahwan et al., 2019). As a result, a wide array of practitioners and scholars have been warning against the broad, unintended consequences of AI-powered solutions that can shape human behaviours and societal outcomes in both intended and unintended ways (Rahwan et al., 2019).

The aim of this paper is neither to discuss potential dystopian futures nor to convince the design community of ways AI could improve human health, safety, productivity or even creativity. Rather, its aim is to identify and elaborate upon possible ways for design to address what we consider to be the major tension of AI-powered solutions interacting with their environments – the incongruence between the purpose (what is intended/anticipated) of the solution and the value³ it delivers which might not always be “aligned with human interests” (Soares & Fallenstein, 2014; Taylor, 2016). For instance, while the purpose of an Apple Watch is to track your heartbeat, the values it delivers to each stakeholder may vary – from saving someone's life to changing how heart disease is diagnosed and thus affecting the market for diagnostic equipment, changing the cardiologists' job or even failing to alert for heart anomaly in a context where people blindly trust it and consequently contribute to someone's death.

As such, this paper is structured as follows, first we unpack the current state of design's involvement in ensuring the delivered values are aligned with humans' interest. Then we identify additional design practices that could help us to address the tension. These practices are combined in an initial framework of logical inferences on how to design for identifying and addressing potential unintended values early in the lifecycle of AI-powered solutions. The paper is concluded by an elaboration upon three viable directions for future research.

2. Aligning values with human interests through design

One of the most prominent emerging ways to ensure values created by AI-powered solutions align with humans' interests is the so-called human-centered machine learning (HCML).

3 We consider value to have a broader meaning that includes dimensions such as practical, economic, ethical and aesthetic rather than only moral values or (economic) utility. As such, the value we describe is aligned with the definition of value-in-use elaborated upon by Vargo and colleagues (2008).

HCML highlights the need to take a human-centered perspective on how ML solutions impact people (Ramos et al., 2019). The approach is based on principles, guidelines and strategies for designing user interactions with AI-powered solutions developed in the Human Computer Interaction (HCI) community in the past twenty years (Amershi et al., 2019). As such, to our knowledge, its efforts are geared towards making the output of an AI model easier to understand by its users, ultimately ensuring a seamless user experience and personalisation (PAIR, 2019). Currently, companies like Google, IDEO and Microsoft are spearheading the efforts in this area with recent releases of Google’s People + AI handbook, IDEO’s set of AI ethics cards (Sampson & Chapman, 2019) and Microsoft’s design principles (Amershi et al., 2019). Academia is slowly catching up. In November 2019, the number of articles appearing on Google Scholar that have the following strings in their titles: “human-centered AI”, “human-centered ML”, “human-centered machine learning”, “human-centered artificial intelligence”, amounts to almost 500 with scholars from the HCI field thus far taking the lead.

As already mentioned, however, one of the biggest problems with current AI-powered systems is the fact that they create values that are not intended and can ultimately inflict harmful impact on humans and humanity. This problem is not specific to AI. In fact, technology and design have a long-standing tradition of producing unintended values (i.e. the typewriter, microwaves, the Internet, Facebook’s like button). According to Ihde (2018), the notion that one can design into a technology its purposes and uses is a fallacy since the designer’s intent may be subverted, become a minor use, or produce completely unintended results (Ihde, 2008). Even human-centered design practices have been repeatedly shown to lead to unintended consequences or the so-called “dark patterns” of design (i.e. the “pull to refresh feature”) (Gray et al., 2018). As AI-powered agents gain autonomy and act in more complex domains, it may become progressively harder to anticipate the impact and implications of the array of possible unintended values (Amodei et al., 2016). Therefore, before carrying over existing design practices and methods to designing (with) AI, attention should be given to whether the limitations such exhibit could get amplified when transferred to the new context. Moreover, to be able to create a principled approach to identifying and addressing unintended values early in the solution’s lifecycle, we should critically assess existing practices and identify the ones that could help us to deal with the purpose-values tension.

We contend that the criteria for such design practices are three: (1) they should address the incongruence between purpose and (unintended) values, (2) they should proactively anticipate potential future values and (3) they should make a clear distinction between the way a system behaves and the way it is being used. The criteria are interconnected and continuously amplify each other. For instance, an AI-powered solution is created with a certain purpose (e.g. to monitor the heartrate of its user). However, the way it is used influences what it learns and consequently its behaviour might be novel. This makes the future values it can deliver difficult to anticipate and analyse (Rahwan et al., 2019).

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A clear distinction between biases and values has to be established, however. The majority of AI models are trained on implicitly biased human-generated data. Moreover, they are designed to be biased towards the variables that will allow them to achieve their goal (Dixon et al., 2018). To exemplify that, let us speculate about the Apple Card example mentioned above. The model trained to define credit limit is instructed to be biased towards the probability of people paying their credit card bills on time. As such, it parses through a large database of past credit card transactions. The problem arises, therefore, once the model that is not explicitly instructed to discriminate between the gender or socio-economic background of its users, starts doing so. This is called unintended bias. Unintended values are produced when this unintended bias starts to affect the use of the system and in particular when different individuals are treated differently (Dixon et al., 2018). Therefore, while biases are inherent to the data and the design of the model, it is their manifestation, once they start to interact with their context, that produces unintended values. As such, we deliberately choose to focus on the values since latent biases are notoriously difficult to identify when dealing with non-binary data (Bellamy et al., 2018). Moreover, we do not wish to label all biases as bad since such cognitive heuristics play an important role in human cognition. Therefore, instead of directly trying to identify biases, we focus our efforts on identifying their observable results: the created values.

A prominent theory addressing the notion of purpose, the way a solution behaves and the way it is being used is that of *innovative abduction* elaborated upon by Roozenburg in 1993. According to him, the design process always starts with a purpose. For instance, when designing a kettle, the purpose would be to “be able to boil the poured-in water”. To fulfil its purpose, however, the kettle needs to behave in a certain way (e.g. the bottom needs to heat up, so it can transform the heat to the water inside). Roozenburg terms this **mode of action** and uses it to signify the (functional) behaviour of the artefact in response to influences exerted on it from its environment. It is our contention that this notion is well-adjusted to represent the way an AI-powered solution behaves, since, according to Roozenburg, the mode serves as the bridge between the artefact and its immediate environment. To account for the user’s action on the product (e.g. putting the kettle on the burner), Roozenburg introduces the notion of **actuation**. Such signifies the continuous action of a user that allows the artefact to function and be ‘connected’ to its immediate environment. Finally, the **form** of the artefact should also be considered. Therefore, the form of the kettle and the way it is used (actuated) causes it to behave in a certain way (mode of action), and therefore, by this behaviour, it can fulfil its purpose. The logical expression of the innovative abduction process is, therefore, as follows:

((form and actuation) → mode of action) → purpose

As such, Roozenburg’s theory accounts for **purpose**, the way a solution behaves (**mode of action**) and the way a solution is being used (**actuation**) and elaborates upon the relationship amongst them. However, he does not deliberate on how value is created. To search for guidance in this direction, we consider the theory on abductive reasoning Dorst (2011) introduced. Partially iterating on Roozenburg’s work and reflecting the changes in the field,

according to Dorst (2011), value is the result of the following inference:

WHAT + HOW → VALUE

The WHAT in the formula represents an object, a service, a system – a wider domain of application than Roozenburg’s Form. The HOW signifies the working principle of the solution. The sum of both leads to (an aspired) VALUE that is known at the start of the design process and therefore, intended. To ensure that this intended Value results from the combination of the What and the How, Dorst introduces the frame creation practice (Dorst, 2015). He defines it as a cognitive act of looking at a problem situation from a specific viewpoint that informs how the problem can be solved. Therefore, it delivers the intended value the designer strives for (Dorst, 2011).

These two theories allow us to identify the design practices that could address the elements of value, purpose, mode of action and actuation⁴. However, neither of them fulfils our second criterium: *“they should proactively anticipate potential future values”*. A design practice that could allow us to anticipate future values and monitor changes over time is prototyping. Prototypes are widely recognised as an important means to explore and communicate what it will be like to interact with future products, systems and services (Buxton, 2007; Lim, et al., 2008). They are oftentimes used to help designers learn, discover, generate, and refine designs (Buxton, 2007) by stimulating framing, and discovering possibilities in a design space (Lim et al., 2008). As such, they can play different roles– evoke a focused discussion in a team, test hypotheses, confront theories, allow users to experience their world differently (Sanders & Stappers, 2014) or generate deep level of understanding about novel contexts (Lim et a., 2008). Therefore, they can minimize design errors that may otherwise occur late in the process (Deininger et al., 2017). While many definitions of a “prototype” exist, depending on the design field (i.e. Sanders & Stappers, 2004; Lim et al., 2008; Pei et al., 2011), instead of defining what a prototype could look like, we adopt the notion that prototypes should provide help in discovering new aspects of the problem at hand and support the invention of design requirements (Schön & Wiggins, 1992; Suwa et al., 2000). As such they can take any form, shape, and appearance, based on the choice of material (Lim at al., 2008; Deininger et al., 2017) and the phase of the design process in which they are being used.

3. Initial Framework

To present and explain the initial framework, we will use a fictional example of a designer who wants to create solutions that reduce the burden people with chronic kidney problems

4 We referred only to these core papers of Roozenburg (1993) and Dorst (2011) because they are very explicit in their definition of abductive reasoning in the field of design while maintaining a broader orientation (they adopted theories from e.g., March (1976), Habermas (2015) and Schön (1983)). The most important conclusions we draw here have been checked with other (later) papers by Roozenburg, Dorst and other authors (i.e. Kroll and Koskela (2017)). Moreover, the formulation of our framework was also informed by the work of Dong (i.e. Dong and MacDonald (2016), Takeda (i.e. 1994; 2001) and the work on Function-Behavior-Structure ontology of Gero (i.e. 2007). Last but not least, we took a conscious decision to only include these two theories for the sake of readability and theoretical coherence.

feel⁵. Therefore, our purpose becomes *“to ensure people with chronic kidney conditions are in control of their health”*. That would mean that a process of transformation needs to happen from the current situation of kidney patients spending a considerable amount of time undergoing dialysis, lacking an overview on their daily progress and not knowing whether the problems they experience are life-threatening or simply mild ones, to the preferred one of being informed and in control of their health.

To be able to design a solution that fulfils the intended **purpose**, the first step will be to collect **data** (both qualitative and quantitative). This process could go as follows: we would carefully study our patient’s context through regular interviews and observations, and then map their day-to-day journey. These will provide contextual understanding of the problem and help us to discover, for instance, that physicians are oftentimes unsure about the precise dosage of medications since each one of them can directly influence the blood potassium levels of the patient. Higher levels than recommended can be fatal and require immediate treatment. Yet, the only way to identify blood potassium levels is for the patient to undergo an invasive test performed in a laboratory. This produces high levels of uncertainty and stress for the patient and all stakeholders involved.

We, then, build upon this insight with the medical research knowledge that potassium levels can be detected in an electrocardiogram (ECG) (Topol, 2019)). Subsequently, we should collect a database of ECGs. This combination of **purpose** and **data** allows us to define an interesting vantage point (a frame) from which we can achieve our purpose or:

purpose + data → frame

Going back to our example, a possible frame in our situation could be that *“if potassium levels are detected regularly, changes in the dosage of a medicine can be easily administered in the comfort of the user’s home (no need for blood tests)”*.

The next step is to explore different modes of action our solution can exhibit within the frame we created. We define the mode of action as the way an AI-powered solution attempts to influence its environment. Such mode is always associated with the identified frame. Therefore, for our example, a plausible **initial mode of action** is: *“deep neural network detects potassium levels in ECGs”*. The combination of the mode and the frame will help us to understand how a prototype can be manifested. We specifically refer to the result of this inference as a prototype instead of a “What” (Dorst, 2011) or a “Form” (Roozenburg, 1993) since, as discussed, prototypes allow us to anticipate future values. Moreover, since AI-

5 Although, this is a fictional example, to provide the necessary level of detail, we use the case of the company AliveCor. The start-up produces cell-phone cases and AppleWatch wristbands that can perform electrocardiograms (ECGs) (Topol, 2019). Based on them, potassium levels in “near real time” can be detected without drawing blood (Dillon & Friedman, 2018). This case was deliberately chosen as it addresses the complex context of healthcare in which multiple stakeholders (e.g., patient, nephrologist, GP, hospitals, hospital staff, medical device systems manufacturers, insurance companies) come into play. They all expect the solution to deliver values tailored to them, while the AI-powered solution continuously learns from its users and consequently could exhibit novel behaviours. Due to the complexity of the context, potential values are difficult to anticipate. As such, this case provides a wide range of challenges and exemplifies the type of contexts and domains for which our framework is developed.

powered solutions continuously learn and adapt to their contexts, we contend that viewing each of their states as a prototype will promote the notion of designing for something transient (i.e. a solution that can always change the values it delivers). In effect, this will enable the designer to learn continuously as the solutions evolves. This leads us to:

frame + mode of action → prototype

A prototype resulting from this inference might be manifested as a simple piece of hardware (e.g. a strip) equipped with electrodes that can measure pulse. It is important to note that at this initial stage, the prototype we make use of is generative⁶ as we still do not have a clear hypothesis neither on how the strip will be used, nor on the values it will produce. Therefore, we need a prototype that will aid us to generate such hypotheses. Since the goal of this prototype is to better understand the context, a good starting point would be to provide the users with the strip and without much guidance to observe the way they use it over the course of a month. Doing so will generate multiple insights on the context, time of day, actuation and expectations users have while wearing the prototype. As well as on the way it affects and impacts their daily routine and that of the already identified stakeholders. Therefore, it is through this first prototype that we understand the ways it can be actuated and ultimately observe the different values it can create. When put in a formulaic expression, this appears as:

prototype + actuation → values

The value here is not necessarily the same as the purpose and can be different for each user and stakeholder. In our case, it could be that we observe that the strip creates new dynamics in our patient's life by introducing a lot of uncertainty and tension between the patient and her partner as they begin to obsess over even insignificant changes registered by the strip. While this value stems from the fact that the patient is more in control of her life, it creates unintended and undesired values – i.e. tension between her and her partner.

This insight will trigger another loop through our framework. Therefore, we start collecting new data (both qualitative and quantitative) on how the patient's daily routine changed, interviews with the patient and her spouse, as well as with the involved stakeholders. But also, reviewing the ECG and potassium levels and map them to events of what was observed and communicated in the previous loop. This new iteration of data collection will help in refining our frame and add another dimension to the mode of action by adding behaviours that could address the identified tension. These are reflected in a new, more detailed, prototype. Consequently, gradually new intended and unintended values are uncovered in later iterations. As such, also the prototypes we design could be more detailed or help

6 Apart from using prototypes as a means to evaluate design's failure or success (Lim et al., 2008), they can also be used as a tool for learning, discovering, generating, and refining designs (Buxton, 2007) by stimulating framing, and discovering possibilities in a design space (Lim et al., 2008). Moreover, using externalisations in a generative manner is not new to the scientific practice. According to Magnani (2007), for instance, they can be used to capture the part of scientific thinking in which the role of action is central, and the features of this action are implicit and difficult to elicit. He terms this manipulative abduction.

us to understand a different part of the solution such as the way to deliver information to nephrologist, GPs and patients. Therefore, the effect these delivered values have not only on the patient, but also on the community and the other stakeholders (i.e. the GP, nurses, family) can be studied. Doing so will ensure that more details about the interaction between the unintended values and the context they operate in could be generated. Moreover, the collected insights might necessitate the creation of a different, more accurate frame and/or mode of action. In some cases, the purpose also could be refined or even reconsidered. Thus, we contend that designing (with) AI-powered solutions could go through a continuous loop of this framework:

purpose + data → frame

frame + mode of action → prototype

prototype + actuation → values

The deliberate choice whether and how the solution should be changed to address the identified values resides with the designer or the multidisciplinary team that designs the solution. While at different times, different variables might come into focus, this framework will allow the team to understand the context and proactively anticipate the possible implications of their design. In fact, it is our contention that this framework will allow the teams designing such solutions to identify and address potential unintended values early in the solution's lifecycle. Furthermore, once the solution is deployed, the variables dedicated to each aspect of an AI-powered solution will make the monitoring and eventual explanation and troubleshooting easier.

4. Future Research Directions

The framework we present is explorative and purely theoretical in nature. It is our contention, therefore, that empirical research on its implementation will help us better understand its nature and the manner in which it could identify and address the unintended values AI-powered solutions create. As such, we have identified and outlined below three possible directions for future research.

4.1 Identifying values

Being able to continuously identify and address values that the ever-adapting AI-powered solutions provide to their users is of paramount importance. It is our contention, therefore that an important distinction has to be made between two variables: V_i denoting the intended values and V_u which represents the unintended ones. For instance, the solution delivers a value that ensures that the person with kidney problems is in control of her life by giving her an overview of her daily activities and providing tips how she can improve. As such, it stays within the boundaries of the initial purpose and can be denoted as V_i . If the solution, however, suddenly starts to deliver values outside of the intended ones like the one we described earlier, the delivered value falls within V_u . These unintended values, however,

could be both positive and negative. Nevertheless, to be able to identify such values, we first need to carefully study their nature, the way they emerge and evolve, the manner in which they could be calculated, and the role designers should play in deliberately steering the solution towards certain values. While these should always align with human interest, a way to consider the different stakeholders should be designed and further studied as well.

4.2 Prototyping

Our framework also directly deals with the uncertain implications AI-powered solutions have on society by continuously re-examining the problem and solution space (Dorst & Cross, 2001) through the practice of prototyping. This makes the proposed approach different from the notion of HCML which is based on purely inductive and deductive ways to test hypotheses (i.e. Google's PAIR handbook, 2019). In our framework we propose to use prototyping not only as an evaluative (analysis) means, but also as a generative (synthesis) one. As already explained, using prototypes in a generative manner can create communicable accounts of new experiences that can be integrated into previously existing systems of experimental and linguistic (theoretical) practices.

The importance of using generative prototypes is best exemplified by the case of Microsoft's bot Tay who "emulates the casual, jokey speech patterns of a stereotypical millennial". The aim of the bot was to learn from her conversations with people on Twitter and get smarter over time. Even though the team worked with comedians and extensively tested the bot with users before being deployed, (Lee, 2016), it quickly started generating racist tweets, defending white supremacy, denying the Holocaust and praising Nazis (Price, 2016). Testing the bot inductively and deductively before its release did not allow its creators to envision all possible ways in which the bot could be "attacked" (Lee, 2016).

Our deliberate effort to explore the context through a loop of generative and evaluative prototypes allows—in theory—for better understanding of the possible unintended values. Therefore, further empirical research is necessitated to corroborate this statement and it is our contention that those should try to address the following challenges: 1) prototyping with AI is challenging since the performance of a deployed AI system can constantly fluctuate and diverge when it gains new data to improve its learning. Consequently, it seems that established prototyping methods cannot address this new context (Yang et al., 2020); and 2) prototypes are usually intended for and tested with individuals. Yet, the majority of recorded unintended values of AI-powered solutions happen when the individual interacts with her context and community.

4.3 New methodologies

Building on our previous point, it is our contention that a fruitful third area for further research could be the investigation of new research methodologies that allow us to combine the language-based research methods for studying design activities such as protocol analysis (see e.g. Cross, 2001; Hay et al., 2017) and/or natural language processing methods (see

e.g. Dong, 2005) with such that allow design researchers to incorporate non-verbal design activities such as prototyping. Doing so would not only generate insights about the possible approaches to design (with) AI, but also about the different processes under the umbrella of design (Kleinsmann & Ten Bhömer, forthcoming). A steppingstone in this research direction could come from the work of Cramer-Petersen and colleagues (2019) who analysed the reasoning patterns in design at a micro-level. According to them, doing so holds the potential to advance the understanding of design activity and can be applied to develop support tools and methods given future research (Cramer-Petersen et al., 2019).

5. Conclusion

The aim of this paper was to identify design practices that could address the incongruence between the purpose of an AI-powered solution and the (unintended) values it delivers to its multifaceted users. To address this tension, we identified three criteria that design practices and methods should fulfil if they are to be used in the context of AI: (1) address the tension between purpose and (unintended) values, (2) proactively anticipate potential future values, and (3) make a distinction between the way a system behaves and the way it is being used. Using these as a guideline, we identified the elements of purpose, mode of action and actuation (Roozenburg, 1993), value and frames (Dorst, 2011) and prototyping (both to generate hypotheses and to evaluate them). We then elaborated upon the connection between purpose and intended and unintended values through a series of logical inferences (a framework). Last but not least, we introduced three directions for future research.

The tension between intended purpose and delivered values is not new to the design discipline. Nevertheless, it is our contention that it gains fundamental importance in the context of AI-powered solutions and should be deliberately addressed. When the discipline was primarily concerned with the design of a product, a clear line could be drawn to where the responsibility of a designer ends. If a designer creates a kettle, for example, and someone is murdered with it, the blame can clearly be assigned to the user who uses the product in an unintended way. However, in the case of Apple Card, despite using the service as intended by the designer, the user gets punished (i.e. a woman receives much lower credit limit). The responsibility and the blame cannot be easily assigned and, in most cases, the reason for the undesirable outcome cannot be readily understood either (Amodei et al., 2016; Rahwan et al., 2019). The important question is then: *“How are we, as designers, going to deal with this conundrum – do we hide behind the notion of technology we don’t understand, or do we take full responsibility for all the unintended values we create?”*.

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Design prototyping for policymaking

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Abstract: Design has an increasing role in the development of public services and policies. The implementation of policies is now considered a matter of design, especially in the field of public services. Moreover, design has been slowly entering the process of policymaking. Meanwhile, policy scientists' promoters of Policy Design have started to analyse design discipline's approaches on the design of policies. Among design activities, prototyping has been recognised as a valuable instrument for policy, also aligned with the new experimental approach in the public sector. However, it is still unclear how prototyping could intersect formal administrative and bureaucratic structures, including their traditional processes for policy analysis and experimentation. This research identifies frameworks for prototyping drawing on relevant authors in design-related disciplines in Europe. Then it characterises these diverse perspectives and suggests the benefits of design prototyping for policy analysis, to communicate, explore, evaluate and refine policy options before decision making.

Keywords: design prototyping; policymaking; policy design; policy implementation

1. Introduction

Over the last ten years, *design* has been contributing to public sector innovation, increasingly positioning its role in the implementation of public services and policy (Bason, 2014; Design Commission, 2013; Junginger, 2014; Kimbell & Bailey, 2017; Mager, 2016). In this regard, typically contributing to implement policies by creating and developing products and services (Junginger, 2013). More often, this collaboration involves service designers working both from outside the public sector (e.g., FutureGov, IDEO, LiveWork, The Australian Centre for Social Innovation -TACSI-) and from inside (e.g., Government Digital Service -GDS- and Policy Lab in UK) (Design Commission, 2013; Mager, 2016; McGann, Blomkamp, & Lewis, 2018).

Lately, design scholars and practitioners have started to reflect on this phenomenon mainly empirically by collecting and sharing their experiences in these collaborations (e.g.; Junginger (2013); Bason (2014); Software Acumen (2014); Kimbell (2015); Siodmok (2017); McGann, Blomkamp & Lewis (2018); Mortati, Christiansen & Maffei (2018); Kane & Jordan (2019)).



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Notably, the arguments concern the analysis of the strategies and methods used to guide civil servants in creating more citizen-centric policies and services (Junginger, 2017, p. 298; Mortati, 2019, p. 2).

Furthermore, these publications document the evolution of the role of design in the public realm, describing how the collaboration between designers and civil servants is transitioning from implementing public services and policies to informing and envisioning policies (Junginger, 2013). On this subject, the idea of thinking the process of policymaking as designing has been argued (Junginger, 2013, 2014) and design approaches in public policymaking have been exemplified (Bailey & Lloyd, 2017; Kimbell, 2015, 2017; Policy Lab, 2019).

Among the design approaches, prototyping has been gaining attention in policy (Kimbell & Bailey, 2017) and its potential benefits for the public sector have also been described for a wider non-academic audience (e.g., Appadoo, 2019; Bloomberg Cities, 2019; Buchanan, 2018; Holliday, 2019; Leurs & Duggan, 2018). For instance, Bloomberg Cities presents examples of design prototyping for policymaking in policy areas such as child arrest and citizens participation in city's development. These examples use prototypes as role play and storyboarding (respectively) to test a policy idea or pieces of it (Bloomberg Cities, 2019).

Prototyping is an iterative cycle with a significant role in the design process. In this cycle, designers build representations such as *prototypes* which are used to understand, learn and refine design ideas (Blomkvist, 2014; Floyd, 1984; Gero, 1990; Stickdorn, Hormess, Lawrence, & Schneider, 2018b). Generally in design, prototyping supports communication, both within the team and with external actors (Blomkvist, 2014, pp. 24–25; Floyd, 1984, p. 3), and it saves money and time by identifying problems and permitting to fail earlier in the process (Blomkvist, 2014, pp. 24–25; Ulrich & Eppinger, 1995, pp. 298–300).

Likewise, in the public sector *design prototyping* has been recognized as a valuable instrument (Clarke & Craft, 2019; Howlett & Mukherjee, 2018; Mager, 2016). It can help to mitigate the fear of failure to innovate, for example by testing new policy options and service models before a large-scale roll out (Clarke & Craft, 2019, p. 12). Furthermore, by focusing on users, prototyping can offer a method to adapt the policy to its diverse targets (Clarke & Craft, 2019, p. 12-13; Bloomberg Cities, 2019; Kimbell, 2017, p.216).

Correspondingly, in the context of policymaking and policy implementation, public servants are also addressing uncertainty with other methods for policy analysis and initial roll out. Terms like *policy experimentation*, *evidence-based policymaking* and *policy piloting* populate literature, while *prototyping in policy* is only beginning to gain attention (see Figure 1). Building on this, the current research developed within a doctoral study, investigates how the practice of prototyping, typical in design, could complement traditional policymaking processes and methods: what are the valuable elements of design prototyping for policymaking? What is a prototype for policymaking? How can prototyping contribute to building a practice of *policymaking as designing*? This paper focuses on the exploration of the first of these questions.

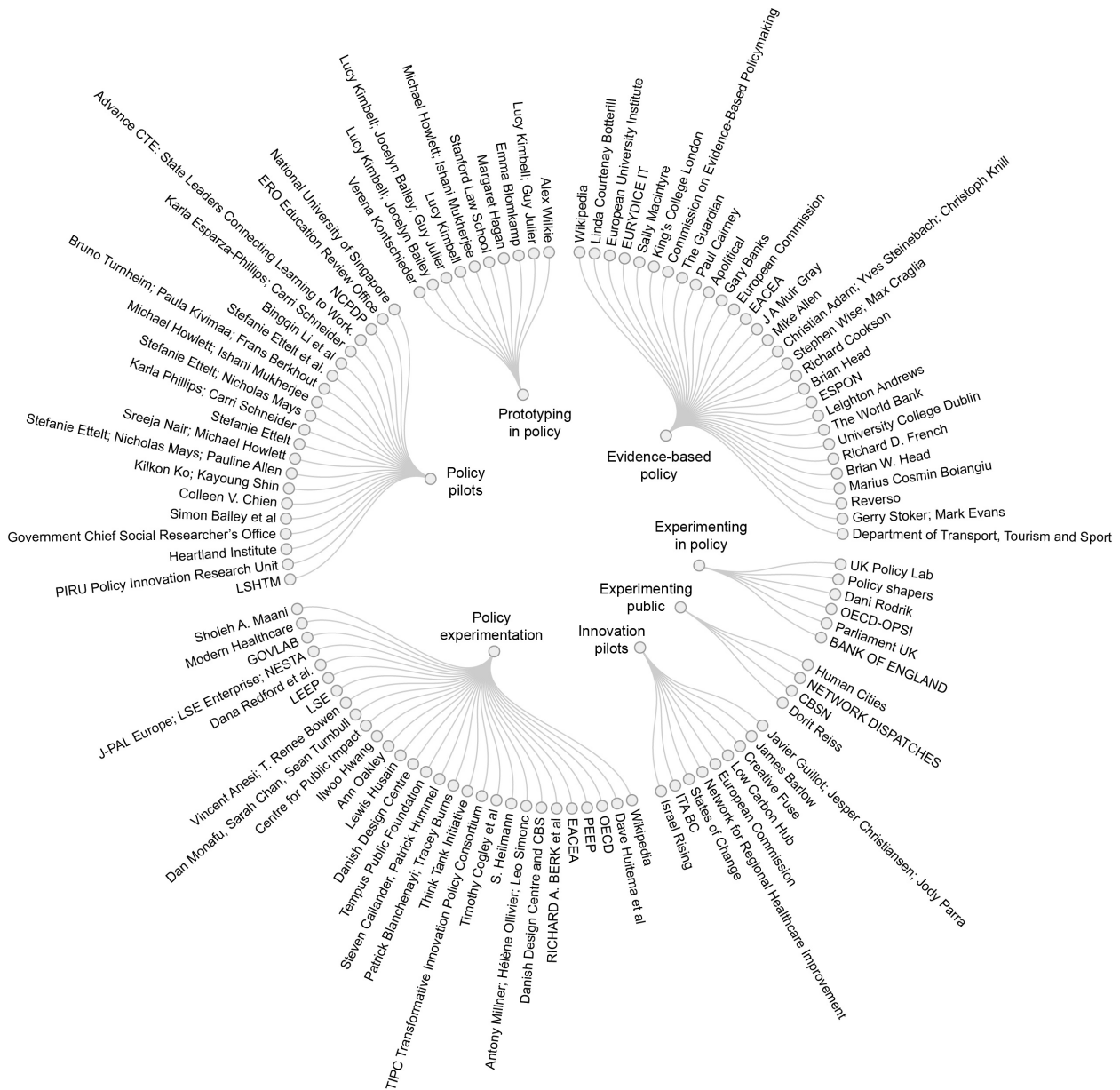


Figure 1 Issue Mapping of design prototyping in the experimentation landscape in policy. Visualization elaborated by the authors. Terms: policy experimentation, policy pilots, prototyping in policy, evidence-based policy, experimenting in policy, experimenting public and innovation pilots.

Performing a literature review, this research identifies, compares and analyses a series of frameworks of prototyping in design to propose a theoretical intersection between design prototyping and the policy cycle. The study adapts primarily *the service prototyping framework* (Blomkvist & Holmlid, 2011), complementing it with the *framework for prototyping in policy-making* (Kimbell & Bailey, 2017) and focusing on the purposes for prototyping.

The resulting framework is then presented to propose how prototyping could be used along the policy cycle according to the different purposes of each stage. The paper thus

argues that, just like in the design process, prototyping could facilitate the understanding of users. Moreover, policy prototypes could be used to learn about future policy options, helping to refine them for policy implementation. Finally, prototyping in the policy cycle could also complement current policy experimentation approaches such as evidence-based policymaking and policy piloting in understanding *how* a policy *could work* in the future.

2. Context

2.1 Design in policymaking

Design researchers adopt *the policy cycle* to reflect on the role of design approaches in the policy process (e.g., Junginger, 2013, 2014; Kontschieder, Vaz, & Sonalkar, 2018). The *policy cycle* model (see Figure 2) generally includes five stages composed by *agenda-setting*, *policy formulation*, *decision-making*, *policy implementation* and *policy evaluation* (Araral, Fritzen, Howlett, Ramesh, & Wu, 2012, p. 17). During the first three stages, a variety of solutions to a problem are proposed, developed and filtered to be finally adopted as a policy in the stage of decision-making. Consequently, during the implementation, different bureaucrats interpret the public policies to develop programs and projects, and influence the outcomes of these policies, which are evaluated at the end of the cycle (Araral et al., 2012, p. 17).

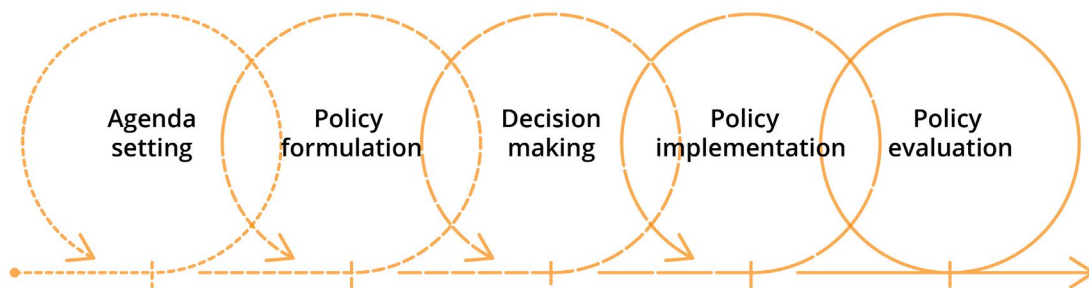
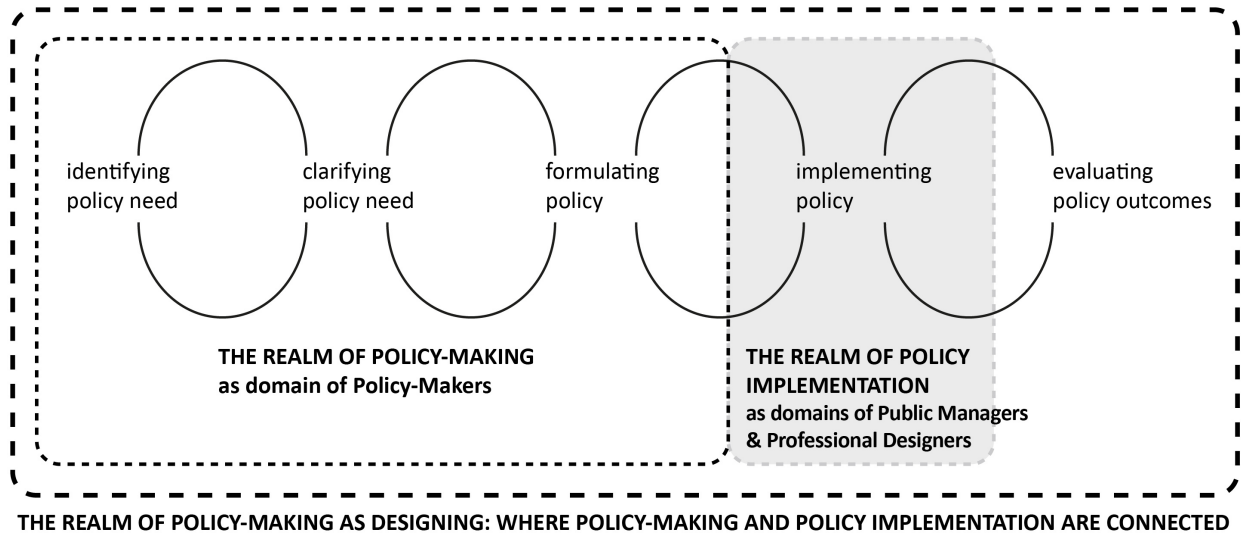


Figure 2 The policy cycle. Visualization elaborated by the authors from the description of Howlett and Giest about the policymaking process in Araral et al. (2012).

However, scholars have also critiqued this way of understanding the process for developing a policy. For instance, Junginger (2013, 2014) argues that the policy cycle is a fragmented policy process as it divides *the realm of policymaking* from *the realm of policy implementation* (see Figure 3), while considering “policymaking as designing” would integrate these realms in a single process (Junginger, 2013, 2014).

Furthermore, Junginger sustains that designers have been active in “implementing existing policies” by designing and developing products and services. However, their role is transitioning to “informing new and existing policies” with the insights gained during the implementation. In this emerging role, design can also help to “envision future policies”, enhancing the process with the “design inquiry” and *human-centred approaches* (Junginger, 2013, 2014).



THE REALM OF POLICY-MAKING AS DESIGNING: WHERE POLICY-MAKING AND POLICY IMPLEMENTATION ARE CONNECTED

Figure 3 The policy design cycle adapted from Howlett and Ramesh (2003) in Junginger (2014, p.58) presents the policy cycle divided by the realms of policymaking and policy implementation. In contrast, thinking on “policymaking as designing” integrates these realms.

2.2 Policy Design and Design discipline

Designers in policymaking practice are starting to name their activities in this emerging role as policy design. However, it is important to acknowledge that the term *policy design* has been used in the past by policy scientist without a direct relation to the design discipline itself. The term *policy design* emerged in policy studies in the 1950s (Dahl & Lindblom, 1953; Kirschen et al., 1964; Tinbergen, 1952. As cited in Howlett & Mukherjee(2014)), and it “involves the deliberate and conscious attempt to define policy goals and connect them to instruments or tools expected to realise those objectives” (Howlett, Mukherjee, & Woo, 2015, p. 291).

This approach, proposes to think about policies “in design terms” (i.e., as a process) (Howlett & Mukherjee, 2018, p. 3; Peters, 2018, p. 3). Only recently, these scientists have started to mention the design discipline in their discourse, making a clear distinction between these two diverse design approaches to policy, and analysing concepts familiar to the design discipline such as *user experience* and *prototyping* (e.g., Clarke & Craft, 2019; Howlett & Mukherjee, 2018).

2.3 Prototyping in policy

Notably, policy scientists find value in design prototyping. In their perspective, prototyping can allow civil servants to improve new policy interventions earlier in the process: experimenting before investing in a large scale implementation can mitigate the “fear of failure” to innovate (Clarke & Craft, 2019, p. 12). Furthermore, the iterative cycles of prototyping with users favour the adaptation of policy designs to diverse target populations

(Clarke & Craft, 2019, p. 12; Howlett & Mukherjee, 2018, p. 288).

Likewise, from the design discipline, Kimbell and Bailey (2017) investigate the implications of prototyping in policy and propose a framework describing this approach. Concluding their investigation, they raise the question of “how small-scale prototyping can relate to concurrent forms of democratic participation producing ‘mass’ policies that can [be] delivered at scale” (Kimbell & Bailey, 2017, p. 222). This question becomes the starting point for the current research and is developed through the analysis of design prototyping.

2.4 Prototypes in design

Designers externalise ideas and concepts by creating visual representations (see some examples in Figure 4). Generally, design representations appear in two moments of the design process. In early stages, to communicate (Ulrich & Eppinger, 1995, p. 173), “experience, test, transform, develop and complete” initial ideas (Sanders & Stappers, 2014, p. 6); and later, as an approximation to the final artefact (Ulrich & Eppinger, 1995, p. 291), which are used to test whether or not the concept should be developed further (Sanders & Stappers, 2014, p. 6). In both moments, there is an iterative process seeking to refine and evolve ideas and concepts into products (or services, spaces, etc.) (Sanders & Stappers, 2014; Ulrich & Eppinger, 1995).

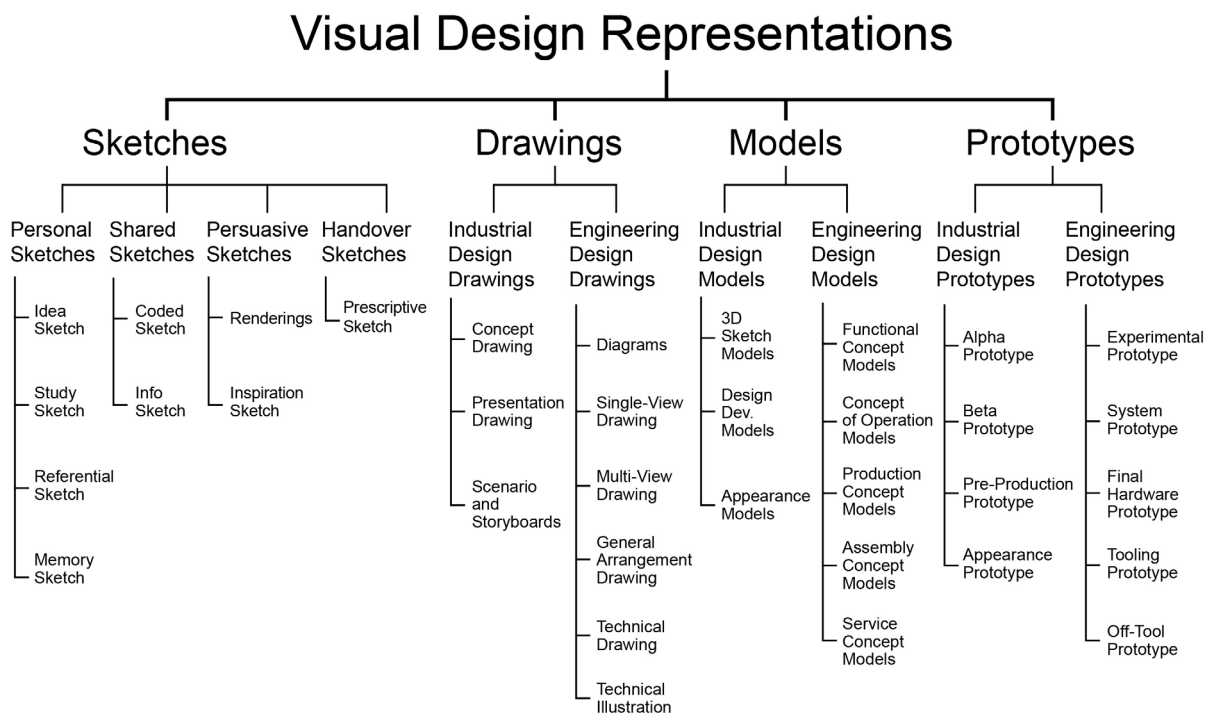


Figure 4 Taxonomy of Visual Design Representations (Pei, Campbell, & Evans, 2011, p. 7) used by industrial designers and engineering designers mainly in creating physical artefacts. However, each design branch has its own variety and terminology.

Among the design representations, the notion of prototype is probably one of the most popular. A *prototype* is “any shared physical manifestation externalising an otherwise internal

or unavailable vision of a future situation” (Blomkvist, 2014, p. 23). Whether physical or digital (analytical), prototypes represent future versions of *design artefacts* (e.g., physical or digital artefacts, spaces, services, etc.) such as:

- “prototypes of physical objects” (industrial product design);
- “prototypes of environments, spaces, and architecture” (interior design and architecture);
- “prototypes of digital artefacts and software” (UX design, interaction design, software or web development);
- “prototypes of (inter)actions, service processes, and experiences” (service design, interaction design);
- “prototypes of ecosystems and (business) value”.
- (Stickdorn et al., 2018b, pp. 67–74).

An additional type could be added to this typology:

- “*holistic prototypes*” which are composed by more than one type of prototype (e.g., prototypes of space and service)
- (Blomkvist & Holmlid, 2010, p. 6).

Many other dimensions to classify prototypes are portrayed in the literature (e.g. *role, look and feel, and implementation* (Houde & Hill, 1997), *filtering and manifestation dimensions* (Lim, Stolterman, & Tenenbergs, 2008), *fidelity and representation* (Blomkvist & Holmlid, 2011);. All these dimensions serve to define the characteristics of prototypes according to the purposes of prototyping.

3. Method

In order to explore the encounter between the understanding of prototyping in design and in policymaking, this paper identifies, compares and analyses a series of frameworks to characterise prototyping in the literature. This analysis is later adopted to propose a hypothesis of how prototyping could intersect current practices and theories of policymaking and policy implementation.

This review started from previous research on “prototyping” found in databases such as *Web of Science*, *Scopus* and *Google Scholar*, as well as articles recommended by researchers on the topic. A general overview lead to identify a reduced set of authors proposing prototyping frameworks (See Table 1). These authors mainly characterise prototyping in design-related fields.

However, the work of Floyd (1984) in the area of software development is the exception to the rule. Her introductory paper for the *Working Conference on Prototyping* in the 80’s has also become a reference in design. Indeed, Floyd’s paper is cited by Blomkvist & Holmlid (2011) and Kimbell & Bailey (2017) whose work was also selected for the framework analysis.

Table 1 Overview of the authors selected to characterise the framework of prototyping for policy. *Number of citations taken from Google Scholar (Updated in March 27, 2020). Source selected because of its coverage on academic publications but also books, thesis and technical reports (Yang & Meho, 2007).

Source	Area	Prototyping Framework	Prototyping Purpose	Secondary Research	Primary Research	Number of Citations*
Floyd (1984)	Software Development		x	x	x	708
Buchenau & Suri (2000)	Experience Design		x		x	1427
Blomkvist & Holmlid (2011)	Service Design	x		x		50
Camburn, Viswanathan, Linsey et al. (2017)	Mechanical Engineering, Engineering Design	x	x	x		52
Kimbell & Bailey (2017)	Design for Policy	x		x	x	37
Stickdorn, Hormess, Lawrence et al (2018)	Service Design		x		x	148

The analysis of these studies resulted in the combination of the frameworks of Blomkvist & Holmlid (2011) and Kimbell & Bailey (2017) as well as the diverse perspectives in a more detailed framework proposal. Furthermore, this new proposal focuses on the *purpose* of prototyping as the most important guidance for the additional layers of the prototyping framework.

An initial assumption in this research is that the frameworks of prototyping selected are complementary to each other and facilitate the study of holistic prototypes. This type of prototypes is relevant because it comprises diverse prototypes and it could resemble the prototype of a policy. An additional assumption is the general notion of prototyping, which in this research involves other techniques for creating representations such as sketching, drawing, modelling and theatrical methods, among others.

4. Design prototyping framework

The term *prototyping* refers to the creation or building of a prototype (e.g., rapid prototyping techniques (Thomke, 1998, p. 747)); or to the use of prototypes for generating knowledge (Blomkvist, 2014, p. 23). Nevertheless, in this research, *prototyping* implies a specific cycle within the design process where a prototype is made, used for testing and learning (Floyd, 1984, p. 2; Stickdorn et al., 2018, p. Chapter 7). Thus, using prototypes to explore or demonstrate specific characteristics of a future artefact, rather than the technique and tools used to create the prototypes (Houde & Hill, 1997, p. 2).

The *prototyping cycle* is generally described in three steps: build, run and analyse. Some authors also suggest a preliminary step to prepare the experiment (Thomke, 1998, p. 744), choose the functions of the prototype (Floyd, 1984, p. 4) and formulate prototyping questions (Stickdorn et al., 2018b, p. 214; Ulrich & Eppinger, 1995, p. 303). This cycle provides a method based on trial and error, to learn in each of the iterations until the prototype evolves into the final artefact. This is based on the assumption that it is “unlikely to come up with a complete, effective design in a single iteration” (Wheelwright & Clark, 1992, p. 223).

In order to characterise prototyping, Blomkvist & Holmlid (2011) developed a five-level framework from literature review (See Figure 5). This was considered the most clear and comprehensive model reviewed. According to it, the decisions about prototyping are taken orderly, and they start by defining the stage in the design process in which prototyping will happen.

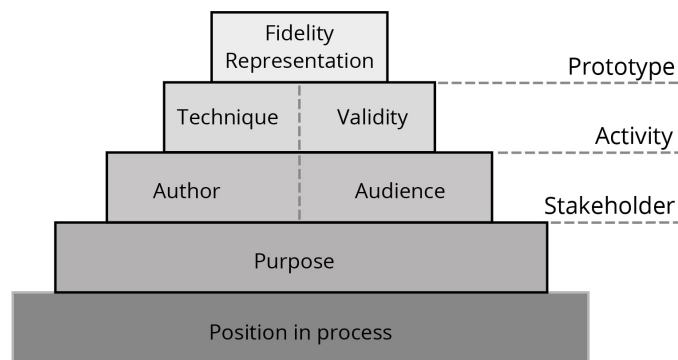


Figure 5 Service Prototyping Framework. Perspectives on prototyping and prototypes (Blomkvist & Holmlid, 2011, p. 7).

Alternatively, this paper proposes a *design prototyping framework* composed by four layers: *purpose*, *participants*, *activity* and *prototype* (see Figure 6). This framework adopts as referents the frameworks of Blomkvist & Holmlid (2011) from the service design field, and Kimbell & Bailey (2017) from the design for policy area, to define the steps (see Table 2), and then details the purposes of prototyping by combining the proposals of Floyd (1984), Buchenau & Suri (2000), Stickdorn et al (2018) and Camburn, Viswanathan, Linsey et al. (2017) (see Table 3).

Table 2 Comparison of prototyping frameworks ordered according to the proposal of Blomkvist & Holmlid (2011).

Framework/ Aspects	“Service Prototyping Framework” Blomkvist & Holmlid (2011)	“Framework for describing and assessing prototyping in policy-making” Kimbell & Bailey (2017)
Position in the process	<i>Position in the process</i> : “an event that happens at a particular time in the process, following a research phase and possibly a phase of idea generation, and preceding the implementation phase” (p.4).	<i>Uses</i> : potentially contribute to all phases of the policy cycle to explore, validate, understand and communicate.
Reason for prototyping	<i>Purpose</i> : exploring, evaluating, and communicating.	<i>Logics</i> (experimental logic): exploratory (“inventive moment of synthesis”) or experimental (to create evidence or validate requirements) (p.219).
People involved	<i>Stakeholder</i> : <i>author</i> (the creator of the prototype) and <i>audience</i> (clients, users/ customers, and colleagues).	<i>Participants</i> : policy ecosystem (users, citizens and beneficiaries, experts and policy implementers).
Method/ Technique	<i>Activity</i> : <i>technique</i> (tool or method e.g., sketches, mock-ups, paper prototypes, video prototypes, wizard of Oz and scenarios) and <i>validity</i> (similarity to the test and implementation contexts).	<i>Pace</i> : <i>fast</i> (validate quickly the user experience) or <i>slow</i> (explore adaptation).
Prototype / Object	<i>Prototype</i> : <i>fidelity</i> (level of refinement or degree of detail displayed by a prototype) and <i>representation</i> (appearance and materialisation).	<i>Objects</i> : “policy is a complex assemblage” of objects and interfaces in systems and processes (p.221).

Unlike the work of Blomkvist and Holmlid, the first perspective in the proposed framework is not the position in the process but the purpose. This choice is due to different reasons. First, because purpose is considered the most important step for defining the strategy of prototyping and it also affects the decisions taken in the next steps. Second, because Floyd and Stickdorn et al. relate the purpose to a particular position in the process (Floyd, 1984, pp. 6–11; Stickdorn et al., 2018b, pp. 212–214); and third, because prototyping is nowadays an activity performed along the design process (Blomkvist & Holmlid, 2011, p. 4; Sanders & Stappers, 2014, p. 6). Thus, starting from the first level of purpose, the steps of the design prototyping framework are described as follows.

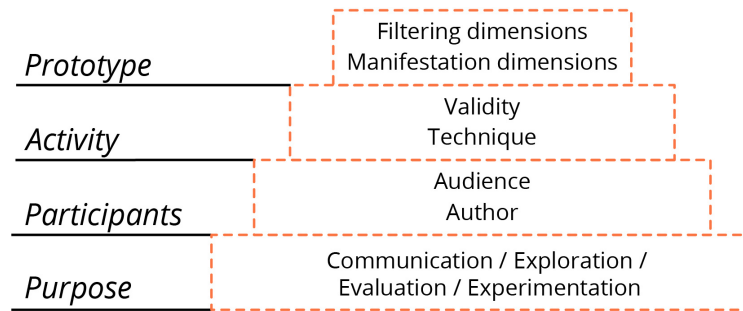


Figure 6 Design prototyping framework for policymaking. Visualization elaborated by the authors adapting the framework of Blomkvist and Holmlid (2011).

4.1 Purpose

The purpose is a prioritized perspective because it also determines how the prototypes will be built (Blomkvist & Holmlid, 2011, p. 4). The preparation to prototyping, as well as the formulation of prototyping questions can ensure a common understanding of the goal (Stickdorn et al., 2018b, p. 214; Ulrich & Eppinger, 1995, p. 303).

According to the literature review, prototyping has four main purposes: communication, exploration, evaluation and experimentation, followed by learning, evolution, understanding, demonstration, integration, piloting and milestones (see table 3). A single prototyping session is frequently developed with multiple purposes (Stickdorn et al., 2018b, p. 212). Therefore, the boundaries among them can be sometimes fuzzy (Floyd, 1984, p. 6). The four main purposes are described hereunder.

Table 3 Prototyping purposes found in the literature review. Excerpt from the authors’ purpose matrix providing a focus on the work that characterises prototyping more extensively. In grey, the main selected sources used in this study.

Author/ Purpose	Floyd (1984)	Budde et al. (1990)	Ulrich & Eppinger(1995)	Baumer et al. (1996)	Buchenau & Suri (2000)	Stowe (2008)	Blomkvist & Holmlid (2011)	Passera, et al. (2012)	Blomkvist (2014)	Camburn et al. (2017)	Stickdorn et al. (2018)
Understanding					X						
Learning			X			X				X	
Communication	X	X	X		X	X	X	X	X	X	X
Demonstration						X					
Exploration	X	X		X	X		X	X	X	X	X
Evaluation		X			X		X	X	X		X
Experimentation	X	X		X							

Piloting		X								
Evolution	X	X		X						X
Integration			X			X				
Milestone			X							

- Prototyping for communication [presentation and persuasion]:
Prototyping supports internal and external communication, and serves for “sharing information about the design” (Camburn et al., 2017). Moreover, *communicative prototyping* seeks to present features of the proposed solution to a key audience in order to clarify aspects and perspectives, support decision making and facilitate collaboration on a common understanding (Stickdorn et al., 2018b, p. 213). Furthermore, it is also oriented to persuade the audience (Blomkvist & Holmlid, 2011, p. 4; Buchenau & Suri, 2000, p. 429; Stickdorn et al., 2018b, p. 214), reason why the prototypes created resemble closely the final proposed solution.
- Prototyping for exploration
Exploratory prototyping (Floyd, 1984, pp. 6–7) or *explorative prototyping* (Stickdorn et al., 2018b, p. 213) (see Table 4) is used in early stages of the process to generate new options and compare alternatives. In this prototyping, an initial idea, concept or prototype “serves as a catalyst to elicit good ideas and to promote a creative cooperation between all parties involved” (Floyd, 1984, p. 6). Explorative prototyping could be used by the design team (only internally) or also by users, so the team can gain knowledge about the proposal from the potential users.

This type of prototyping allows to learn about opportunities and challenges of the solution (Stickdorn et al., 2018b, p. 213) and aids to establish the features, requirements and specifications the solution should offer (Floyd, 1984, p. 7). Regardless of its informal nature, the characteristics of the prototype should be strategically selected to generate explicit feedback from users (“likes or dislikes”) (Floyd, 1984, p. 7), “inspire and reveal new information” (Blomkvist & Holmlid, 2011, p. 4), guide the team on “the user experience and the tangible components which create it” (Buchenau & Suri, 2000, p. 428), as well as generate hypothesis about how the future solution “might create value, might work or might feel”(Stickdorn et al., 2018b, p. 213).

When prototyping for exploration, the prototype is built to be discarded. Accordingly, the construction of the prototype should require a minimum effort (Floyd, 1984, p. 7) and use techniques for creating prototypes quickly (Stickdorn et al., 2018b, p. 213).

Table 4 Summary of Exploratory and Explorative purposes described by Floyd (1984) and Stickdorn et al (2018), combined into one in the framework proposal.

General Purpose	“Exploratory Prototyping” Floyd (1984)	“Explorative Prototyping” Stickdorn et al (2018)
Specific objectives	- Clarify requirements and desirable features - Discuss alternative possibilities for solutions - Communicate with prospective users	- Create new options and new future solutions - Compare quickly different options
Evaluation	Informal: what the users like or dislike about a proposed feature. To reach a common understanding	Creates many insights, new questions, and hypotheses
Participants	Developers and users	Core project team
Type of prototype	- Normally thrown away - Built with minimum effort	- Built to be thrown away - Built quickly - Low fidelity
Stage in the process	Early stages	Early stages

- Prototyping for evaluation:
Evaluative prototyping is used to understand the user experience with the proposed solution, to filter down the number of options and take decisions on what to focus on (Stickdorn et al., 2018b, p. 213). In this prototyping, hypothesis and alternatives are tested with potential users or external selected participants by means of “qualitative research and analysis methods that can provide some hard facts and metrics (e.g., contextual & in-depth interviews, observation)” using a prototype that resembles the final solution as much as possible (Stickdorn et al., 2018b, p. 213).
- Prototyping for experimentation:
In *experimental prototyping* a proposed solution is evaluated in terms of “transparency [of the interface]”, acceptability or feasibility (Floyd, 1984, pp. 8–10). Here, the representation of the solution could be a partial prototype or a simulation that could serve as a specification, a refinement of specifications, or a transition between specification and implementation (Floyd, 1984, pp. 8–10).

4.2 Participants

The participants in a prototyping session can range from the authors of the prototype (the design team), to an external audience (colleagues, intended users, clients and supporting organisations) (Blomkvist & Holmlid, 2011, p. 5; Houde & Hill, 1997, p. 2). In these sessions, participatory (“i.e., user as a partner”) and human-centred (“i.e., user as a subject”) approaches could take place in form of collective creativity (co-creation) and creative collaboration along the design process (co-design) (Sanders & Stappers, 2008, pp. 5–6).

4.3 Activity

The activity includes the *technique* (tool or method) for prototyping and the *validity* of the prototyping context (similarity to real people and context of implementation) (Blomkvist & Holmlid, 2011). Some techniques are: *modular design* (dividing the solution representing it in different prototypes); *simulation* of a real activity (Floyd, 1984, pp. 12–13) and *pace - fast* or *low speed* - (to validate the user experience or to explore the adaptability of the idea to a particular context) (Kimbell & Bailey, 2017, p. 221).

4.4 Prototype

“The best prototype is one that, in the simplest and the most efficient way, makes the possibilities and limitations of a design idea visible and measurable” (Lim et al., 2008, p. 4). The idea *representation* (e.g., drawings, models, or prototypes presented above in Figure 4), the materials used and the *fidelity - low or high* - (resolution, refinement and precision of the prototype in comparison to the final (Blomkvist & Holmlid, 2011, p. 5)) could vary according to the purpose of prototyping.

Alternative to this classification, “The Anatomy of Prototypes” (Lim et al., 2008) suggests to consider “filtering dimensions” (appearance, data, functionality, interactivity, and spatial structure) and “manifestation dimensions” (materials, resolution, and scope) in order to take decisions about the prototype.

5. Towards design prototyping for policy

The policymaking process depicted in the policy cycle model commonly comprises five stages. First, in *agenda-setting* the policy actors examine a problem and then present possible solutions. Second, in *policy formulation* diverse actors evaluate and rank these solutions to narrow down the possibilities and develop specific policy options. Third, in *decision-making* the government moves forward with a course of action. Fourth, in *policy implementation* the action is developed combining public administration tools; and finally, in the fifth stage the results of the action are monitored for *policy evaluation* (Araral et al., 2012, p. 17).

According to Kimbell and Bailey (2017), “prototyping has the potential to contribute at multiple points in the policy cycle” (Kimbell & Bailey, 2017, p. 221). Building on this statement, prototyping can contribute to envision future policies in the policy process. The Figure 7 illustrates how different purposes of prototyping could be considered in each of the stages of the policy cycle.

For instance, in agenda-setting, explorative prototyping could aid to rapidly represent possible solutions and policy options coming from different policy agendas. Then, these could be tested by using evaluative and experimental prototyping in policy formulation, in order to produce qualitative evidence for decision-making. This qualitative evidence would comprise the insights of diverse actors such as potential users, policymakers and policy

implementers. In this scenario, prototyping could coexist with other approaches such as evidence-based policymaking, contributing to the understanding of how a policy option could work in the future.

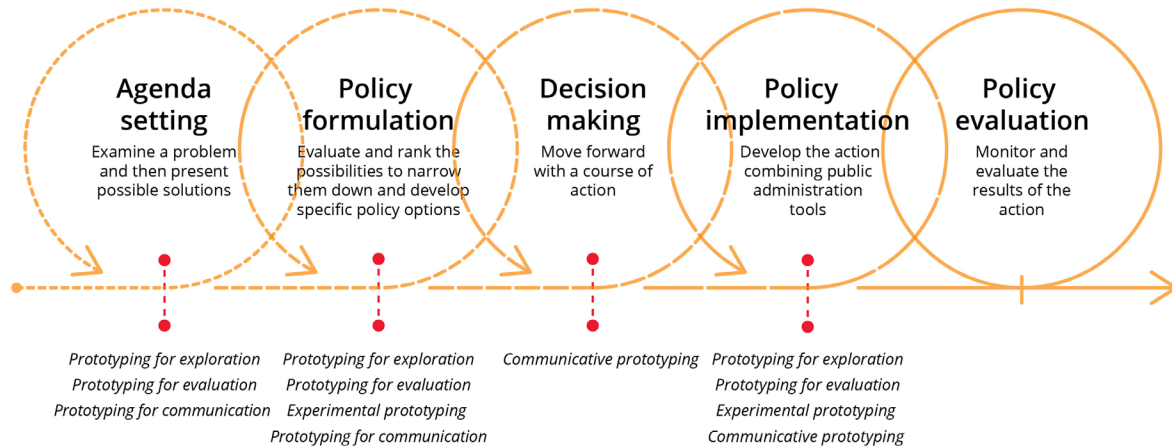


Figure 7 Prototyping in the policy cycle. Visualization elaborated by the authors to illustrate the hypothesis of prototyping for policymaking where different purposes of prototyping could be applied to some of the stages of the policy cycle.

In this regard, Kimbell (2015) exemplifies how prototyping was used by the UK Policy Lab on the policy area “people in work who have long-term health conditions”. In this case the team used exploratory prototyping by creating prototypes (scripts and visualisations), trying them with people and getting feedback from them. The prototypes consisted in a script of a potential interaction between the user (people with a health condition) seeking for support and the service; and a service blueprint visualising the resources supporting the user. These prototypes were useful to discuss with people “with first-hand knowledge of the issue” the elements of the concepts in order to generate insights about the user’s experience and “what would make the service concepts work in practice”. These service concepts for the policy area were later revised and iterated for a next stage of prototyping (Kimbell, 2015, pp. 28–29).

6. Discussion

The concept of the policy cycle offers designers a simple and appealing model to illustrate the role of design in the policymaking process. However, Cairney (2019) argues that in real practice, the policy process is considerably more complex and is affected not only by a “multilevel policy process” but also by a wide variety of influential factors (Cairney, 2019a, p. 18, 2019b). Therefore, policymakers have less control over the policy process which is rather a “complex policymaking system” (Cairney, 2019a, p. 18). Instead, Cairney suggests the notion of *policy learning* as “acquiring new knowledge to inform policy and policymaking” (Cairney, 2019a, p. 1).

Considering this scenario and the correlated political processes, further analysis is required

to describe how policy prototyping can contribute to a more complex policy process and define what policy prototypes could be. Consequently, additional research in the practice of policymaking and policy design needs to be developed to verify the hypotheses presented in this paper. For this purpose, cases of current practices of policy prototyping will be selected, and then studied to analyse the purpose, technique, audience, constraints and results, among other factors of each context and organisation.

7. Conclusions

The prototyping cycle offers to policy actors a model to learn from future policy options in a trial and error cycle, which allows to select and refine policy interventions earlier in the policy process. Moreover, prototyping provides a space for experimentation to “fail early” and identify difficulties with the implementation of the policy, resulting on time and money savings. Furthermore, involving different actors in the process of policy design can feed each iteration with insights from diverse actors such as prospective users and policy implementers. This allows to adapt the policy to the people who will be targeted and part of the implementation. Moreover, it facilitates communication, creativity and collaboration among all the parties involved.

Nevertheless, prototyping in policy must deal with political issues and a complex policymaking system that can restrain the adoption of experimentation practices. Similarly, current policy experimentation practices such as evidence-based policymaking and policy piloting can be complemented by prototyping. However, it is not (yet) clear how learning-oriented feedback gained in the cycle could be integrated to more rigorous evaluation processes and communicated properly to the policy actors.

Likewise, the framework proposed refers mainly to the preparation of the experiment in the cycle of prototyping. For the following stages of building and running a prototype there is design-literature already available on methods and tools (e.g., Stickdorn, Hormess, Lawrence, & Schneider, 2018a, pp. 115–166). Nevertheless, little is said about formative and summative evaluation of prototyping. Further research is required to study evidence and measurements that, in contrast, are particularly valued in policymaking.

Finally, the perspectives presented can be applied in policy processes to define clearly the strategies for prototyping and the types of prototypes to be made. For policy actors this could be a source to gain a clearer understanding of prototyping approaches available. Besides, for design practitioners and researchers, this could be a subject for discussion to enhance the collaboration with policymakers in the design of future policies. The understanding of the practice of design prototyping for policymaking and its relation to current policy analysis and experimentation approaches may be a useful step towards building a practice of *policymaking as designing*.

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Social Media Research and the Impact of Graphic Design: a case study examining an Indonesian political campaign.

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Abstract: Outside imagery, graphic design is largely invisible to the academic fields most interested in communication campaigns, seeing negligible research conducted into its role within campaigns. In an era of social media and participatory culture, the blurring of the boundaries between producers, consumption and audiences through the phenomenon of ‘produsage’ can offer rich, contextualised insights into the impact of the designed aspects of campaigns. In examining Berakar Komunikasi’s online campaign supporting the 2014 and 2019 election bids of Indonesia’s President Jokowi Widodo, our paper explores how qualitative social media research offers fine-grained insights into the reception of campaigns. The paper raises questions about the siloed nature of research which neglects design’s relationship to cultural and social phenomena, underscoring the need for interdisciplinary research that brings an integrated framework of approaches and concepts to knowledge production where design is concerned.

Keywords: communication campaigns; graphic design; qualitative social media research; interdisciplinary research

1. Introduction

Graphic design is an integral element of campaigns, whether commercial, political or social. Yet relevant literature in the fields of social marketing, health promotion and political advertising overwhelmingly concentrates on the textual content of campaigns outside a small body of writing on campaign imagery such as illustrations and photographs. All other aspects of graphic design are seemingly invisible to writers in these fields, with the communicative contribution of graphic design through designer’s strategic choice and application of colours, logos, typefaces and typographic layouts disregarded. This neglect is understandable. Various writers argue, for example, that due to its abstract nature, typography is perceived as less evidently communicative than the pictorial content of graphic design (Crisp, 2012; Hagan,



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2012; Trieb, 1989). Yet the considered application of typography in support of a campaign's objectives and the communication context lies at the heart of the strategic role of graphic design within campaigns in seeking to influence audience attitudes and behaviour.

Current research into the impact of campaigns spans three main forms. First is quantitative survey research based on large data sets, including that focusing on variation of response between audience segments. Second is qualitative interview and focus group research with small numbers of audience members to examine responses to campaign messaging. Third is evaluative research investigating whether campaigns influence outcomes for target audiences and societies. In each case, teasing out the reception of campaigns is complex, their multiple elements creating an array of variables. However, any effort to be comprehensive here is challenged if the designed component of campaigns is not examined.

Although other disciplines might lead campaign development, graphic design is a process that underpins an entire campaign from conceptualisation through to strategic implementation. Adapting Van Der Waarde's (2012) conceptualisation of the fundamental elements of graphic design to the creation of campaigns, Figure 1 characterises the three main dimensions of graphic design as spanning:

The selection and application of visual elements, including typographic elements, image elements (illustrations, photographs, symbols) and schematic elements (colours, line, borders), the main considerations being aesthetic impact and visual coherence.

The selection and application of visual strategies to support the campaign message and strategy, including branding and visual identity to ensure the campaign is identifiable and its textual and visual elements are aligned. In the case of online campaigns, this extends to the design of the behavioural and visual aspects of digital artefact (interaction design), which influence user engagement and experience.

Consideration of the target audience to align communication with their identity, needs and perspectives.

The literature of social marketing, health promotion and political advertising focuses on the analysis of campaign imagery, using various semiotic approaches such as visual rhetoric to examine the connotative and denotative function of images. These approaches 'highlight the communicative dimensions of images' in relation to higher socio-cultural and political meanings (Foss 2005, p. 145). Drake Reitan (2016, p. 507), however, stresses that in the case of graphic design, the object of analysis encompasses *all* 'non-textual materials', not only images. The collectivity of design elements that contextualise campaign illustrations and photographs is meaningful in its own right, its visual rhetoric being properly considered as an integrated whole within the wider campaign.

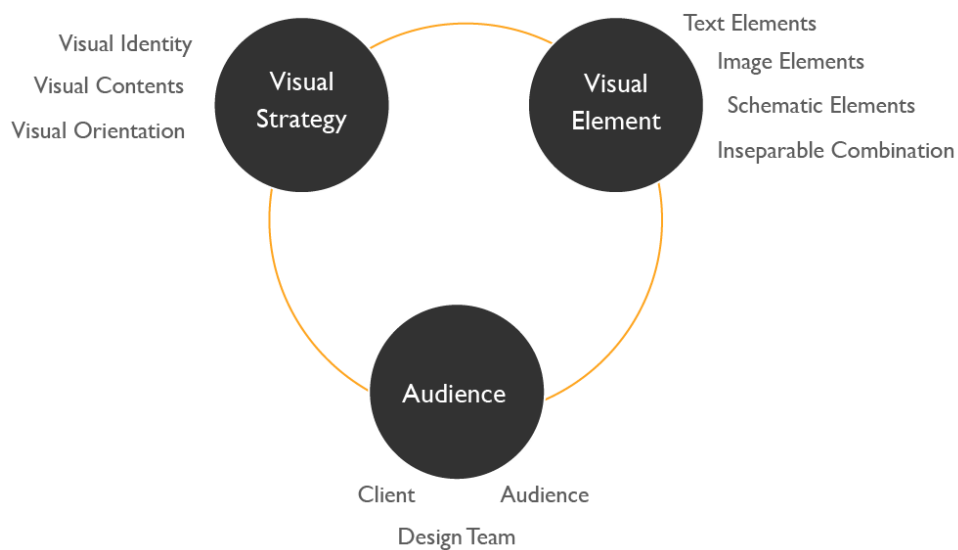


Figure 1 The scope of graphic design in campaigns drawing on Van De Waarde (2012).

In discussing ways to research the role of graphic design in campaigns, this paper examines the phenomenon of produsage, a term coined by Axel Bruns (2006). Since the rise of the Internet and social media, the contemporary zeitgeist has been linked to the emergence of a ‘participatory culture’ in which former divisions between production, consumption and audiences have dissolved (Jenkins, 2006). Pre-empting and paralleling this phenomenon, since the late 1970s, participatory processes that engage people in design have been of growing importance in design practice and research under titles including participatory design, co-design, co-creation and design thinking (Smith, Bossen & Kanstrup, 2017). Contemporary campaigns have similarly sought to become highly participatory, being conducted online to maximise audience engagement and penetration, graphic design serving to add coherence and identity to the manifestation of a campaign across digital platforms, mass media and campaign ephemera.

Social media is seen to create dynamic new power relations between content providers and audience members. Bruns (2006, 2007, 2008) developed the concepts of ‘produser’ and ‘produsage’ to account for the new active role of everyday people in creating diverse digital content on the Internet, thus challenging former ideas of the ‘audience’ for media content. Specifically, Bruns (2006) sees the ‘produser’ phenomenon as resulting in ‘the collaborative and continuous building and extending of existing content in pursuit of further improvement (p. 2)’. As a new model of audienceship and content creation, Bruns and Schmidt (2011, p. 5) ascribe four key features to produsage. Firstly, produsage is open to the broad community with barriers intentionally set as low as possible to encourage participation. Secondly, the open participatory nature of social media drives continual development of ‘unfinished artefacts’. Thirdly, leadership in the context of produsage is a direct result of the quality

of contributions, leadership being open to constant turnover. Fourthly, the media content tends to be thought of as 'common property', making status achieved through the interest of others the main currency, rather than financial rewards.

All four features are potentially significant to the role of the audience and graphic designers in campaigns. Prodsusage challenges the traditional view of designers as holding the power in communication, although the idea of an active audience disrupting such power precedes the phenomenon of convergent production and consumption in social media (e.g. Frascara, 2004). Figure 2 represents audience response as the final stage of design, this paper using the concept of produsage as a basis for examining audience engagement with design in campaigns.

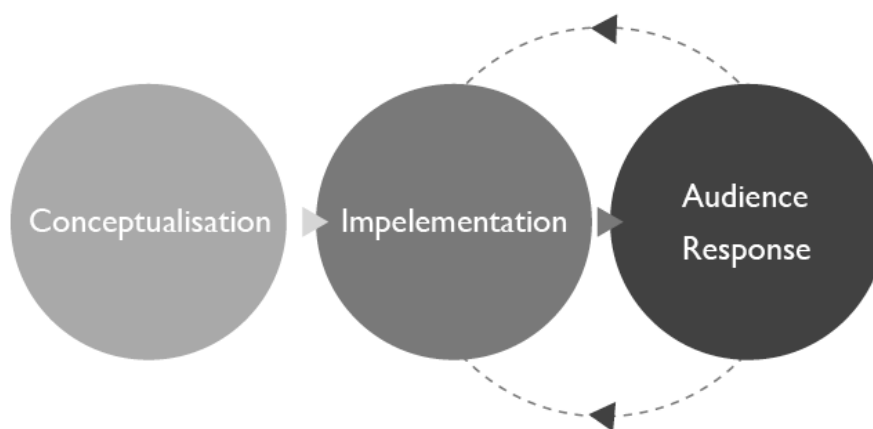


Figure 2 Three stages of the design process.

To draw attention to the lack of understanding of the presence and purpose of graphic design in campaigns, the paper begins with a review of literature on relevant studies from social marketing and political advertising. After outlining the research design and methods, the paper's main body is a detailed examination of the application of graphic design within the "Jokowi Tintin political campaign", considering how the social media response to the campaign, via the phenomenon of produsage, can shed light on the role of graphic design in campaigns. The findings show that the nature and extent of produsage in response to a campaign can indicate that a campaign's creative strategy has resonated with its audience. The paper ends with discussion and conclusions about the effect of disciplinary focus inhibiting research into graphic design's diverse roles in everyday life.

2. Campaign studies and visual content

A review of social marketing and health promotion literature identifies a number of studies on the role of illustrations and photographs in campaigns (e.g. Clarke, Niederdeppe & Lundell 2012; Lagomarsino & Suggs 2018; Potter & Stapleton 2012; Springston & Champion 2004). These articles consider image choice, the semiotics of images and the correlation between campaign messaging and visual content (Wymer 2011). For example, Springston and

Champion's (2004) review of breast cancer screening information examines preferences for colour and for photographic over cartoon-like images. In the political advertising literature, imagery is part of broader discussions around campaigns. For example, the communication of sentiment in political posters (Holtz-Batcha & Johansson, 2013), the dissemination of political advertising (Lee & Campbell, 2016) and the use of attack narratives in campaigns (Dermody & Hanmer-Lloyd's, 2011). McVee and Carse (2016) examine the use of narrative construction and symbolism across verbal, visual and textual content to invoke fear and a need for urgent action. Gadarian (2014) explores the emotional effect of war imagery for persuasive purposes within political campaigns. Dumitrescu (2010) links non-verbal cues and photographic language to the expression of candidates' attributes and party 'persona', while Visgo (2013) analyses its use in the expression of political ideology.

Roland Barthes's (1977) theory of the rhetoric of the image is a common framework for the analysis of the meaning of images in campaigns. It is used to discuss imagery in political campaigns in relation to gender (Bauer & Carpinella, 2018), nationalism (White, 2016) and localism (Jacob & Munis, 2018), and the consistency of political messaging in campaigns across image and text (Dumitrescu, 2019; Hayek 2011; Teer-Tomaseli 2005; Visgo, 2013). Serazio (2017) discusses the importance of candidate branding, but without mentioning graphic design.

The 2008 presidential campaign of Barack Obama prompted more recognition of the role of graphic design in political campaigns (e.g. Franz & Ridout, 2010). Seidman (2010) compares the visual dimension of the Obama campaign to high-end consumer branding, noting the consistent application of high impact branding across all campaign collateral. Zavattaro (2010) attributes Obama's political success to his positioning as a brand through the use of graphic design, this changing conventions in political advertising. Thomas (2010) sees the campaign's consistent application of graphic design using familiar, US-themed elements as enhancing a sense of trust in Obama, while Billard (2016) argues that the range and online distribution of campaign materials allowed the public to engage with and disseminate the campaign.

Although graphic design is recognised for its role and impact in these articles, they include little analysis of the formalistic, symbolic and metaphorical elements of graphic design. An exception in the health promotion literature is Wressel et al. (2011), which examines design strategy for the UK 'Saving Lives' HIV awareness campaign in seeking to increase impact by "steer[ing] away from the traditional colours, typefaces, vocabulary, and style of previous public health campaigns" (p. 82). In the political advertising literature, Billard (2018) examines the contribution of typography in American presidential campaigns to establish candidate identity and campaign messaging. Billard (2016, p. 4584) notes, however, that the impact of graphic design in the Obama campaign has not raised interest among political advertising researchers in the strategic role of graphic design in past or present campaigns.

3. Social media and campaign engagement

Before the rise of social media, the study of campaigns focused on the role of television as the main, proven method for disseminating campaigns (Dauda, Norma & Hasan 2017; Niederdeppe et.al. 2008; Pedrana et al. 2014). Recent studies discuss the role of social media as an affordable and effective medium for campaign delivery (Khawaja, Ali & Khan 2017) that provides political candidates with 'closer and unfiltered' access to voters (Fulgoni, Lipsman & Davidsen 2016, p. 242), enabling interactive communication (Hayek 2011, p. 145) while the range of social media platforms caters to voters' preferred participation style, enhancing engagement (Goldstein & Ridout 2004; Kaid, Fernandes & Painter 2011). Seidman (2010) notes the impact of Shepard Fairey's 'Hope' poster in demonstrating social media to be fertile ground for creating and sharing images to extend official campaigning.

The fields that study campaigns typically use controlled approaches such as focus group, interview and survey to measure the impact of campaign messaging (e.g. Borah, Fowler & Ridout 2018; Fernandes 2013; Phillips, Urbany & Reynolds 2008; Turner, Underhill & Kaid 2013). Recently, researchers have harnessed quantitative evaluative techniques such as Google Trends to examine the level of engagement and patterns of response to political advertising (e.g. Hopp & Vargo 2017; Housholder, Watson and Susan 2018; Sohal & Kaur 2018). Software packages can track the cursor location or clicks within websites to examine user attention, movement, dropout or navigation, although these methods are currently a blunt tool for analysing the role of graphic design in websites.

In pre-campaign studies, social media has been used to identify attitudes of target audiences (e.g. David et.al 2016). Social media equally offers researchers and practitioners access to the unsolicited responses of online audiences to campaign content. Snelson (2016) argues that qualitative analysis of social media data complements quantitative measures of engagement, providing scope to unravel the complexity of response to campaigns. The use of traditional research methods can disrupt 'the ecology of [the participants'] social world by introducing [researcher's] own subjectivity, beliefs, or interests' (Roman & Apple 1990, p. 45). By contrast, social media data affords researchers access to naturalistic data. Diverse fields have made strong use of social media data, for example, Greene et al's (2010) study of the use of Facebook by those with diabetes as an information seeking and support platform while Robards and Lincoln (2017) have analysed the use of Facebook Timeline by people in their twenties to craft 'growing up' stories.

4. Case selection and methods

The study informing this paper combined visual rhetoric analysis of designer-generated and audience-generated contributions to the 'Jokowi-Tintin' campaign with content analysis of social media comments about the campaign. We chose a campaign with a high component of illustrative graphics over those where the creative solution was based in typography and the formalistic elements of graphic design in order to examine conditions where the presence of graphic design would be hardest for non-designers to recognise.

4.1 Data sample

Between May 2014 and May 2019, the first author collected brand and interface designs and illustrations from the campaign's official websites www.gulunglenganbajumu.com (2014) and www.karyaadalahdoa.id (2018– 2019) and its Facebook and Instagram accounts (www.facebook.com/karyaadalahdoa; www.instagram.com/karyaadalahdoa). In total, 1319 images and around 3500 written comments were captured. The extent of data collected suggests the level of interest in a campaign, Van Dijck (2009) arguing that for every 100 people who visit a site, 89 view it, ten engage by commenting while one visitor is an active producer of online content. The visual content contributed by audience members is highly developed. Most written responses are brief, although they do feature an array of emoticons and repeated vowels and final letters in particular words, Calamur (2016) arguing that in short online communications these strategies replace body language and facial expressions to amplify the sense of a message.

4.2 Data analysis approach

The textual and visual data were coded and categorised based on the stages of thematic analysis set out by Braun and Clark (2013). Thematic analysis is a theoretically flexible process for identifying patterns of meaning and effect across data sets (Braun & Clarke, 2012; Clarke & Braun, 2017). Before coding began, the data was organised into two databases to allow for separate analysis of the visual and non-visual material; all data was then reviewed as a single body to gain a sense of its collective nature (Yin, 2011). During this process, first impressions of the data were recorded (Miles, Huberman & Saldana, 2014). Codes were assigned to words and phrases within the textual data and elements of the visual data to identify patterns of significance across the design phases of conceptualisation, implementation and audience response. Following Williams and Karahanna (2013), repeated coding cycles were undertaken, with relations between themes being explored visually using thematic coding schema to arrive at the final themes of stylistic and thematic appropriation, brand identity and visual consistency, Indonesian specificity and nostalgia, and produsage.

4.3 Case background

The creative agency Berakar Komunikasi initiated the 'Jokowi-Tintin' campaign in the last two months of the 2014 Indonesian Presidential election to support Joko Widodo's presidential bid. Against the background of an acrimonious campaign, the agency's key creatives Yoga Adhitisna and Hari Prasetyo sought to mobilise Jokowi's silent supporters to vote, voting being voluntary in Indonesia. Four Berakar employees worked on the campaign, Adhitisna serving as its art director and copywriter, and Prasetyo as illustrator. Berakar Komunikasi reactivated the campaign for the May 2019 Presidential election in late 2018, titling this second phase 'Creation is Prayer'. In addition, Berakar Komunikasi created a Facebook-based online platform called "Demokratif" (See Figure 3), which enabled continued audience contribution of artwork supportive of Jokowi between the elections.



Figure 3 Timeline of Jokowi-Tintin campaign in Indonesia



Figure 4.1,4.2 Typical political campaign posters in Indonesia

Where graphic design in Indonesian political campaigns is typically decontextualized and generic (Figure 4), creativity and sophisticated design strategies are central to the 'Jokowi-Tintin' campaign. The 2014 campaign was built on the illustration style and themes from the comic series *The Adventures of Tintin* (1929–1976), created by the Belgian cartoonist Hergé (1907-1983). Berakar Komunikasi seeded the 2014 campaign with 19 mock-Tintin book covers (Figure 5). The campaign became a viral sensation for its clever representation of Jokowi, via the persona of Tintin, as hardworking, honest and unaffected.

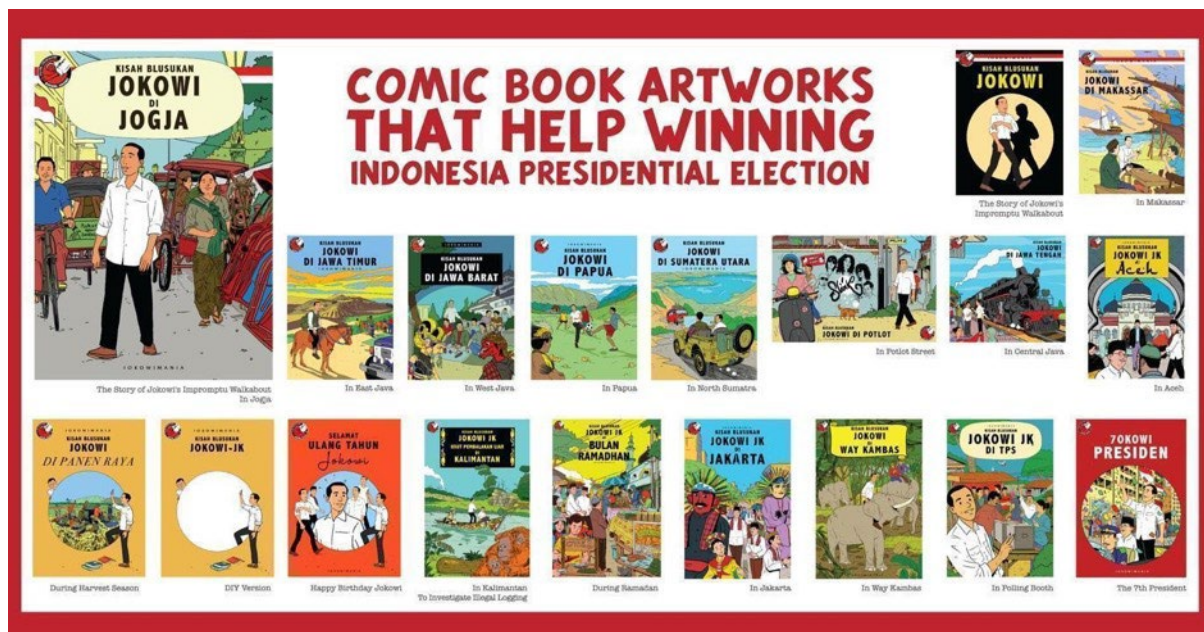


Figure 5 The original 19 images for the 2014 'Jokowi-Tintin' campaign based on covers from *The Adventures of Tintin*.

Within the 2014 and 2019 campaigns, the Berakar Komunikasi team both initiated campaign collateral and sought to foster produsage by providing templates and stickers to prompt audience contribution. In both instances, a group of audience members posted original contributions to create new adventures for Jokowi, reflecting Berakar Komunikasi's rhetorical appropriation of popular culture. By the 2019 campaign, audience members and the campaign team were sharing creative authorship of the campaign as audience members extended the campaign's themes beyond *The Adventures of Tintin*, the campaign's graphic design elements maintaining coherence across the campaigns to weave audience- and campaign-generated content into one recognisable campaign.

5. Findings and discussion

The fields of political advertising, health promotion and social marketing see illustration and photography as the main media of visual communication in campaigns, where communication strategy within graphic design is grounded in a range of aesthetic and typographic elements. Even when operating at an unnoticed level, these frame the presentation and reception of illustrative graphics in addition to establishing campaign identity and experience. The following section provides an analysis of the communicative role of graphic design in the Jokowi-Tintin campaign to show audience response to be negotiated from *within* the matrix of graphic design.

5.1 Characterisation of Jokowi via appropriation

The core creative strategy of the Jokowi-Tintin campaign is the appropriation of the style and themes from the Tintin comics. Originally, the illustration-based campaign was developed to

overcome a lack of access to photographs of Jokowi, but associating Jokowi with Tintin had a clear logic. Tintin, a young reporter who travels the world with his dog Snowy, is an unlikely action hero who takes on bullies and fights for good through his quick thinking. Jokowi came to the 2014 Presidential election as a youthful figure in Indonesian politics with a reputation for tackling corruption and improving life for common people in his roles as Mayor of Surakarta and Governor of Jakarta. The Tintin comics are imbued with themes of adventure, geopolitics and identity (Dunnett, 2009). Hergé’s semi-realistic, *ligne claire* illustration style allows for detailed scene-setting to support narrative richness. The books act as a window to the wonders of the world for readers, also being laced with humour.

The Berakar Komunikasi creative team harnessed these qualities to suggest Jokowi’s promise as a president, showing the candidate venturing around the Indonesian archipelago interacting with the nation’s diverse peoples and cultures (Figure 6). On winning a Shorty Award for the campaign, the creative team explained that, “Depicting Jokowi as a people-oriented leader in light-hearted and idyllic campaign materials sought to enable audiences to express their support and amplify it enthusiastically. We sought to highlight Jokowi’s strengths ... his ‘rolled-up sleeves’ work attitude [alongside] Tintin’s character as a problem solver and action-oriented (Shortyawards 2017)”.



Figure 6 19 Images styled on covers for *The Adventures of Tintin* albums for 2014 ‘Jokowi-Tintin’ campaign.

5.2 Branding and visual identity

Appropriating the style and themes of the Tintin comics set the creative direction of the campaign, but graphic design provided brand identity and visual consistency, with purpose-designed logos, for example, being developed to brand the images. For the 2014 campaign, this was an illustrative logo showing Jokowi rolling up his sleeves ready for work (Figure 7). For the 2019 campaign, a simple, red and white logo bearing the name of the campaign identified campaign artwork (Figure 6). Formalistic elements of the campaign and typography were developed with both legibility and tone in mind. To increase clarity and keep the focus on imagery, campaign messages were positioned on the side of the screen. Where images incorporated typography, typographic choices were authentic to the comic style of the Tintin books while spoken text used the comic convention of speech balloons (Figure 8). Such strategies departed dramatically from the usual typography in Indonesian presidential campaigns with its discordant mix of bold, all caps, sans serif fonts with lowercase serif fonts. By contrast, the novel stylistics of the Jokowi-Tintin campaigns projected political freshness, reflecting the advertising industry's co-optation of fun for marketing purposes.



Figure 7.1,7.2 The 2014 and 2019 campaign logos.
Translation (left) "Roll up your sleeves, support Jokowi"
Translation (right) "Creation is Prayer"



Figure 8 Typography in the 'Creation is Prayer' campaign.
Translation (Left) "Jokowi: Are you ready for debate sir?, Amin: Yes"
Translation (Right) "Clean Law"

The focus of campaign activity was Facebook and Instagram, two platforms developed to accentuate images. The number of Indonesian Instagram users is the fourth highest worldwide, with around 60 million users (Statista, 2019). The level of audience-generated content in Indonesia is also high. The Berakar Komunikasi team fostered audience contribution and collaboration through readily accessible tools and materials, but their attention to branding and visual identity was important to how audience members would recognise and identify with the campaign on these otherwise generic platforms (Figure 9). Interaction and interface design on Facebook and Instagram were also integral to the scope for campaigns to extend into social media, integrating qualities of connectivity, intuitiveness, enablement and responsiveness into the experience of campaigns.

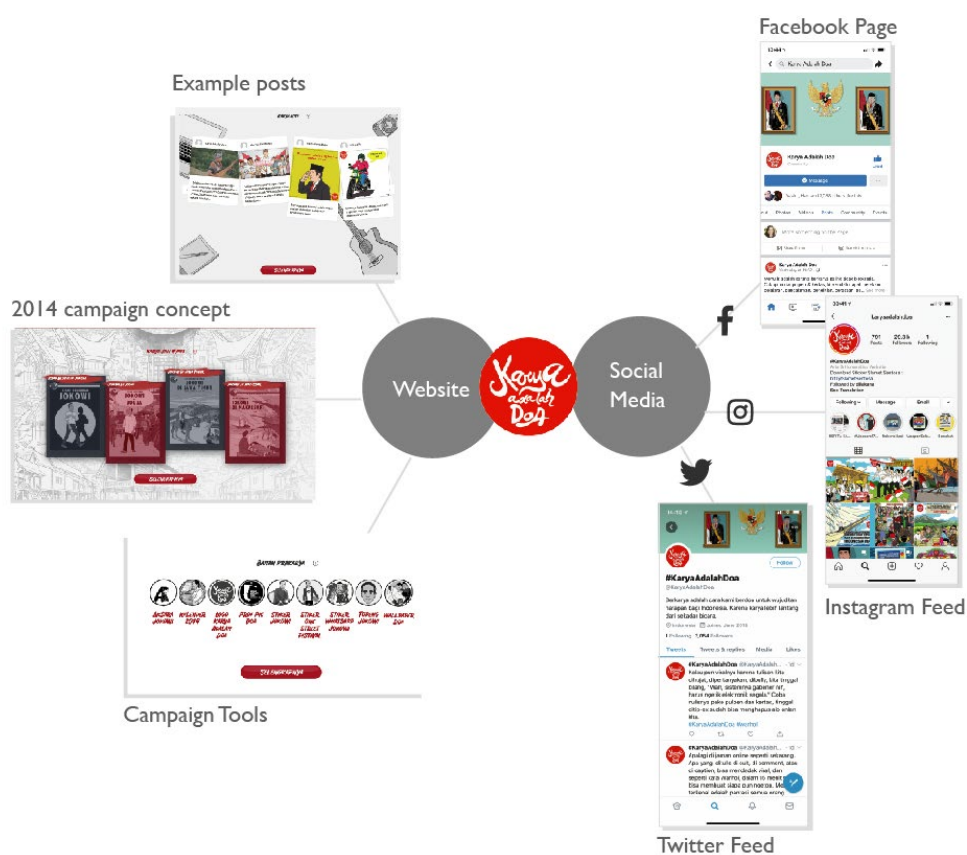


Figure 9 Jokowi-Tintin 2019 campaign website and social media platforms.

5.3 Indonesian specificity and nostalgia

Taylor (2009) updates Bourdieu’s idea of cultural capital to argue that people today have ‘omnivorous’ tastes that range across the high/low cultural divide, with ironic use of cultural references signifying coolness. The Tintin references are meaningful to urban Indonesians, especially Indonesia’s youth, who are well versed in Western popular culture. The campaign also included many references to daily life in Indonesia, these often tinged with nostalgia.

Evoking nostalgia is common in political campaigns, even resonating with generations who never experienced the original (Phau & Marchegiani, 2010). In depicting Jokowi as a modern day Tintin, the 2014 campaign framed the presidential aspirant as an appealing electoral choice for contemporary Indonesians, with references to aspects of everyday life in Indonesia injecting authenticity, familiarity and connection into the campaign. These include Jokowi's family depicted in the style of the iconic *Khong Guan Biscuit* tin and an image of Jokowi seated in the ubiquitous red-rooster bowl of Indonesian street food sellers (Figure 10).



Figure 10 References to daily life in the 2019 campaign.

As with the Tintin illustrations, to further build relatability, campaign illustrations depict recognisable Indonesian gestures, scenes and traits, including characters with varied hair styles, skin tones and modes of dress. Reflecting Tintin's amiable character, Jokowi is portrayed in the midst of the Indonesian people, comfortably interacting with ordinary Indonesians from all walks of life (Figure 11).



Figure 11 Jokowi interacting with everyday Indonesians.

5.4 Campaign implementation and audience engagement

Both the 2014 and 2019 campaigns provided tools to prompt audience contributions. In 2019, this included high resolution digital cut outs of Jokowi to add to a selfie to simulate

meeting Jokowi, something unlikely given the vast Indonesian population and archipelago (Figure 12). The 2019 campaign extended to offline events which participants were encouraged to share online by tagging the campaign accounts to add to the growing body of visual material. Campaign events were oriented towards the young, an event with street culture activists on 24 March 2019 in North Jakarta featuring hip hop and skateboarding competitions (Naufalia, 2019). Jokowi masks and photo zones were established to maximise the flow of images to social media (Figure 13).



Figure 12 Audience-generated content created using the Jokowi stickers.

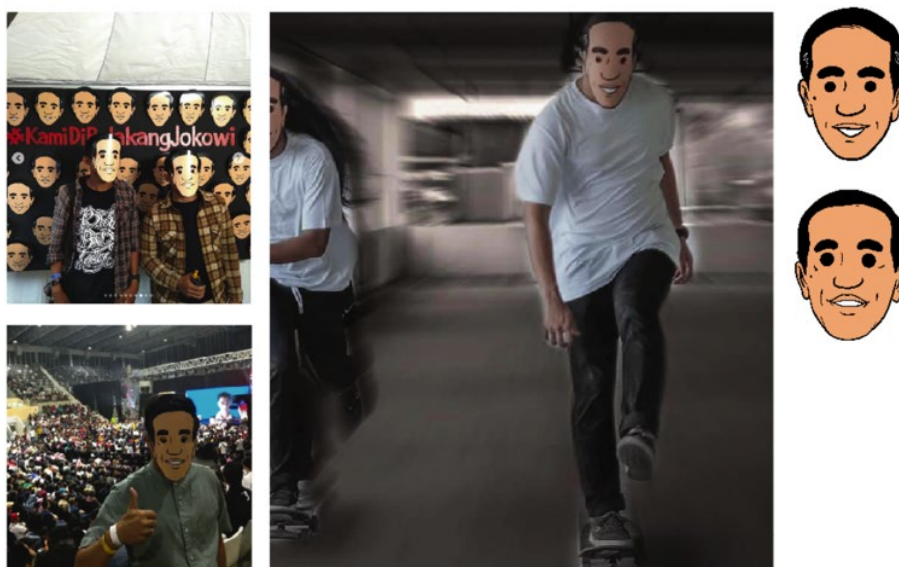


Figure 13 Jokowi's mask and it's application at offline events.

The campaign provided ‘how-to’ guides for drawing Jokowi and his running mate Ma’ruf Amin (Figure 14). These were little used, with audience members introducing a diversity of new themes and pop-culture references. Contributions upheld the creative strategy of using vignettes from the campaign trail, one post illustrating a comment from a Jokowi speech comparing the global trade war to Marvel’s *Infinity War* (Septiari, 2018). These contributions are both original and in keeping with the campaign’s creative strategy, branding and visual identity, highlighting the role of graphic design in the dissemination and reception of the campaign.

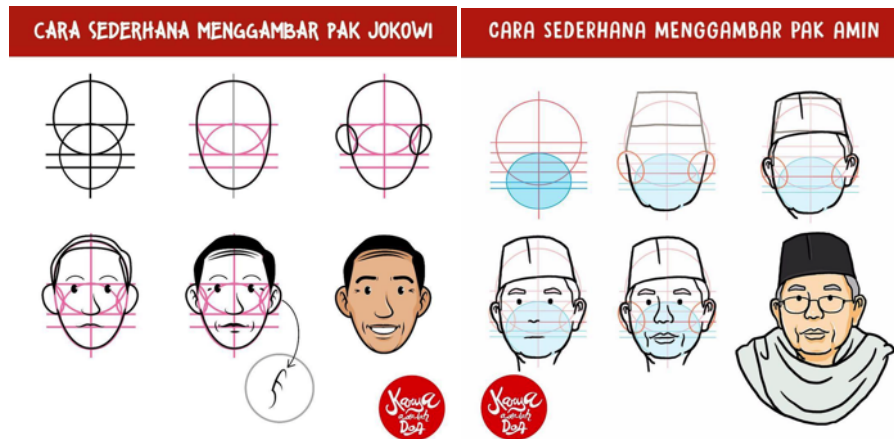


Figure 14 ‘How-to’ guides for drawing Jokowi and Amin Ma’ruf.

In particular, the consistent application of the downloadable campaign logo, accessed via the campaign website, linked the variety of posted images to the campaign, showing that contributors had absorbed the mechanics of branding and visual identity. As illustration styles and pop-culture references diversified in the 2019 campaign, the presence of the logo made campaign contributions consistently identifiable, affording contributors — many of them likely members of Indonesia’s creative community given the skill shown in the images — a real sense of contributing to the campaign. As audience members posted images outside the Tintin theme, the campaign reciprocated by adding other new characters, introducing both nostalgic and contemporary references to the campaign (Figure 15). Indicating that the public found the campaign accessible and compelling, people continued to post contributions between the 2014 and 2019 presidential campaigns despite there being no immediate motivation to do so.

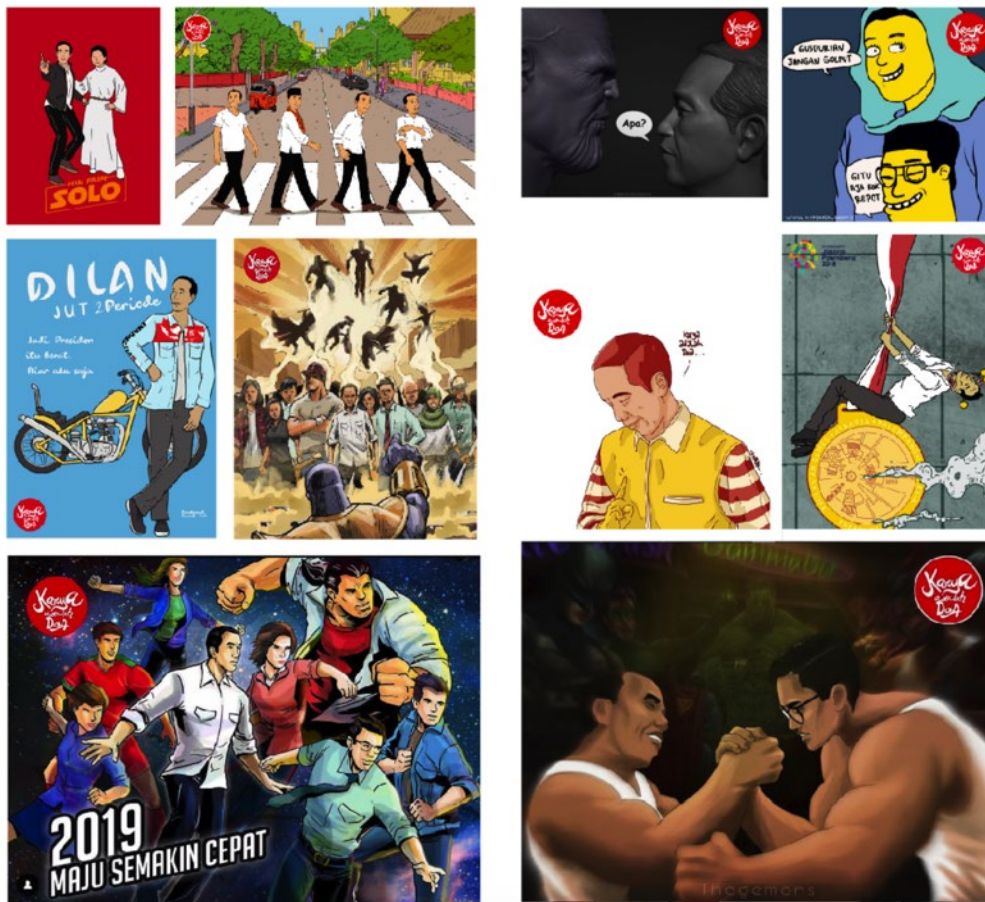


Figure 15 Varied pop-cultural references in campaign- (left) and audience-generated content (right).

5.5 Written commentary

The Jokowi-Tintin campaign generated significant audience response. By comparison to sophistication of the audience-generated images, most comments are brief, banal and often unintelligible, indicating no deep thought. A significant number, however, do express enthusiasm for the creative strategy rather than posting about Jokowi or the Presidential election:

@username: Hahaha Cooool... If only both sides can battle it out through art and creativity, it will be more interesting.

www.instagram.com/karyaadalahdoa, 22 September 2018

@username: Create more of these [posts], it's goooood..

www.instagram.com/karyaadalahdoa, 28 October 2018

@username: So cool ihhh [expression of excitement], creative 👍👍👍

www.instagram.com/karyaadalahdoa, 11 March 2019

Appreciation for the creative strategy even saw a supporter of Jokowi's opponent, Prabowo Subianto, condemning the campaign for its focus on Jokowi:

@Username: This is all for Jokowi, What a joke!? You should treat all candidates fairly as artworks, not only Joko.
www.instagram.com/karyaadalahdoa, 20 January 2019

The extent of comments fostered the sense of a 'crowd' looking at the campaign, the social media audience being highly effective in sharing, re-posting and inviting more social media friends to view the campaign, maintaining currency (Falasca, Dymek, & Grandien, 2018). The enthusiasm and respect for the campaign is exemplified in the number of instances where people ask, albeit in rhetorical ways, for permission to share campaign content:

@Username: Allow me to copy and paste your image in my facebook.
www.instagram.com/karyaadalahdoa, 5 November 2018

The introduction of corporate branding principles into politics alongside the polished visual treatment of professional graphic design agencies is not a neutral enterprise (Aiello, 2012). Moor defines branding as "more akin to a managerial technique or resource that seeks to use broadly 'cultural' ... materials for a range of strategic ends" (2007, p. 88). Graphic design should thus be seen as "constitutive and structuring [of a campaign] in its own right," a "highly selective and ideological endeavour" that "contributes to stylizing rather than simply strategically representing" its subject (Aiello 2012, p. 461). Berakar Komunikasi's injection of visual branding and strategy into Indonesian politics via the Jokowi-Tintin campaign represents the aestheticization of political discourse in Indonesia, operationalising the agency's knowledge of the preferences and persuasion points of the Indonesian public developed through its work in advertising and marketing.

The nature and extent of produsage in response to the campaign indicates the campaign's creative strategy resonated with its audience. Over time, this formed a feedback loop between the campaign creators and audience leading to the diversification of both campaign content and style as set out in Figure 16. The tools to enable ready contribution were effective in fostering broad produsage, but our most significant finding is the evidence of the shared leadership of the campaign, this building the scope of and interest in the campaign in an organic way. Tracking this activity offers new ways to research the reception of campaigns, while the Jokowi-Tintin campaign demonstrates the critical role of graphic design in combining numerous elements into a cohesive campaign that encourages and enables audience contributions.

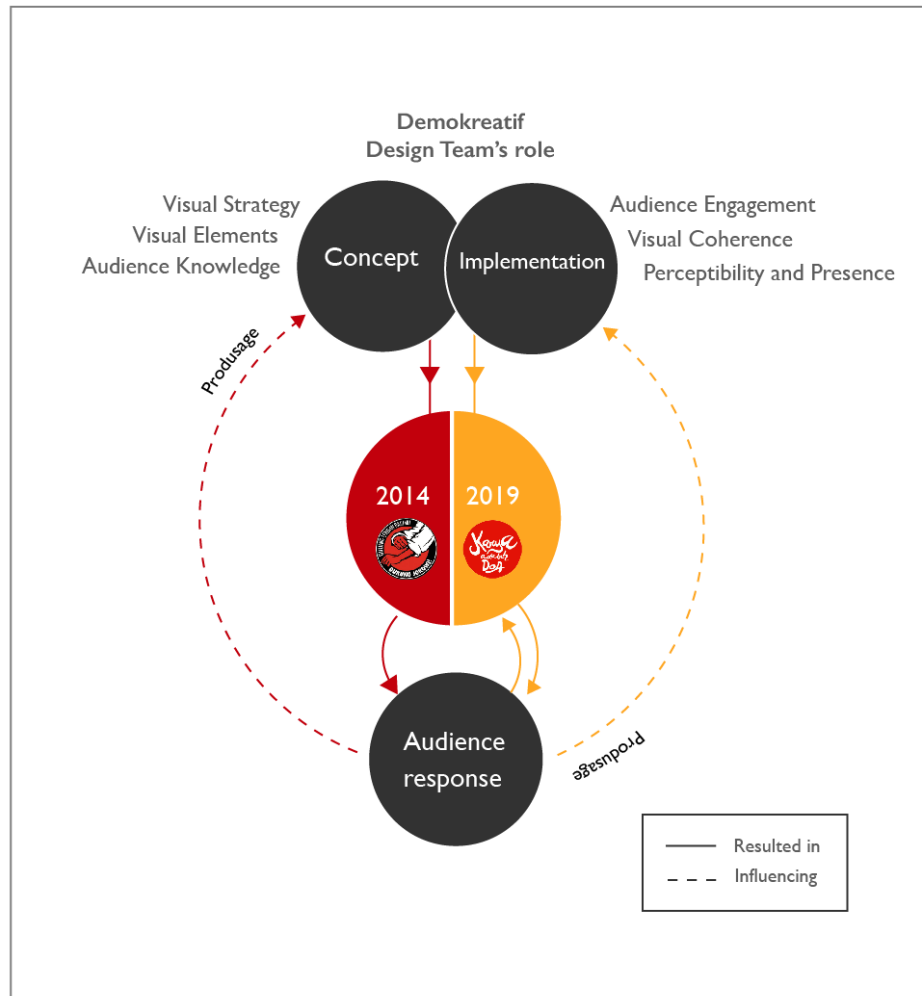


Figure 16 The relationship between campaign creators and audience in the Jokowi-Tintin 2014 and 2019 campaigns.

6. Conclusion

Understanding the impact of graphic design in campaigns is essential to citizen-involving initiatives in public health and safety. In political campaigns, it is important to understand how the designed aspects of campaigns intersect with the democratic ideal of free political participation. By comparison to quantitative research, qualitative research is fluid, contextual and probing, resulting in deep and richly detailed data. Visual research methods are of growing interest in the social sciences, but few researchers in the scholarship of campaigns currently recognise the diffuse presence of graphic design within the fabric of campaigns or have the design literacy to analyse it.

Currently, research into campaigns is fragmented into silos according to the disciplines most concerned with campaign content, the fields of health promotion, social marketing and political advertising bringing their distinct concepts and concerns to the examination of campaigns. This has rendered the role of graphic design invisible at worst, marginalised at

best, with negligible research happening from an informed perspective. Corazzo, Harland, Honnor and Rigley (2019) examine the challenge graphic design has experienced in building a research culture. They attribute this to “the absence of consensual nomenclature, lack of confidence and exemplars with practice-based graphic design research, the uncertain expectations of research audits, lack of venues for dissemination, heavy teaching loads and few established career pathways for research. (p. 2)” Although accepting this assessment, the promotion of graphic design as an intellectually distinct field of research is problematic when the presence of graphic design — as the lingua franca of countless human activities today and hence research questions — highlights the need for the integration of design research into many disciplines.

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Appendix

Images Reference

Figure.1-3. Suhendra, F (2020). Various diagrams.

Figure.4.1. Typical political campaign posters in Indonesia [Photograph]. (2018). Retrieved from <https://www.ajnn.net/news/kampanye-dengan-baliho-sudah-ketinggalan-zaman/index.html>

Figure.4.2. Typical political campaign posters in Indonesia [Photograph]. (2018). Retrieved from <https://www.merdeka.com/foto/politik/341365/20140325124811-nestapa-pepohonan-di-tangsel-jadi-korban-kampanye-caleg-001-nfi.html>

Figure.5. Berakar Komunikasi (2015). The original 19 images for the 2014 'Jokowi-Tintin' campaign [Image]. Retrieved from <https://shortyawards.com/7th/the-story-of-jokowis-impromptu-walkabout-campaign>

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Figure.7.2. Berakar Komunikasi (2018). Jokowi-Tintin 2019 Logo [Image]. Retrieved from www.karyaadalahdoa.id

Figure.8. Berakar Komunikasi (2019). Typography examples in "Creation is Prayer" campaign [Image]. Retrieved From <https://www.instagram.com/p/BsuovHpAW8T/> and https://www.instagram.com/p/BsvCw0VA_IX/

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Figure.10. Berakar Komunikasi (2019). References to daily life in the 2019 Campaign [Image]. Retrieved From https://www.instagram.com/p/BpJCxmYDkp_/ and <https://www.instagram.com/p/Bulj3CaA-Rl/>

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Figure.13. Berakar Komunikasi (2019). Collation of audience-generated using Jokowi stickers [Photographs]. Retrieved From <https://www.instagram.com/p/Bu1RMv7gOnL/>, <https://www.instagram.com/p/BuJbeiTA0bC/>, <https://www.instagram.com/p/Bu0z2wxgFpz/>

Figure.14. Berakar Komunikasi (2019). 'How-to' guides for drawing Jokowi and Amin [Image]. Retrieved From https://www.instagram.com/p/BtTDUZ2gfq_/ and <https://www.instagram.com/p/BtTJB9LgIvV/>

Figure.15. Berakar Komunikasi (2019). Varied pop-culture reference in Creation is Prayer campaign [Image]. Retrieved From www.karyaadalahdoa.id

Sustainability SIG

Overview of papers in the Sustainability SIG highlights

Editorial 710
Emma DEWBERRY

116. Setting the Stage for Responsible Design 713
Wouter EGGINK, Deger OZKARAMANLI, Cristina ZAGA, Nicola LIBERATI

402. Multispecies Cohabitation and Future Design 731
Stanislav ROUDAVSKI

186. The HfG Ulm and Sustainable Design: a comparative analysis 751
Carolina SHORT, Tomas GARCIA FERRARI

285. Over the Rainbow: Sharing a cross-disciplinary philosophy of waste through spectrum visualisation 768
Manuela TABOADA, Alice PAYNE

307. Designery Living Labs: Early-stage exploration of future sustainable concepts 787
Martin SJÖMAN, Mia HESSELGREN

401. When behaviour change is about hot air: home systems should change behaviour to fit practices 803
Elise WABEKE, Stella BOESS, Froukje SLEESWIJK-VISSER, Sacha SILVESTER



DRS2020
BRISBANE, 11–14 AUG
SYNERGY



Editorial: Design for Sustainability SIG

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Introduction

The need to shift the vision, and the rules and processes to support that vision, is palpable in times of crises. As the current global coronavirus pandemic demonstrates while there is the capability and capacity to shift perspectives, actions and outcomes, what is also required are the visions and agreements to work collaboratively, holistically and carefully to achieve these. The DRS Sustainability SIG champions design research that resonates with, and responds to, environmental crises. The relationships between people and planet are central to this focus and research aims to explore design responses to the unsustainable practices of these relationships that have resulted in the deep rooted impacts of climate change, biodiversity loss, soil erosion and land use change, ocean acidification, biogeochemical flows and the inequitable access to natural resources. Proposed solutions to such impacts often reflect current norms and values which can result in an additive mode to improving what exists rather than challenging practices that need to fundamentally change. Creating products, services and systems that deliver greater levels of global, multi species wellbeing may be a long way off if such challenges are not addressed in more critical ways. The current focus on circular resource flow for example can only be holistically effective if it addresses current consumption as well as production practices. Such conversations are tricky: they deeply question how we generate and measure economic wealth and development; how that wealth is better distributed; and how new systems of living and working might arise. Design, in these contexts, is both a philosophical and structural agent as well as a practical one. As design researchers we need to imagine difference, instigate debates, locate new synergies and effectively collaborate in order to broaden the scope of what it is *to design* sustainable futures.

The papers presented at DRS2020 represent a range of research linking to responsible design, transdisciplinary and sustainability agendas. They are split across two sections



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although other papers in other sections also resonate with these broad debates. In the first section three papers are presented. The first paper, 'Setting the stage for responsible design' (paper 116), explores the influence of design on the world through the products and services created and draws on human-technology interactions and user-centred approaches to design to support responsible design practices – or more specifically, the way in which design/ers respond to the needs and challenges faced by society. Design interventions also raise issues around inclusivity, evaluation and unintended consequences. In a transdisciplinary workshop the authors explore issues of responsibility in academic work and more specifically the issues related to a responsible design approach. Ongoing work represents an emerging multi-disciplinary approach to responsible design that aims to develop a much wider understanding of 'responding well' in design terms. The second paper, 'Multispecies Cohabitation and Future Design' (paper 402) presents a sobering overview of human impact on the environment. Here is a more radical call for alternative solutions that celebrate a greater degree of coexistence between species. The author positions designers as the necessary imaginaries of new visions of cohabitation that are diverse, inclusive and multi-temporal. The paper proposes that this new environmental imagination has, at its roots, 'more-than-human' ethics, aesthetics and politics. The paper integrates a multi-disciplinary literature in establishing the otherness required to develop and sustain multispecies togetherness at all scales and in all places. The final paper of this section, 'The HfG Ulm and Sustainable Design: a comparative analysis' (paper 186), presents a historical analysis of the contribution of the Ulmer Institution (mid-20thC) to the development of contemporary sustainable design discourse and practice. The paper's comparative narrative uses a transportation context to illustrate examples of language and practice that reflect the forward thinking HfG Ulm contributions. The use of systemic approaches as integral to the Ulm Model of problem-solving, combined with ideas of resource optimisation (challenging the then emerging norms of planned obsolescence), ecological care and social equity all illustrate a design programme attuned to societal and planetary needs. It highlights that significant cultural and ecological challenges were recognised by some, early on in design education and practice. It is perhaps striking that where this comparison shows so much commonality with contemporary sustainable design, it also demonstrates a lack of progress in design research to imagine other ways to effectively respond to the ecological and social crises.

The second section also presents three papers. The first of these 'Over the Rainbow: Sharing a cross-disciplinary philosophy of waste through spectrum visualisation' (paper 285) usefully reviews a number of representations of resource flow and asks pointed questions of when waste is waste and when it is not, almost philosophically asking us to consider whether waste is a state of mind! The authors create a 'waste rainbow'; a useful visualisation of states of resource and how those states are ascribed waste descriptions at different stages of lifespan e.g. pre-waste, waste and post-waste. Each 'waste stage' has a number of interventions associated with it: from those that aim to prevent or postpone waste, to ways to transform waste (recycle or conversion) to post waste strategies that repurpose resources. With discussions of circular resource flow prevalent today, it is important to

reflect on traditional hierarchies and representations of waste and how it, as a 'construct', is positioned in complex systems of resource flow. The second paper in this session, 'Designerly Living Labs: Early-stage exploration of future sustainable concepts' (paper 307), address the complexity inherent in encouraging behavioural shifts towards more sustainable lifestyles. The Designerly Living Labs method used is based on empirical findings from four living labs to inform the development of concepts that nurture sustainable everyday practices in society. Through these living lab experiments the authors have developed eight characteristics that define the living lab approach and that enable design for behaviour change interventions to be trialled in creative and exploratory ways. Whereas sustainable lifestyles may sometimes be viewed as choice limiting and inconvenient, the living lab approach perhaps allows for more radical and structural interventions to be explored and played with in different spaces with engagement from a wider range of actors. The final paper, 'When behaviour change is about hot air: home systems should change behaviour to fit practices' (paper 401), explores the everyday practices of residents in differently ventilated housing and specifically the range of feedback required by people to understand how zero energy home ventilation operates and how it achieves effective air quality. Comparing behaviours of those living in controlled ventilated zero energy environments with those in more traditional housing stock shows that expected feedback signals are still relatively universal and behaviours are influenced by those norms. For example, feeling fresh air coming in through an open window as opposed to trusting a control switch to function and to provide the additional air flow needs in a more controlled ventilated environment. The paper looks at various examples of design for positive feedback to support and improve residents' understanding of new systems of heating and air flow and that encourage new practices of ventilation in zero energy homes.

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For more information on the Sustainability SIG, please visit the SIG's webpage at <http://drs.silkstart.com/cpages/sustainability-sig>. To find out whether the SIG is organising a satellite event to the DRS2020 conference, or just to get in touch with members and see news on the SIG, please visit the SIG webpage.



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Setting the Stage for Responsible Design

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Abstract: Designers have responsibility by the very nature of their activities; bringing new products and services into the world of the user. Recently there is also raising interest in specifically addressing social issues by deliberate design interventions. Within the University of Twente we strive to shape this responsibility in the context of the design of Human Technology Relations, combining human-technology interaction with scenario-based, user-oriented product design. The research groups associated with design have each developed their own perspective on how to implement this responsibility in design research and practice. Three different design approaches, each of which are strengthened with methods and tools. Although these three perspectives are complementary, they also have their limitations. In this paper we describe how we broadened the three research strands into a multidisciplinary research agenda through a workshop with a diverse group of participants. Providing the stage for a “Twente School” in responsible design.

Keywords: responsible design; design for society; transdisciplinary design; diversity

1. Introduction

Designing requires enormous social and moral responsibility as we are surrounded by products and services that shape – and simultaneously get shaped by – the way we live. Not only do these products and services serve utilitarian functions, but they also influence our norms and values in multiple and often unforeseen ways. Consider, for example, the dockless rent-a-bike mobility services that were introduced in many cities. They provide locals and tourists with the opportunity to explore the city in a healthy and environmental friendly manner. However, at the same time they flock the streets with broken and abandoned bikes. Papanek has appropriately phrased design’s influence on society in his seminal book, *Design for the Real World*, originally published in 1971:

“It is important to remember that architecture and design are the social arts par excellence. It is possible to avoid theatre and ballet, never to visit museums or galleries, to spurn poetry and literature and to switch off radio concerts. Buildings, settlements and the daily tools of



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living however, form a web of visual impressions that are inescapable.” (Papanek, 1995, p. 174).

In other words, designers have a responsibility towards others as what they create has inescapable consequences for nearly every living being in the world. This responsibility can also be extended to future generations, as design is a future oriented activity. To broaden the concept even further, everybody can be considered a designer. This is voiced by leading design thinkers and researchers such as, Tim Brown, the CEO of global design agency IDEO:

“Whenever we do something to improve the state of the world, we’re designing,” [...] “Design is everywhere, inevitably everyone is a designer.” (Tim Brown, cited in: Lavender, 2014).

and pioneer of emotional design Donald Norman:

“We are all designers. We manipulate the environment, the better to serve our needs. We select what items to own, which to have around us. We build, buy, arrange, and restructure: all this is a form of design. When consciously, deliberately rearranging objects on our desks, the furniture in our living rooms, and the things we keep in our cars, we are designing.” (Norman, 2004, p. 224)

Considering the omnipresence of design, we perceive this as a call to everyone, and most importantly to designers, to explicitly consider the responsibility of what we are doing everyday: i.e., the responsibility that comes with changing the world we live in. In our local context, which is the Industrial Design Engineering programme of the University of Twente, we explore questions surrounding the responsibility of designers in the Human Technology Relations track (Eggink, 2014; Eggink & Bijl-Brouwer, 2010). This exploration is embedded in the vision of the University, phrased as High Tech – Human Touch, wherein the organisation has set out design as one of the central themes in the development of the institute. Very broadly, “High Tech” refers to disciplines in natural sciences as well as applied and engineering sciences; and “Human Touch” refers to social sciences and humanities. In this vision, design is meant to be the ‘binding glue’ of the two kernels of our university. On the one hand, the technological advances are researched and created in our technology oriented departments, and on the other hand, insights in contemporary developments of society are researched by our department of Behavioural, Management and Social Sciences (Eggink, 2015a). Note that this vision is to be understood as high tech and human touch, instead of high tech or human touch. This also means that technology cannot be understood independently of its social influence. In this perspective, a technology is not valuable when it is not made applicable for users.

In addition, this vision has also been adopted by the DesignLab, the University’s cross-faculty eco-system for ‘connecting technology and society through design’ (Eggink, 2015a). As designers’ attention has expanded to addressing societal challenges beyond designing products and services, new research is required to examine the role of design in facilitating new ways of working with other disciplines to successfully unpack the historical, cultural, and technological issues underpinning such challenges. DesignLab forms a interdisciplinary platform for accelerating this type of research.

Following the arguments of Papanek, Brown and Norman, our goal in this paper is to provide a starting point for examining what Responsible Design means as an emerging research field. We address the questions: what is responsibility? And how can it be handled using a bottom-up, interdisciplinary approach? First, we discuss a preliminary definition of Responsible Design in connection to literature in fields that also utilize responsibility as a central concept, such as Social Design, Design for Behaviour Change, Participatory Design, and Critical Design. Next, we share the results of a workshop on 'Co-creating Responsible Design' conducted to reveal the pressing research questions related to this theme in our local context. Finally, we discuss our findings on how our understanding of Responsible Design differs from and contributes to existing discussions on the topic.

2. Responsibility & Design

We first start by taking apart the term 'Responsible Design' to better illustrate what can be meant by it. The term 'responsibility' contains the verb 'to respond' and can be interpreted as the ability to respond to the needs of and challenges faced by the society. 'Design' is to be interpreted both as a process – i.e., the act of designing – and the outcome of that process – i.e., the designed artefact. Noteworthy here is that the term design is used in its broadest sense and applies to the creation of 'design interventions', including but not limited to products, services, spaces and systems.

What marries these two terms – Responsibility & Design – is that the change brought about by design should be for the better. This simultaneously raises multiple questions such as: What is better and for whom (or what)? How to evaluate what's better? And how to deal with unforeseen consequences or unwanted side-effects of design interventions?

One of the 'responses' of the design discipline to the aforementioned questions is to deliberately design interventions to address social issues and societal challenges (Dorrestijn & Verbeek, 2013; Tromp et al., 2011). Examples include health related issues such as how can products encourage people to exercise more to fight obesity? Or to consume less to reduce waste? How should a robot system that supports people with dementia behave? And what does this mean for existing care-givers?

Another response to the broader question of responsibility is raising awareness through the encouragement of reflection. Critical Design, for instance succesfull in this by showing radical alternatives for common practices (Malpass, 2010). A more constructive response is the consideration of all consequences of design by incorporating stakeholders in the development process through Participatory Design (Ehn, 2008). Yet another response comes from interaction technology in the form of Value-sensitive Design, where the answer to "what is right?" should be understood from an ethical standpoint (Friedman, 1996).

These approaches are all unique in their goals and ideologies. What's similar is that they – implicitly or explicitly – account for the notion of responsibility as a core design concept. Based on examining the nuances among these approaches, we offer three categories on how to think about responsibility more explicitly. These categories first emerged when we started

to think about how we, as a design department, dealt with responsibility in the context of a research grant proposal (Eggink, 2015b). These three strands are:

1. Designing in a socially responsible manner by organizing the design process in a responsible way.
2. Designing in such a way that the responsibility of the user is addressed through the designed artefact.
3. Designing in such a way that the outcome (product or service) encompasses social responsibility.

2.1 Three Strands of Responsible Design

We will further explain these three strands of Responsible Design and how they are currently implemented in research and design practices in our local context:

1. Designing in a social responsible manner by organizing the design process in a responsible way.

Designing is a complex process that requires not only a creative problem solving attitude – but also the integration of multiple perspectives, values, and wishes. This means that all stakeholders who ‘have a stake in the matter’, should be involved in collaboratively defining ‘what is better?’. Traditionally, this is mainly the terrain of methodologies such as the aforementioned Participatory design and Value-sensitive Design. In our local context, this strand is researched within the chair of Human Centred Design which builds on the ideas of the participatory Design Movement (Garde, 2013), combined with developing theories from Scenario Based Design (Bijl-Brouwer & van der Voort, 2009). Especially, the question “what is better, and for whom?” is also addressed by Dilemma Driven Design (Ozkaramanli et al., 2017).

2. Designing in such a way that the responsibility of the user is addressed through the designed artefact.

Don Ihde argued that a product that is not used is ‘just a piece of junk’ and that the meaning of an object is only determined by the interplay of object and user (Ihde, 1993). One can say that the way of using a product is never fully defined in the product itself, and therefore the designer can also not be fully responsible. On the other hand, any design offers certain affordances for a typical type of use (Rietveld & Kiverstein, 2004) for which the user can not be held fully responsible. By deliberately balancing these two mechanisms one can shape responsibility by sharing it between designer and user. In our local context, this strand is represented by the idea of Open Script design (Stam & Eggink, 2014) which is developed within the chair of Interaction Design. In Open Script design, responsibility is shared between the designer and the user by leaving the exact use of the product (more) open to interpretation by the user (Stam, 2015). In the ideal situation then the answer to the question “what is better?” is also shared. Moreover, the answer can also still develop and be given more meaning during the use of the product.

3. Designing in such a way that the outcome (product or service) encompasses social responsibility.

This is mainly researched by investigating the impact of products in society and social context. Thinking about the consequences of new technologies is traditionally the domain of Philosophy of technology. Especially after the so-called Empirical turn, these consequences are also investigated for specific products (Brey, 2010). Imagine, for instance, the influence of the Walkman on the ongoing individualisation in society. In this case, the question “what is better?” is not directly answered but rather actively reflected upon from the expected consequences of design. In our local context this strand is primarily based on the collaboration between design research and philosophy of technology in the so-called ‘Practical Turn’ (Eggink & Dorrestijn, 2018). Within this collaboration, the impact of products can not only be investigated and reflected upon, but it can also actively be explored through design. Important instruments within this collaboration are, for instance, the Product Impact Tool by Dorrestijn (Dorrestijn, 2012; Dorrestijn & Eggink, 2014) and Mediation Theory by Verbeek (2005, 2011, 2015). In addition, the impact of technology can also be explored by the use of the aforementioned Critical Design (Lee et al., 2019) and the akin Speculative design (Lindley et al., 2018).

Although these three perspectives -or strands if we like to call them- are complementary, and can be powerful in supporting Responsible Design, they also have their limitations, namely:

1. Focusing on the process of designing, and incorporating input from all stakeholders gives less control over the actual outcome of the design process. At the same time, end-users and stakeholders are not always aware of what they really want, and thus, fully focusing on stakeholders can inhibit radical changes (Norman & Verganti, 2014).
2. Shared responsibility between the designer and the user means that the control over the outcome of the design intervention is also shared. This further limits the agency of the designer (Tromp et al., 2011).
3. Focusing on the impact of the product or service itself relies on the analysis in hindsight: these theories are mostly applicable to products or services that are already in use (Raub et al., 2018).

Covering Responsible Design in this context thus becomes a balancing act. To develop the notion of Responsible Design further and to address the issue that the responsibility is not limited to Industrial Design Engineering, we organized a workshop with participants from various disciplines in our local context.

3. Co-Creating Responsible Design Workshop

The goal of this half-day workshop was to do the balancing act together. We therefore wanted to explore how the participants dealt with responsibility in their own discipline and how they connected to Responsible Design. We also wanted to raise awareness for

Responsible Design and work towards developing research questions. As a result, we dealt with two main questions in the workshop:

1. How do you handle ‘responsibility’ in your work?
2. What might be the pressing research questions for ‘Responsible Design’?

3.1 Method

A total of 19 persons participated in the workshop, from which eleven were researchers from the university, five were students and three were the facilitators. From all the participants, six identified themselves as doing work in a design-oriented discipline. Backgrounds outside the design discipline ranged from Science and Technology Studies, Computer Science and Communication Science, to Public Administration.

Following a short introduction to the topic and the goals of the workshop, the participants engaged in discussions in randomly assigned groups with equal sizes to address the research questions. We structured the discussions in two main phases of approximately 1 hour each. The first phase focused on the question “How do you handle ‘responsibility’ in your work?” First, the participants were asked to share their individual perspectives, and next, to reflect on and discuss the similarities and differences in what they heard. They were asked to summarize their conclusions in a template that corresponded with the three strands of Responsible Design (see Figure 1).

Responsibility can be created / shaped in three main spheres:

1. Designers, 2. Society, and 3. Objects (technologies).

Can you categorize the ways in which you handle responsibility in your work according to these three main spheres?

1	2	3
<p>Designers acting responsible – relating to participatory design, co-design, being reflective, designing with empathy, gender neutral design, and inclusive design.</p>	<p>Enabling others in society to act responsibly, to be informed, to reflect and to make decisions – relating to open script design, critical design, design for democracy.</p>	<p>Creating objects that do not destroy the world – relating to sustainability and circularity in products, and also to the objects that make these possible.</p>

Figure 1 Template for the first exercise

The second phase focused on the question: “What might be the pressing research questions for ‘responsible design’?” The participants were first asked to brainstorm about possible important research questions to move this research agenda further, and next, to reflect back

on the discussion and choose the three 'most exciting' research questions, to be filled in at the a second template (see Figure 2).

What are the pressing research questions for 'responsible design'?
Use this side of the template to write the 3 'most exciting' research questions you came up with as a group.

1

2

3

Figure 2 Template for the second exercise

In addition to the pre-prepared templates, we used the flip-over sheets and post-its to capture the insights from the discussions. In addition, a photographer captured the interactions among participants and a visual artist captured repeating remarks or heated discussion points in illustrations.

Following the group discussions, all participants could individually vote for the most interesting research question using round stickers. As input for a plenary discussion and reflection, we displayed the three research questions with the most number of stickers on whiteboards. To stimulate an engaging discussion, we used the format of a famous Dutch children's television show (Ren je Rot: Run like Hell) to engage the participants with the selected research questions. Using this format, participants 'ran to' and stood in front of the research question they found the most exciting. We ended the workshop with a plenary discussion and reflection. This also served as a starting point for matchmaking and further collaboration plans.

3.2 Findings

Figure 3 and 4 show an example outcome of the group discussion addressing the question 'how do you handle responsibility in your own work?' We noticed that, in general, the participants did not experience difficulties thinking about the notion of responsibility in terms of the three strands in their own work. However, a common remark was that the three strands overlap.

Responsible Design can (tentatively) be defined as the act of questioning and shaping responsibility. Use this side of the template to record the similarities and differences in what you heard from each other about **how you handle 'responsibility'** in your project(s) / topic / expertise.



Figure 3 Example of poster with post-its addressing responsibility in the own practice of the participants.

Responsibility can be created / shaped in three main spheres:

1. Designers, 2. Society, and 3. Objects (technologies).

Can you categorize the ways in which you handle responsibility in your work according to these spheres?

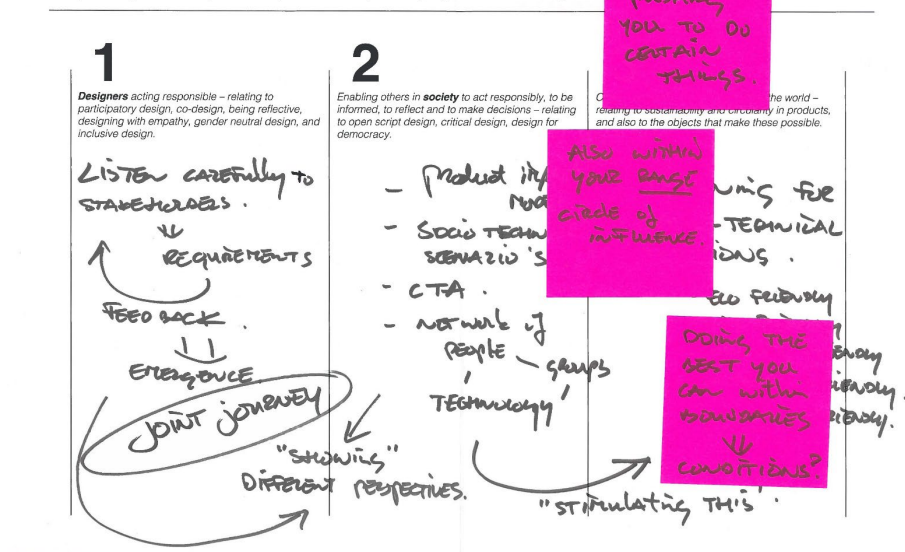


Figure 4 Example of a poster "How do you handle 'responsibility' in your work?", created by one of the groups.

Figure 5 shows a photo from the group discussions demonstrating the collaborative work between students and academics from various disciplines.



Figure 5 Participants of the workshop discussing (photo Enrico Bertolotti).

In addition, the sequence of images by the visual artist nicely summarizes the narrative of the group discussions, from problem identification to research statements (Figure 6 - 10). Seeing a visual summary of the discussions helped the participants to articulate concerns on the topic better and to build on what was captured (and not captured) through the illustrations which gave depth to the discussions. The captions illustrate the explanation that was provided with the images.



Figure 6 "Responsible design is open and inclusive" (image by Hugo Freutel).

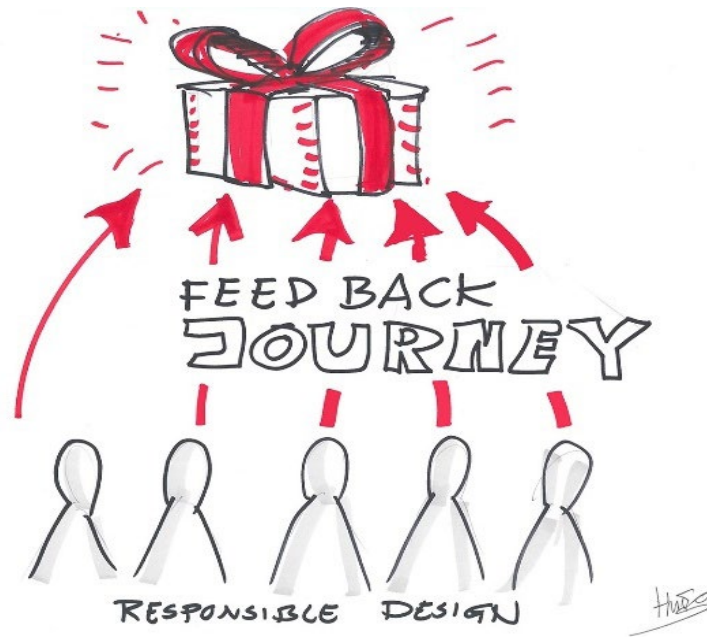


Figure 7 “Responsible design is about considering the consequences, by addressing the user” (image by Hugo Freutel).



Figure 8 “Addressing the user not always leads to the desired outcomes (because the user is only a partial expert)” (image by Hugo Freutel).

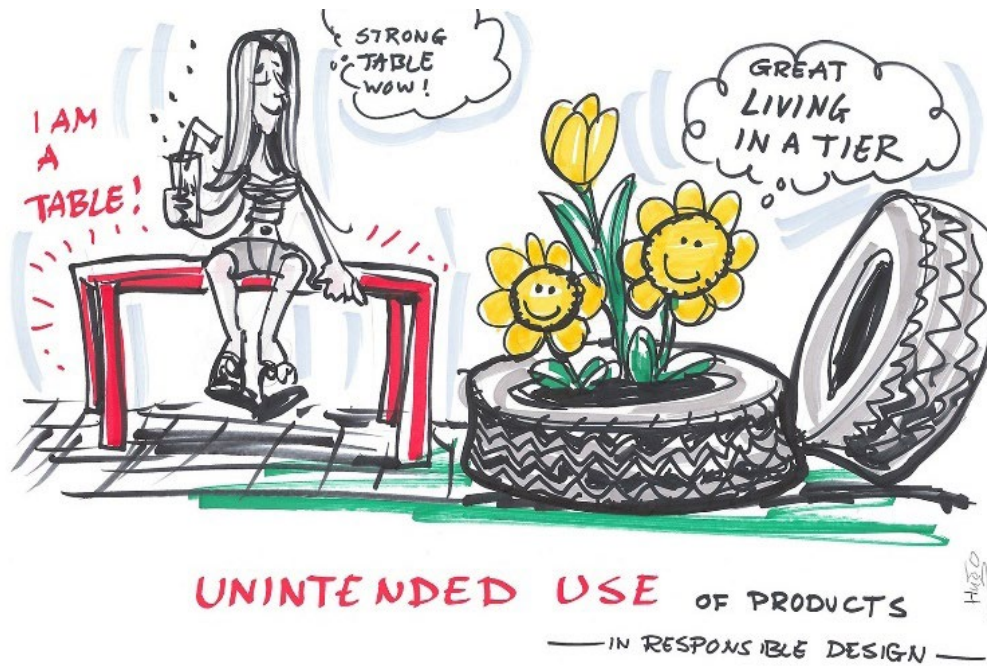


Figure 9 “Unintended use is a form of sharing the responsibility, however not always in a desirable direction” (image by Hugo Freutel).

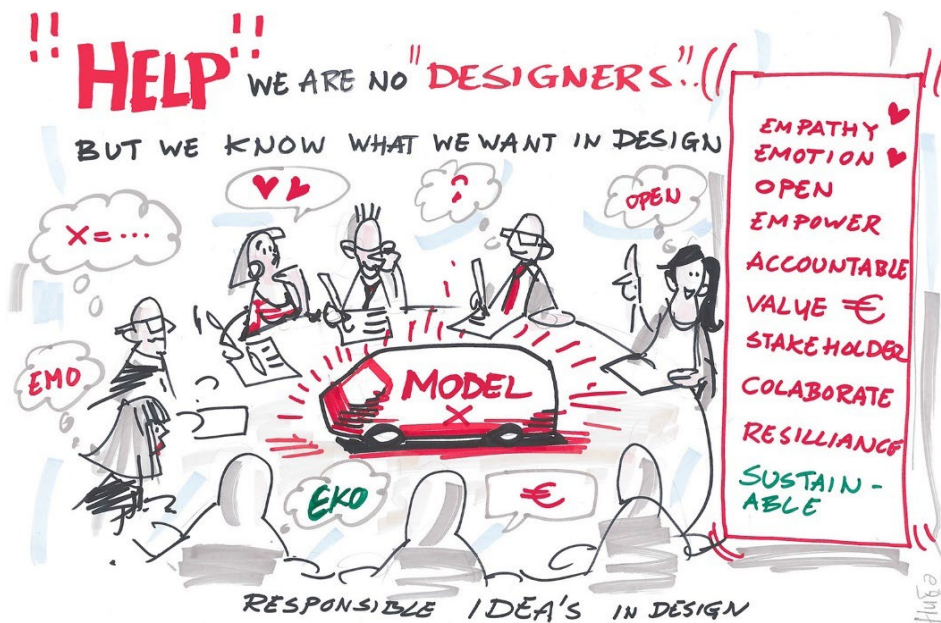


Figure 10 “If we are all designers, we also have to feel that we are capable of designing/have control over the design outcomes (?)” (image by Hugo Freutel).

In the second phase of the group discussions, the participants developed four sets of possible research questions within the same groups. Figure 11 shows an example of such a group result.

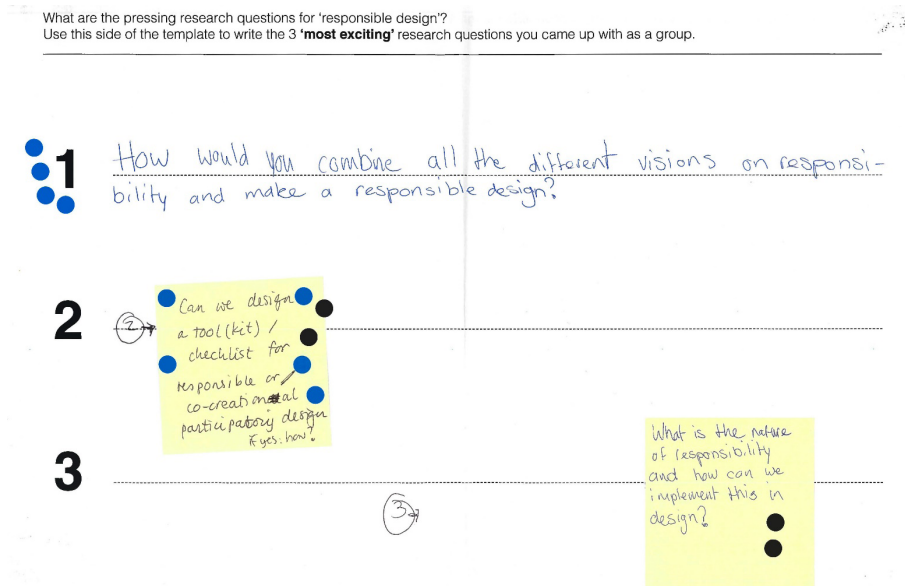


Figure 11 Example of a poster “What are the pressing research questions for ‘responsible design’?”, created by one of the groups. The black and blue dots (stickers) represent the votes.

All the research questions are gathered in Table 1. For each research question, the total amount of votes (i.e., stickers) is listed in the score column.

Table 1 Formulated research questions, with scores

Research question	Score
1.1 How to define RD from different perspectives?	4
1.2 How to create urgency for stakeholders to embrace RD?	1
1.3 How to make RD a mainstream concept?	3
2.1 How would you combine all the different visions on responsibility and make a responsible design?	4
2.2 Can we design a tool(kit) / checklist for responsible or co-creational / participatory design? If yes; how?	7
2.3 What is the nature of responsibility and how can we implement this in design?	2
3.1 How to include ethical reflection and human-technology interaction in design methods and design thinking?	2
3.2 How to make responsible design accessible for university research groups? (Values that matter plus awareness of ethical questions)	5
3.3 How to anticipate and evaluate future impacts of technologies?	5
4.1 How do [our] (working) conditions/contexts/incentives enable and constrain responsibly designing?	4
4.2 What is the range for which we can take responsibility (circle of influence)?	7
4.3 How to make visible the consequences of un-responsible behaviour?	4

During the workshop we decided to combine two popular questions that looked similar [e.g. 1.1 and 2.1] and selected two other ones that scored high [2.2 and 3.2]. The “Ren je rot” exercise showed that the resulting questions all sorted comparable interest of the participants. In the heat of the moment we oversaw one of the highest scoring research questions [4.2]. However, during the evaluation of the workshop, we came to the conclusion that this question could also be related to the first question about the different visions and perspectives on Responsible Design, which was then extended with defining the goals of responsible design.

3.3 Research agenda

Based on our findings, we arrived at a set of research questions that could form the basis for expanding the notion of Responsible Design within our academic environment. These three research directions with accompanying questions are:

1. How to combine all different visions? Or in other words: how to define Responsible Design from different perspectives? This aims at defining the goals of Responsible Design.
2. How to make Responsible design accessible for university research groups? Which aims at defining or developing a practice in Responsible Design.
3. Can we design a toolkit/checklist for responsible (co-creation / participatory) design? And if so, how? Thereby aiming at making Responsible Design applicable.

After the workshop we were also able to refine our definition of Responsible Design into the following:

“Responsible design is the act of questioning and shaping responsibility. This responsibility is uniting, open and inclusive. This responsibility is visible by addressing three main lines: designers, society, and objects (technologies).”

We also learned from the workshop that the threefold characterisation can work effectively to organise and structure the discussions, practices and research questions around this complex topic. Therefore, we will use these three categories as a starting point for further investigation:

1. Designers acting responsibly: relating to participatory design, co-design, being reflective, designing with empathy, gender aware or inclusive design.
2. Enabling others in society to act responsibly (to be informed, to reflect and to make decisions): relating to open script design, critical design, and design for democracy.
3. Producing things that do not destroy the world: relating to sustainability and circularity in products, but also to the objects that make the previous thing possible.

We aim to research the three strands in such a way that we can combine the pro’s and minimize the con’s to come to a better understanding of doing responsible design. For this,

our research at the moment encompasses three consecutive (?) activities:

1. A systematic literature review on what types of design approaches may fall under these three strands.
2. Using these three strands in a generative manner to evaluate the adoptability of the strands in design activities
3. Synthesis of a shared interdisciplinary framework based on the outcomes of the step 1 and step 2.

4. Discussion

In the first half of the workshop, the participants agreed that responsible design is important and should be diverse and inclusive. As can be seen in the images by the visual artist, the “challenges of responsibility” were also shared. The workshop method worked well in the sense that it yielded important research questions with a shared understanding of what they should deliver. Moreover, it showed that the questions designers and design researchers ask themselves about responsibility in design are shared with various other disciplines.

On the other hand, one can argue that by presenting the threefold approach as a frame of reference for the exercises steered the participants heavily in this direction. During the exercises the participants did question the three strands, as some reported to have difficulty with putting aspects of their work in either of the three categories. Leaving out the categories however would make the subject less graspable. This confirmed our idea that the three strands should not be seen as separate categories, rather as three different perspectives on the same topic. The strands form a framework for structuring discussion, reflection and development of the principles and practices of responsibility (and not to be interpreted as a taxonomy of responsible design).

Another point of discussion is the relationship between the proposed Responsible Design strands and other approaches. Fortunately, taking responsibility is not unique. The goals of Responsible Design are very akin programmes like Responsible Innovation (Grunwald, 2011) and Responsible Research and Innovation (Owen et al., 2012) so a lot can be learned from these programmes. The latter even has a three-fold characterisation:

“We [...] identify three distinct features that are emerging from associated discourses. The first is an emphasis on the democratic governance of the purposes of research and innovation and their orientation towards the ‘right impacts’. The second is responsiveness, emphasising the integration and institutionalisation of established approaches of anticipation, reflection and deliberation in and around research and innovation, influencing the direction of these and associated policy. The third concerns the framing of responsibility itself in the context of research and innovation as collective activities with uncertain and unpredictable consequences.” (Owen et al., 2012, p. 751)

Although Responsible Research and innovation makes a slightly different distribution, we see the same topics emerge: involving stakeholders (being democratic) as in our first strand; anticipation and reflection, and being responsive. The last statement about uncertainty and

unpredictable consequences is also related to the issue of impact and unintended use as raised in the workshop. Although directed at influencing the direction of innovations and policy, we think that the pro-activeness of design as a direct shaper of responsibility is not so apparent. Another difference is that Responsible (Research and) Innovation is still rather technology oriented, in the sense that it looks at future technology-society relations from a 'technology-driven' perspective rather than a 'people-driven' perspective.

Working together with the other disciplines in the workshop also yielded suggestions for possible practices. One approach that surfaced in the workshop is Constructive Technology Assessment, aimed at actively managing technology development in and with society (Albert de la Bruhèze & Oldenziel, 2009; Rip et al., 1995; Robinson, 2010). Although not particularly aimed at design, the advantage of this approach is that it has already a long track record in consulting 'society' through direct and indirect stakeholder involvement. Another promising direction is Citizen Science, which is also based on the participation of stakeholder groups (Phillips et al., 2013; Wiggins & Crowston, 2011). With the advantage that it is also targeted at real world problems, rather than technology oriented innovation (Cohn, 2008). Some Citizen Science projects are also geared towards impact and change (Jiang et al., 2016; Nascimento et al., 2014). However, there is still work to do in developing and integrating these approaches in the broader concept, as the report of the 2016 European Stakeholder Round Table on Citizen and DIY Science and Responsible Research and Innovation states: "For acting more responsibly, only including citizens is not enough." (Göbel et al., 2017, p. 10).

5. Conclusion

We have proposed a three-fold perspective on Responsible Design, emerging from our research and design practice. From the elaboration in a workshop with multiple colleagues from a wider field, we were able to rephrase our proposal for application within a broader notion of design. Based on the workshop we also pointed out a research agenda for our initiative. We expect our research to result in a framework that combines and/or integrates the three different strands of incorporating the notion of responsibility in design and beyond. This framework should also encourage the integration and collaboration of other disciplines with design by strengthening the mutual understanding of the topic.

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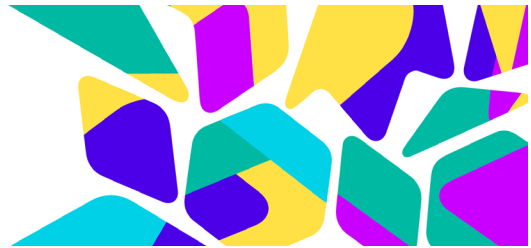
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Multispecies Cohabitation and Future Design

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Abstract: How should humans live with animals and other forms of life? Could responses to this question improve the health and wellbeing of the biosphere? This paper argues that design researchers ought to engage nonhuman lifeforms as collaborators: informants and co-designers, or clients and users. Inspired by recent design challenges involving birds, bats and trees, this paper positions emancipatory multispecies cohabitation as a goal that can alleviate ongoing biodiversity losses and human-wildlife conflicts, in cities and beyond. It opens an interdisciplinary conversation by translating emerging scholarship in ethics, politics, and aesthetics to a narrative about desirable more-than-human cultures. This discussion has significant implications and can help to inform regulation, instrumentation, and pedagogies of future design.

Keywords: more-than-human design; multispecies cohabitation; urban rewilding; sustainable futures

1. Introduction: Nonhuman Clients

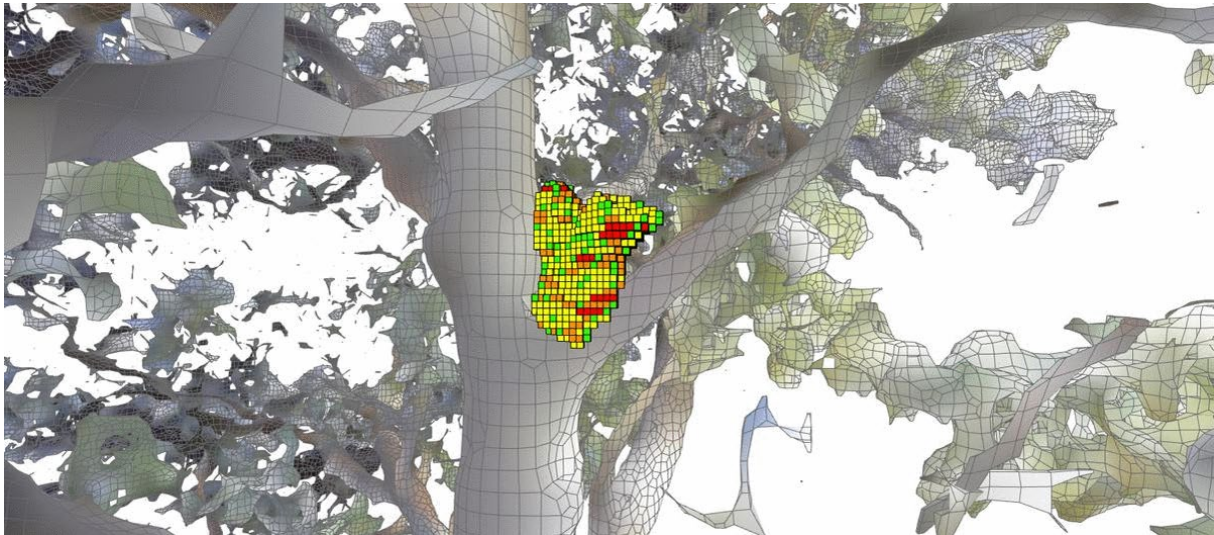
The ongoing COVID 19 epidemic is but one demonstration of what can happen to health and wellbeing if planning and designing do not engage with nonhuman life and whole ecosystems. This paper argues that design researchers should consider multispecies cohabitation and more-than-human cultures in all designs of future settlements. This position is inspired by existing projects for ‘nonhuman clients’ undertaken by the Deep Design Lab and its collaborators. These include designs of artificial replacements for bird nests (Fig. 1) (Roudavski & Parker, 2020), designs of artificial structures to replace disappearing keystone habitats such as large old trees (Fig. 2), analyses of existing trees in terms of their affordances for nonhuman life (Fig. 3) including their heritage value (Roudavski & Rutten, 2020), development of intelligent lighting systems to combat environmental light pollution (Fig. 4) as well as designs for insects, mosses and urban marine life.

A recurrent theme in these projects is the need to achieve persistent modifications in behaviours, traditions, and cultures of human and nonhuman cohabitants. If the efforts to make human-populated environment more hospitable to nonhuman life will prove to be



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successful, such challenges will multiply and become more important. Intellectually exciting and pragmatically significant, the task of understanding and cultivating broadly beneficial multispecies cultures will be continuously relevant for future societies. Yet, the common understanding of culture excludes nonhumans even though they permeate human bodies (Dunn, 2011) and human homes (Dunn, 2018). Human societies should learn to resist such exclusions because successful multispecies cohabitation will depend on designs that consider nonhuman as well as human cultures.



*Figure 1 Design of a prosthetic nest design for the powerful owl (*Ninox strenua*) in a host tree. Each nest fits precisely to the host's dimensions. Lead designer: Dan Parker.*

This paper thus seeks to highlight the need for a structural reform in human/nonhuman relations. It identifies the target of this change as thriving 'more-than-human cultures' and pencils some aspects of the resulting societies by collating scholarship from multiple fields. The argument first contextualises the inquiry. It provides a brief background to the current exclusion of nonhuman perspectives and its accompanying planetary crisis. It then considers the limits of human intentions and proceeds with an outline of sources that can support imaginative visions of interactions between diverse stakeholders, human and nonhuman. Having begun with design examples, the bulk of the paper is necessarily devoted to an interdisciplinary engagement. It provides illustrations of the challenges and possibilities in three domains: ethics, politics, and aesthetics. The conclusion suggests that while more-than-human cultures are both plausible and desirable, their theoretical grounding and practical development require much subsequent work.

2. Background: The Planet in Crisis

The human impact on the planet is undeniably dramatic. Today, most commentators agree that the situation amounts to a global crisis (Díaz et al., 2019; Laybourn-Langton et al., 2019). Some see it as an existential threat to whole ecosystems (Lenton et al., 2019), others – to

human civilizations (Spratt & Dunlop, 2019) or even to human existence (McKibben, 2019).

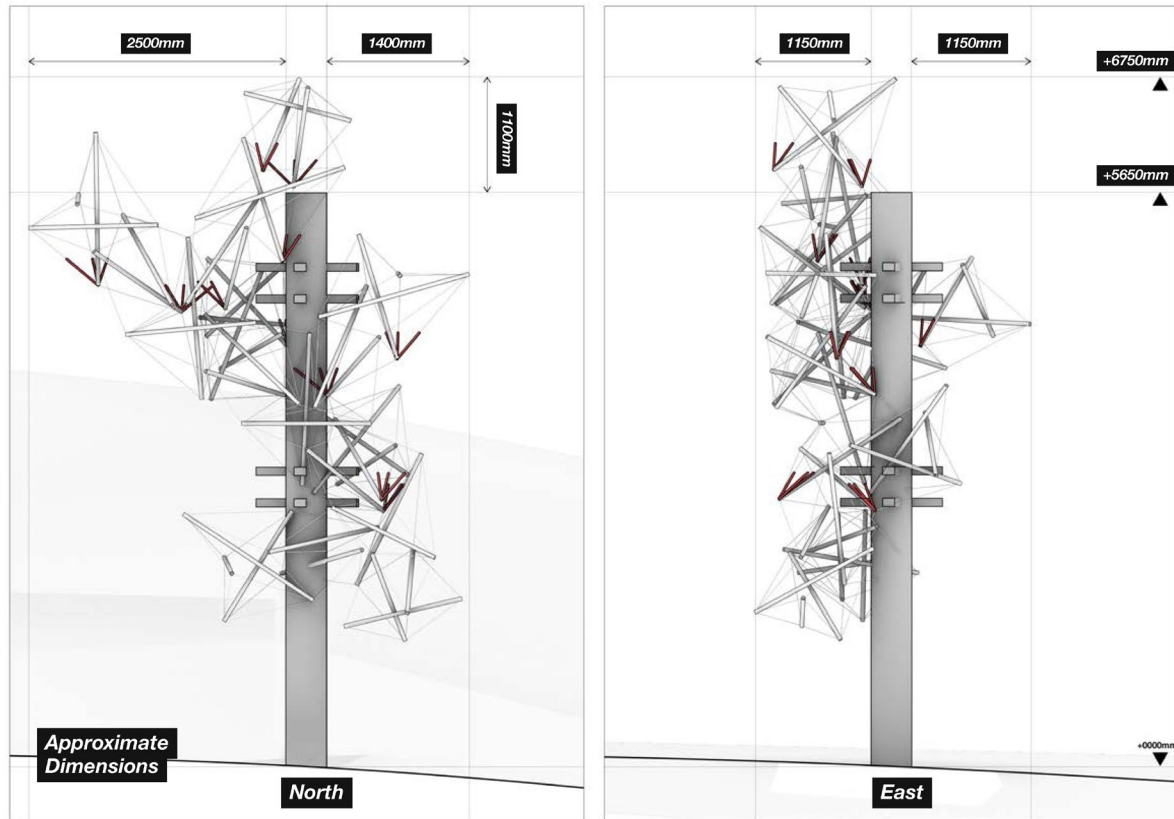


Figure 2 Design for a prosthetic tree that can serve as a habitat for arboreal wildlife. This image shows a version of tensegrity structure that can attach to existing telegraph poles. Lead Designer: Alexander Holland.

Much of this human impact is relatively recent (Dukes, 2011; McNeill & Engelke, 2014; Steffen et al., 2011). Yet, the damaging actions are persistent and ancient (Barnosky et al., 2014; Ellis et al., 2013; Foley et al., 2013). In the areas of human settlement, the diversity and abundance of nonhuman life have dramatically diminished shortly after the dispersion of *Homo sapiens*, sometimes many millennia ago (Diamond, 1989; see MacPhee, 2019 for a recent review in application to megafauna). For example, Australia lost 86% of its large mammal genera in 4000 years, an extinction that began about 45,000 years ago with the dispersal of humans (van der Kaars et al., 2017). The Americas lost up to 80% some 11,000 ago (Surovell et al., 2016) and in New Zealand moa birds have thrived for millions of years but disappeared abruptly with the arrival of *Homo sapiens* in the late 13th century (Allentoft et al., 2014). In most places, even the oldest human traditions have no tangible memories of the environments before these destructions, only echoes in old creation myths. Today, degradation and extinctions are on the increase. The estimates suggest that men, women and children have destroyed a tenth of the Earth's wilderness in the last 25 years (Watson et al., 2016). Most living organisms exist because of human activities.

A series of comparisons between human and nonhuman species provide important illustrations of the situation. For example, all humans weigh some 300 million tons. Their agricultural animals, including cows, pigs, sheep, and chicken, total some 700 million. This managed life together adds up to about 1 billion tons. In comparison, the combined mass of all surviving large wild animals is less than 100 million tons, ten times smaller. The contrasting numbers of species are also telling. For example, according to recent estimates, the Earth supports some 1.5 billion cattle but only 80,000 giraffes, 400 million domesticated dogs but less than 200,000 wolves and 250,000 chimpanzees but 7 billion humans (Harari, 2014, Chapter 18). Human control clearly extends beyond agriculture, with most of species surviving in intentionally managed habitats. The wilderness is already overwhelmed.

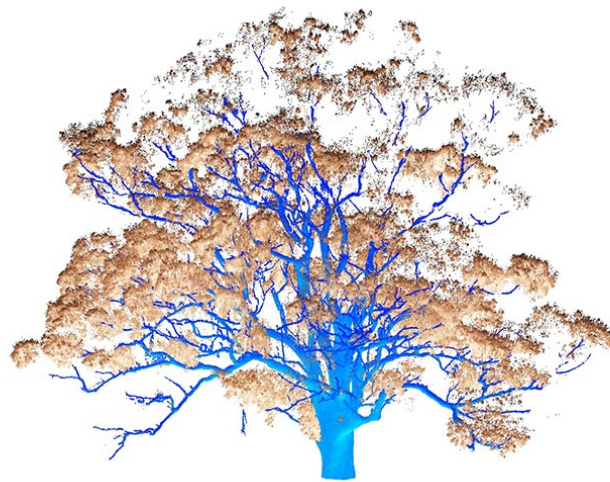


Figure 3 Feature recognition and statistical analysis algorithms applied to a point cloud of a tree. This approach can inform designers about the features that are important for birds and bats, such as the length and orientation of roosting sites. Lead designer: Alexander Holland.

Against this background of the biosphere in crisis, human intentions stand out as a major cause. Of course, there are physical, energetic, and chemical constraints to planetary life. However, some key drivers of the degradation are civilizational or cultural (Clammer, 2016). Some called the negative impact of human-centred cultures the crisis of reason (Plumwood, 2001), others—the crisis in habits of thought (Morton, 2013).

Given the growing human populations and their increasingly pervasive influence, one inescapable problem is the cohabitation of human and nonhuman lifeforms. This challenge occurs in less affected environments as well as in substantially modified settings such as cities. While better protection of existing ecosystems is of utmost importance, there is a growing recognition that artificially changed environments, including inner cities and other urbanised areas, also require support as sites of valuable lives. Recent research shows that cities already house many species (Douglas & Goode, 2011; Gaston, 2010; Parris, 2016; Sandberg et al., 2015). Urban environments can serve as biodiversity repositories (Ossola

& Niemelä, 2018) and host many nonhuman organisms. It is possible—and reasonable—to significantly amplify this capacity. Such an expansion of cohabitation will not be without problems (Adams, 1999/2016; Soulsbury & White, 2016), including the increased potential for conflict, violence and other risks including bacterial or viral exchanges that can harm both humans and nonhumans. However, potential advantages for human and, especially, nonhuman life can outweigh or cancel the risks and call for the development of knowledge and practices that can make such cohabitation possible.

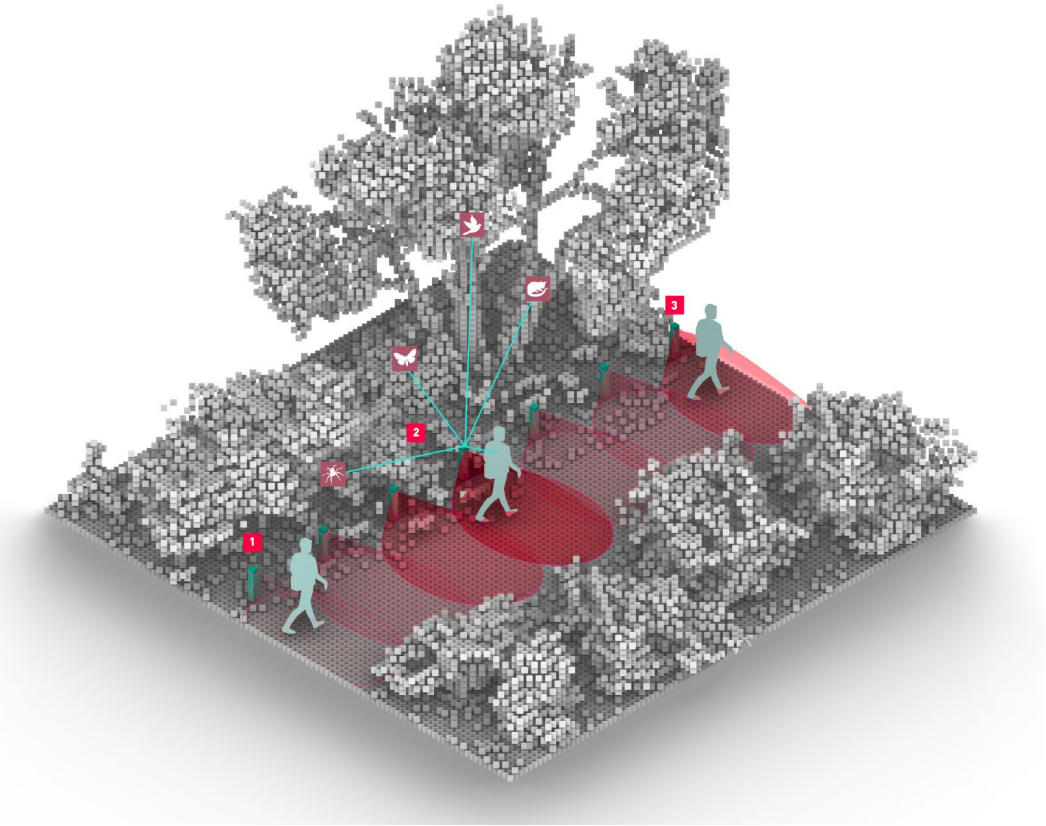


Figure 4 Design for a component of an intelligent lighting system that knows about historical and current behaviours of the local wildlife. Light pole activation is a minimal impact compromise between human and nonhuman stakeholder needs. Lead designer: Tony Yu.

3. The Will to Cohabit

Any attempt to design towards a goal of multispecies cohabitation will face considerable challenges that extend beyond the confines of current professions and disciplines. The scale and impact of these challenges are unfamiliar to science, to written records, to oral histories and to humans as species. Importantly, this venture is novel to human imagination. All past human practices have neglected and abused other forms of life, even if some are considerably worse records than others. What can inform a plan for a mutually rewarding cohabitation?

The aim to design for cohabitation presumes the introduction of further control towards intentional goals. However, such goal-directed planning can be difficult and sometimes impossible or undesirable. The dominant political paradigm prioritises self-organising market mechanisms and the resulting 'cheap natures' (Moore, 2016). Arguments that defend the autonomy of 'nature' (Merchant, 2016) or the need for spontaneity in place-making (McClay, 2014) doubt the usefulness of planning. The unpredictability of forecasting the behaviour of complex nonlinear systems leads to low confidence in planned outcomes. Tensions arising from the unfair distribution of hardship (Low & Gleeson, 1998; Sandler & Pezzullo, 2007; Shrader-Frechette, 2002) and distinct ways to pursue environmentalism (Guha & Martinez-Alier, 1997) complicate conversations about possible actions. It is difficult to notice the 'slow violence' of unfolding environmental change (Nixon, 2011). It is impossible to imagine socio-environmental conditions without being influenced by 'environmental imaginations' of others (Purdy, 2015). Humans struggle to relate to global patterns with no direct links to local practices (Heise, 2008).

The common outcome of these constraints on human intentions is the impression that no radical alternatives to the present are available or practical. Are there other options than growth, capitalism or consumerism? What are the contrasting choices to the ingrained cultural commitments to meat, eggs, milk, wool, silk, or sickly dog breeds? Such questions are relevant because they highlight the extent of societal changes necessary for any significant increase in cohabitation. As Plumwood (2009/2010, p. 32) argued, the most challenging task facing the world today is the engagement with "a thorough and open rethink which has the courage to question our most basic cultural narratives." Existing disciplines like political science explores a range of options including versions of ecosocialism (Pepper, 2010), green versions of nation states (Eckersley, 2004) and forms of a cosmopolitan global state (Held, 1995). Such efforts are necessary but will not be enough for practical change-making without an integration with the theory and practice of future-planning fields such as engineering and design.

4. Sources of Imagination

This paper suggests that design can contribute through the provision of inspiring and plausible visions of the future multispecies cohabitation. These visions need to broaden and concretize the space for alternatives. Such space needs to include extended time scales and diverse cultural practices. It ought to include a broad range of stakeholders, human and nonhuman. It also should learn from contrasting examples of cohabitation, however unpleasant or counterintuitive. These can be available through historical research, cultural or social studies of the present or as counterfactuals.

To illustrate, some more dramatic likelihoods of the near future can resemble past situations. For example, the current biodiversity collapse (Díaz et al., 2019; Kolbert, 2014) follows five other planetary extinctions. The plans for space colonization (Musk, 2017, 2018) evoke the biological unification of the Earth after the Age of Discovery (Crosby et al., 2004). The

predicted separation of humans into new species (Fry, 2012; Hawking, 2018) parallels the historical coexistence of multiple species of *Homo* (Berger et al., 2017).

In the order of such hard-to-imagine events, rewilding is one characteristic example. Rewilding is a deliberately future-oriented activity (Gammon, 2017), with nonhuman autonomy at the core (Prior & Ward, 2016). Such autonomy presupposes open outcomes that can appear detrimental to humans and nonhumans alike. In contrast to this emphasis on autonomy are the efforts to preserve cultural landscapes (Jones, 2003) that have formed over centuries, for example by the European Landscape Convention or the 'Caring for Country' (Lennon, 2018) approach practiced by Traditional Owners in Australia. There is a fear that such rich landscapes (Schama, 1995/1996) can disappear or become meaningless and alien. Others argue that there is no worth in preserving cultural landscapes that represent environmental harm (Monbiot, 2014).

The co-presence of such incompatible positions indicates the difficulty in imagining or planning towards any concrete future states. Instead, it might be more productive, fair, or plausible to think in terms of exchanges and procedures instead of destinations. When relationships are actuated into events without certainty, the agenda of multispecies cohabitation shifts from the making and implementation of plans towards the effort to specify the rules of engagement. These can take form of research methods, techniques of governance, approaches in education, technical tools, or design agendas. The resulting interaction between multiple ideas, ways of living and stakeholders provides procedural rather than prescriptive templates. In this context, design can play a useful role by staging 'design experiments' to test theoretical approaches as well as by building instruments to enable better integration of nonhuman participants.

5. The Challenge of Culture

Existing trends in conservation, such as the 'new conservation science' (Kareiva & Marvier, 2012) seek to emphasize the goals of protecting the environment for human benefit. Alternative views emphasize the need to preserve nature for its intrinsic values (Curry, 2011). The proposition of this paper is that the expansion of environmental imagination should not be undertaken by humans alone. The historical trend toward a more inclusive justice that emancipated slaves or women and seeks to include disempowered minorities should address the oppression of nonhuman life. Such approaches seek to maximize the freedoms of all entities, as, for example, through a reconsideration of nation states in critical political ecology (Eckersley, 1992, 2004) or in the proposal to extend citizenship to animals (Donaldson & Kymlicka, 2011).

The gaps in the current knowledge and the opportunities for contribution from within design lead to the key question posed by this paper: what conceptual and practical steps will be necessary for ecocentric, more-than-human design? This brief paper cannot answer the question in full.

Instead, it focuses on one specific aspect and hypothesises that any successful multispecies cohabitation will depend on design that considers nonhuman as well as human cultures.

To test its hypothesis, the paper first defines designing as an activity that happens in shared cultures. With this understanding, it considers the role of culture in three areas: ethics, politics, and aesthetics.

6. Forms of Interspecies Culture

By multispecies or more-than-human design, this article does not mean designs of farms, agriculture, zoos or aquaria (such as those described in Kisling, 2001). These and similar designs bring nonhuman beings into proximity with humans for human enjoyment (as pets or garden plants) or for other human-use purposes, such as nutrition (milk and flesh), sources of materials (wool and horn) or psychological therapy, for example. Designs of this type aim to support human needs, often (or always) at some expense to nonhumans. These anthropocentric projects ignore nonhuman needs or intend to control and oppress. The celebrated penguin pool at the London zoo and the resulting hurt to the animals is a typical example (Gutierrez, 2019).

By contrast, this paper understands more-than-human design as a practice that seeks to benefit nonhuman as well as human stakeholders. As in other forms of design, more-than-human design can achieve better outcomes by designing 'with' nonhuman users and not only 'for' them. This need to 'design with' highlights the existence and importance of overlapping human/nonhuman worlds: spaces, structures, behaviours, memories, stories. The list of shared interspecies phenomena will vary depending on who is involved. The subjective interpretations of shared physical realities will also vary between species and individuals. Examples in this paper refer to the cultural overlap, evoking animals, but also (possibly) plants and various others.

6.1 *More-than-Human Ethics*

The first of these shared cultural areas is ethics. Morality in animals is an important emergent concern (Rollin, 2017). However, I must leave this aspect outside this brief paper. Instead, this section considers human-formulated ethics in application to nonhumans as the first step towards more inclusive cultures.

Reintroduction of nonhuman life into areas also inhabited by humans will necessitate a consideration of principles that regulate interactions between species and individuals, raising difficult questions about the applications of human power. For example, in 2019, Natural England, the official government's adviser, revoked general licenses for killing 16 species of birds including crows, woodpigeons and jays after a legal challenge by a not-for-profit organisation Wild Justice. This led to acrimonious protests and even death threats from farmers and shooters because of the resulting damage to lambs, young crops, and ground-nesting birds. This example is characteristic of the tensions between the interests of nonhuman life mediated via human cultures that class them as 'pests', 'endangered species'

or 'livestock'.

Similar tensions arise in other situations. In the Australian states of Victoria and New South Wales, the struggle to protect feral horses from those who want to remove (and possibly kill) them to preserve the native bush in the Alpine National Park exemplifies a tension between interests of a species and an ecosystem as well as a mismatch between the value of an introduced and native species.

Beyond these examples, human capabilities for rewilding begin extending into reviving. Is it acceptable or desirable to recreate mammoths or even Neanderthal children? Some human groups take such a possibility seriously, radically expanding cohabitation to encompass an even broader range of ethical concerns.

Existing research in ethics covers a broad range of approaches, from the often ineffective mainstream of animal welfare, to the proposals to abolish all animal use (Francione & Garner, 2010) and more speculative considerations of ethics in relation to other lifeforms, such as plants (Kallhoff et al., 2018). Approaches akin to Leopold's "land ethic" (1949) seek to include an even wider set of concerns and stakeholders including, for example, soils, waters, plants and animals. The challenge of cohabitation specifically highlights the need for the understandings of justice that could account for entire ecosystems, including their physical dynamics as well as the resulting intelligences, behaviours, and cultures. Such socio-environmental ethics should describe ways of being besides (or instead of) defining the codes of conduct (Dobson, 1990/2007). It invites a reconsideration of sociality in relation to non-human communities and all biosphere/noosphere (for the context on the noosphere, see Samson & Pitt, 1999).

Anthropologists such as Ingold (2000) and Descola (2013) show that some human societies have a history of seeing nonhuman lifeforms as integral to their cultures. Such societies think that the human self is part of the nature-culture continuum (Harvey, 2013). These attitudes typically occur in nonindustrial or indigenous communities, often leading to more caring (but as often still exploitative) attitudes to nonhuman neighbours. Unfortunately, such communities are increasingly rare. They provide valuable precedents for more inclusive ethics, but their views and practices often refer to intensely local and already non-existent or rapidly disappearing environments.

Future environmental challenges will require the inclusion of relationships and phenomena that are outside of such local traditions. Examples might include distant sources of pollution and the resulting climatic effects or remote consequences of production/consumption chains that extract resources from and deposit waste to remote regions, such as the unempowered and poorly protected Global South (Gould et al., 2008) or even the Moon and the asteroids. Already occurring and predicted migrations of human and nonhuman lifeforms in response to environmental change will also result in challenging novel conditions (Higgs, 2017).

To conclude on the contribution of more-than-human ethics in terms of the aims of this paper, I consider existing ethical approaches to provide a promising foundation for the consideration of future cohabitation. However, its ethical framing requires further

development. This is clear from the established topics in one of the more developed areas of moral concern: animal ethics. One recent edition of a comprehensive reader (Armstrong & Botzler, 2003/2017) lists sentient capacities; animal use for food, experimentation and biotechnology; issues with wildlife, zoos and companion animals as key topics. It does not explicitly address the issues of multispecies cohabitation or the capabilities of design. Another (Linzey, Andrew & Linzey, Clair, 2018), structures the issues differently and looks at control, captivity, killing and suffering. All are relevant in design, with control being particularly important. Further work is necessary in this domain, and the next section highlights some relevant existing research.

6.2 More-than-Human Politics

Human cultures have provided many framings for the notion of control, including politics, governance, and law. The precedents within this complex field range from tyrannies to anarchies. Animals, plants, and other subjects of multispecies cohabitation already pertain to this sphere of power struggles but merit and will have to obtain greater influence. The task of imagining a substantially different future poses political as well as ecological questions (Robbins, 2004/2012). Multiple recent examples can illustrate the challenges that multispecies cohabitation will only intensify. Should koalas have property rights over their forests (Bradshaw, 2018; Hadley, 2017)? Can rivers act as persons and have parliamentary representation (O'Donnell, 2019; Youatt, 2017)? Should cats and dogs be citizens and the wild ecosystems have legal entitlements of sovereign nations (Donaldson & Kymlicka, 2011)? Do sheep and cows or frogs and bees deserve labour rights (Cochrane, 2016; Porcher, 2017)?

Let me use this last idea as an illustration of one possible path. It proposes to consider all work as collective and distributed labour of humans and nonhumans (Battistoni, 2017). Suggestions include generic ideas on the solidarity between species as well as concrete rights for holidays, sick leave, workplace safety, retirement pensions and so on (Coulter, 2016). Such rights represent an intermediate solution. Their provision is a stronger choice than animal welfare laws, which many researchers and activists perceive as insufficient (Francione, 2009). At the same time, the introduction of labour rights is less radical than a parity between animal and human rights that the lay public typically sees as unrealistic or unacceptable. To date, practical implementations involve domesticated animals such as police or guide dogs. Similar rules can apply to wild animals. For example, workplace safety would prevent the use of pesticides that harms insects or birds whose labour benefits all ecosystem stakeholders, including humans, in cities or in the country.

To emphasize, the point of this section is that the project of multispecies cohabitation will have to consider who might enjoy or suffer from its effects, and how. Current capitalist, neoliberal political structures seek to put nonhuman life to work as capital, commodities, services or labour (Barua, 2019). It is necessary to guard the proposals for cohabitation from the adoption of templates that encourage further exploitation.

A viable approach might extend green or inclusive (human and nonhuman) deliberative

democracy (Smith, 2003). This can take the form of enfranchisement or political representation of 'mute' groups such as animals but also young, mentally ill or otherwise marginalised humans (see an overview in Garner, 2016). Another path is through citizenship/denizenship for animals (Donaldson & Kymlicka, 2011). Adoption of such approaches will call for design protocols that can:

1. Provide novel means to include nonhuman stakeholders because humans such as experts, indigenous knowledge holders, human/nonhuman family members or various human others can only represent nonhumans (Essen & Allen, 2017) with significant limitations;
2. Extend beyond representation to the construction of mini-publics (Fung, 2010) through the ongoing nonhuman participation in decision making and management; and
3. Widen into the participatory work of imagining possible futures, practically and morally (Mulgan, 2018).

Currently, most researchers understand social constructivism as an interpretative work by human stakeholders understanding their worlds in subjective ways. Design is relevant here because it is a collection of attitudes and practices that encourage and instrumentalise the construction of states that do not yet exist. Effective (or even plausible) approaches to doing this work with nonhumans will require further research.

Resulting multispecies-design processes will not only bring together various points of view and contribute towards productive communication between stakeholders but also provide patterns for the observation, appreciation and cross-adoption of creative skills and expertise. The challenge here is to acknowledge and cultivate skills emanating from nonhuman as well as human practices and cultures.

6.3 More-than-Human Aesthetics

Questions emerging from concrete design challenges require interactions in hybrid, human/nonhuman cultures. For example, should humans teach birds to migrate (Fritz et al., 2017)? Should children learn to accept as normal the dismembered parrots under owls' nests? Should urban designers teach birds or bats to see buildings as nesting sites? How might human education frame nature's spontaneity when it leads to death, decay, disease, or pollution? The amount of suffering among wildlife leads some to argue that the prevention of existence might be a better option for many animals (Tomasik, 2015). Most of this suffering has nothing to do with humans and recolors the much-praised nature's autonomy (e.g., see Heyd, 2007) as a questionable ally. The future of multispecies cohabitation will not escape engaging with such concerns.

The notion of a more-than-human culture, to which such questions pertain, cannot be given justice within a short paper. Instead, this section focuses on one aspect of culture: aesthetics. Aesthetics can serve as a useful example. Understood inclusively, aesthetics is a way to form subjective evaluations of the surrounding world (e.g., see Volland & Grammer, 2003; Welsch,

2004; Høgh-Olesen, 2018). Such evaluations can guide animal behaviour in the environment and society, for humans and nonhumans. It is one way to define subjectivity, which is a characteristic of all life (e.g., see Maturana, 1972/1980; Miller et al., 2019) and maybe even of all self-organising systems.

Aesthetics is undeniably significant in environmental management because it underpins thinking and practice of all humans, including scientists, professionals (Kovacs et al., 2006) as well as indigenous communities (Roque de Pinho, 2016) or the unconcerned. In the future, human preferences will increasingly influence which species will survive or vanish (Stokes, 2007).

Similarly, aesthetic values will play a significant role in multispecies design, framing data collection and interpretation as well as governance (Richardson et al., 2018) and planning. Rewilding can bring difficult aesthetic experiences. Some discuss such experiences as unscenic and ugly (Prior & Brady, 2017). When nonhuman life repopulates degraded or abandoned land, people often see the resulting spaces as feral and associate them with illicit or devious activities (Farley & Roberts, 2012; Gandy, 2012; Lorimer, 2015; Sinclair, 2011). In general, valuing nature's autonomy is still contrary to the dominant human-aesthetic discourse and practices (Godlovitch, 1998). Other interpretations are possible and do exist in many human-cultural practices. International artistic movements such as 'land/environmental' (Brady, 2007; Lintott, 2007) or 'systems' art (Halsall, 2008) provide some examples. Such movements can contain interesting models but emerge from and impact relatively confined 'artworlds' (Danto, 1964). Indigenous cultures with their spiritual perceptions and dreaming stories provide another. When human practices develop alongside ecosystems over extended periods, sustainable practices are likely to emerge. However, as discussed above, all human cultures produced substantial environmental changes with negative impacts on other lifeforms. Therefore, their aesthetic interpretations of the resulting environments and the remaining nonhuman inhabitants require interrogation.

Forms of Japanese aesthetics supply another example of cultural appreciations that appear to value natural processes because they prize qualities such as transience and imperfection (Saito, 1997, 1998, 2007). However, such aesthetics have been cultivated and practiced in dense cities by small numbers of privileged people who knew little about wildlife or ecosystem interactions. Consequently, Japanese traditions tend to appreciate highly stylised nature. They focus on individual species and lack ecological and ethical awareness (Kellert, 1991), leading to very low popular support for the environmental movement (Heuer & Shan, 2018; Mitsuda, 1997).

Such precedents and practices can be useful but given the novelty of the challenges it is also reasonable to expect that in many cases experimentation with new aesthetics, a reconceptualization of aesthetic categories and education of relevant human stakeholders will be necessary. In the least, it will be important to show how human aesthetics can extend to accommodate the agency of all relevant agents (including wild organisms).

Any serious effort aimed at including nonhuman stakeholders will pose further, more radical

questions. As mentioned above, culture and aesthetics frame understanding, learning, behaviour, and traditions of nonhuman as well as human organisms. Given that evolution conditioned human aesthetic preferences, it is reasonable to expect that other species also have aesthetic experiences or tastes. Birds, monkeys and raccoons can favour order, symmetry and regularity while many species differentiate between visual appearances or construct aesthetic displays (Ackerman, 2016; Davies, 2012; Hogh-Olesen, 2018; Prum, 2013, 2017; Ryan, 2018; Welsch, 2004; Westphal-Fitch & Fitch, 2018). Consequently, while the expanded human aesthetics would be an important advance on the current conditions, further and more challenging work on true interspecies aesthetics and, more broadly, on interspecies cultures will still be necessary to support design for sustained multispecies cohabitation.

7. Conclusion: Multispecies Cohabitation in the Future

While brief, the sections above indicate that future design of multispecies cohabitation will have to engage with more-than-human cultures. Existing work in biology, ecology, environmental history, animal studies, ethnography, geography, and other disciplines demonstrates that multispecies interactions are common, making focused design work in this direction appear plausible. To contribute, design disciplines will have to update their practices including education, certification, and tooling.

For example, notions of ecocentric (Kopnina, 2019) and ecojustice (Martusewicz et al., 2011/2015) education or radical ecopedagogy (Kahn, 2008) are relevant for the cultivation of the conducive approaches. In parallel, descriptions of desirable destinations can provide useful problem framing. These might include ideas for the abundant Earth (Crist, 2019), shared Earth (Wilson, 2016), the reconciliation ecology, the Ecozoic Era (Swimme & Berry, 1994), bioproportionality (Mathews, 2019) or ecological ethics (Curry, 2011). Initiatives like the Statement of Commitment to Ecocentrism or Architects Declare (highlighting the biodiversity emergency) provide further examples.

This paper positioned emancipatory multispecies cohabitation as one of the approaches that can alleviate the planetary crisis. The continuing loss of nonhuman habitats is not inevitable. Human settlements can house many more lifeforms than they do currently. With this in mind, the paper sought to point out some challenges of such cohabitation. It hypothesised that any successful multispecies cohabitation would depend on design that considers nonhuman as well as human cultures. To test this hypothesis, the paper sampled the implications of multispecies cohabitation in ethics, politics, and aesthetics. This discussion provides provocations for further theory construction and practical experimentation.

In summary, the paper argued that long-term planning is difficult on multiple counts, including insufficient knowledge, fundamental unpredictability of complex systems and disagreements about desirable futures. In response, my argument proposed a shift of attention from the attainment of preferred future states towards the organisation of relationships between human and nonhuman cohabitants. Many of the prevailing

environmental forecasts are gloomy and demotivating. Rewarding, plausible and just prognoses are harder to come by. While the prolonged and global outlook for multispecies cohabitation is uncertain, an ecocentric and multicultural approach discussed here is valuable because it provides exciting intellectual, emotional, and functional challenges that can motivate further research and practice. To fulfil its promise for a substantive refashioning of urban life, future design will have to abandon the anthropocentric bias of human governance and seek to extend the existing emancipatory trends to include nonhuman stakeholders.

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The HfG Ulm and Sustainable Design: a comparative analysis

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Abstract: This article presents a comparative analysis between ideas of the HfG Ulm and the contemporary understanding of Sustainable Design. The Ulmer institution, through an innovative curriculum, an articulated discourse and a significant set of projects, manifested an avant la lettre awareness of social and environmental issues. Through a series of case studies, the research looks at the School's approach to design problems, focusing on the design for transportation and systems. The purpose is to identify whether the concepts of Sustainable Design were present in these earlier developments. Considering the impact of its legacy, we propose the HfG as a predecessor of an understanding of design that, from its conception, is respectful towards the environment, seeks social equality and aims for society's improvement. A broader perspective will enable more accurate work in design projects with a Sustainable perspective: recovering valuable practices from the past to step purposefully into the future.

Keywords: sustainable design; hfg ulm; ulm school of design; design for sustainability

1. Introduction

The present work is an attempt to bring back ideas and approaches produced in the middle of the 20th Century at the HfG Ulm and contrasting them with contemporary Sustainable Design practices and discourses.

There is a neglected area, in present design discussions, concerning a historical acknowledgement of the HfG contribution to what is nowadays called Sustainable Design. Our work aims to broaden the current knowledge of the influence of the Ulmer institution in this area.

Mobility and transportation are key topics for sustainability. Transportation contributes to economic growth and trade opportunities, as a reliable and safe transport system helps to integrate the economy with the environment. Both people and goods need constant flow in order to operate, and an efficient transport system improves social equity, health,



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the connection between rural and urban communities, the exchange of resources, and more. Transport systems relate to more than vehicles. They involve access to services, environments where vehicles move, different types of vehicles according to different needs, and infrastructure to support all these systems.

In the 1967 Montreal exhibition, the school presented a panel with several vehicles and products related to transportation (Figure 1). To expand those cases, in several courses the students worked on vehicles (truck and bus bodies, utilitarian vehicles, affordable cars), road and traffic framework (lights, signals, gas stations), bus-related services (bus stops, shelters, ticket sales), among others (Figures 2, 3, and 4). Based on the facts mentioned above, and considering the HfG's concern for transport systems and logistics, a few of those projects were selected to be exposed in this article.



Figure 1 Exhibition panels from the Ulm School exhibit at Expo 1967 in Montreal, Canada. Photo: HfG-Archiv Ulm.



Figure 2 Gasoline pumps. Academic year 1964-65. Instructors: Gui Bonsiepe, Peter Raacke. Students: Franco Clivio, Horst Emundts, Peter Hofmeister, Verena Loibl, Thomas Mentzel, Alexander Neumeister, Edith Ross, Werner Zemp.

The following sections present a comparative analysis between information gathered from the *ulm* journal (published by the HfG in the 50s and 60s), the catalogue of the *Ulmer Modelle* exhibition (Hochschule für Gestaltung (Ulm, Germany) et al., 2003), and a contemporary bus shelter project developed and tested under sustainable design parameters, described in the *Routledge Manual for Sustainable Product Design* (Chapman, 2017).

2. The HfG Ulm and the design profession

Through the Ulmer texts and in the products developed at the School one can perceive these ideals: the betterment of the human life, consideration towards the user, minimisation of materials, honesty and transparency, innovation, simplicity, and links to the industry with aims to produce cooperation. Designers were presented as coordinators in the development of a product, from its conception to its final delivery to the client, assuming the responsibility of their practices (Hausmann, 2003; Rinker, 2003b). The designer's profile defined at the HfG Ulm was of an agent of positive change, in consonance with the definition provided by Simon years later, saying "everyone designs who devises courses of action aimed at changing existing situations into preferred ones." (Simon, 1996) This professional profile did not previously exist and had no place in the German industry when the school started operating in 1953. Only in the 60s, a handful of Ulm graduates inserted themselves in the industry and created some demand (Jacob, 1988).

Products designed at Ulm tended to present a long-life design; they avoided the addition of non-functional features and ornaments or decorations. Objects with the purpose of being consumed and discarded had no place in the school's programme (Bonsiepe, 2003).

This applied functionalism had its risks. The concept originated in the 40s, at a time of austerity when Germany had to reconstruct itself after the war's devastation. The economic situation improved in the 50s, by the time the school opened in 1953. Industry boomed, and it was the era of conspicuous consumption: after years of deprivation the wealthy wanted comfort and pleasure, and at this point, the HfG philosophy somehow failed to fulfil this need. There was no place for differentiated or individual wishes. Functionalism, can be perceived as "fitness for mass-production" (Jacob, 1988).

This tension between industry and social needs, in Jacob's words (1988), between "commitment to excellence" and "maximisation of profit", was an issue at the time the school was open, and it remains today, as addressed by several authors when speaking about sustainable design.

Some postures affirm that the work done at the HfG by students and teachers for big companies – such as the designs for Braun or Lufthansa – were targeting the idea of mass production rather than serving the public needs. However, work performed in the classes, where teachers gave the students the task of thinking on the public transportation services or the urban traffic, contradict these postures (Quijano, "personal communication", 2014). Nearly all these projects were dealing with the creation of services rather than a single object. An example was the ticket vending systems, which alleviated the job of the bus drivers by stripping them of the task of selling tickets. In the area of transportation, there was a heavy emphasis on social welfare and the community. A whole range of projects developed at the school were devoted to contributing to the public transportation services: from the design of urban trains to poster layouts with buses' timetables (Rinker, 2003a).

Placing *need* in the core of the design process leads to the optimisation of resources and puts human life as a central concern. By being resourceful in the usage of natural assets, we can lower the negative impacts of a product or service. Transportation, nourishment, shelter, education, health, communication, and energy are unavoidable areas of human activity and are needed by almost every community (Benjamin, 2017).

3. Reading the past with current Sustainable Design parameters

Relevant texts from the *ulm journal* (Journal of the Ulm School for Design) published in the 1958–1968 period, accounted the practice at the school as well as the theoretical topics discussed at the moment. These texts will provide evidence for analysing both ideas and projects. Later articles by authors linked to the HfG (teachers, students, researchers) will provide additional perspectives and details on products developed during the time the school was functioning. Together with this evidence, the HfG-Archive provided information and facilitated access to prototypes and material used at the school.

To analyse and help identify the sustainability of products, we will use some methods and tools suggested in D4S (design for sustainability) approaches. These provide techniques for boosting an environmental observance in products, systems and services; they promote efficient energy use, encourage recycling, and consider all the social benefits related to

usability, fair-trade practices, and social responsibilities (Bhamra et al., 2013).

Benjamin (2017) explains how sustainable design methods have the goal of decreasing the negative impact of human activities on the environment. There are several degrees of sustainability, making it challenging to find a proper measurement, which will indicate whether we are successful in achieving the goal. The most popular assessment parameter is carbon dioxide reduction.

Among the numerous terms and methods that connect with the notion of SD, Benjamin lists the following:

- Green Design
- Eco-design
- cradle-to-cradle
- Design for the circular economy
- Environmentally Conscious Design
- Sustainable Product Development and
- Design for social innovation.

From those terms and methods, the following parameters can be derived:

- reusability
- renewability
- recyclability
- longevity
- emissions and
- multifunctionality.

Another important consideration is the *need*. Although the perception of need can be subjective and dependent on context, Benjamin suggests essential categories to meet human needs such as transportation, resources, education, textiles, healthcare, communication, shelter, agriculture, and energy. The way these needs are fulfilled and how the resources are applied to the purpose can vary, and this is where Sustainable Design can contribute to improving the equation (Benjamin, 2017).

In the following section, we discuss whether some Ulmer projects on the theme of transportation, transportation systems, and concurrently, the use of systems and modularity might contain a sustainable design approach. To pair the Ulmer projects with contemporary sustainable design examples, we examine the *D4S Bus shelter for London*, a sustainable project by Benjamin & Stedman. The project has been described in chapter 12 of *Routledge Handbook of Sustainable Product Design* edited by Jonathan Chapman as “A journey of two designers” (Benjamin, 2017).

4. Ulmer developments and Sustainable Design examples

“Over a span of two decades, good design, *el buen diseño*, *bel design*, and *gute Form* have

become more or less international trademarks of German design. The concept met its first serious challenge in the 1970s (critique of functionalism), and an even stronger one in the early 1980s (postmodernism). Nonetheless, many German businesses have applied its principles with considerable success". (Bürdek et al., 2015)

The Ulm School of design has developed some iconic products, mainly in the project groups where faculty and students worked with industry partners, that gave the institution a worldwide recognition. The Braun electronics line that became archetypical has even created a style with a name: *German Design*. Bürdek et Al. (2015) explain that Braun developed a formal design language that soon was converted into the standard associated with features such as practicality, rationality, low cost, and neutrality. However, the school also took care of essential topics for the development of a fair society. Quijano, HfG-Archive director until 2013, explains that the design of traffic systems is an example of this. In 1967 the school participated in the Expo 67 Montreal, invited as one of the world's eighteen best design schools. The exhibition panels taken to Montreal were on methodology and transport systems. At the time, the academic level at the school was high despite the institutional crisis it was undergoing. This exhibition gives evidence on the social interest of the school curriculum. It was not only the producer of the Braun Style, as their interests revolved around cities' development, transport systems and the problems arising from these matters. There was, at the time, a crucial concern about the transport expansion, in which design had an extensive responsibility that touched all disciplinary areas. These projects presented at the Expo did not belong to the school's commercial development groups that worked under industry commissions. The projects represented the work performed during the classes, given by teachers concerned with actual topics related to human needs and social development, far from the commercial interest of an electronics consumer brand (M. Quijano, personal communication, 2014).

Transportation is a central sustainability topic. Solutions on how people move from one place to another are a concern for big cities in all countries. These solutions are vital to environmental issues, as transportation is the primary source of carbon dioxide. Transportation not only involves moving people, but also raw materials and merchandise: 85% of which is not in factories or shops, rather travelling through routes, in ships or planes, or stored in warehouses waiting to be moved (Thackara, 2005). Global sustainability deals with the reduction of this impact through all means and strategies. In the HfG Ulm this concern was shown through the years, not only through the products portrayed at the Montreal Exhibition but through multiple projects such as the compact city car Autonova fam, the small utilitarian moped for a mobile grocery, truck bodies, traffic lights, street lighting, petrol stations and gasoline pumps, bus shelters, and others.

Sustainable Design discourages consumerism and promotes an environmentally friendly lifestyle, one that will encourage the improvement of human well-being. The lack of advertising at Ulm favoured an approach through a rational methodology related to science and opposed to consumerism (Bonsiepe, 1965; Maldonado, 1964).

In the 80s, Ecodesign was presented as an approach that was good for the environment and

economically feasible. Later, sustainable design included social issues such as equity and ethics (White et al., 2012). It is interesting to note how the Ulmer thinking went even further from those concerns, as part of the debate present at the school was social equity, and a social-democratic conception of equilibrating and redistributing social benefits, for example, through efficient public transportation. This connection represents a significant link between sustainable design and Ulmer thinking.

The following subsections present a comparison between transportation projects done in the context of the HfG Ulm and a bus shelter for the city of London, done in 2008 – considered an example of sustainable design. An extra subsection extends on the use of systems in the HfG Ulm and its relevance in the context of actual sustainability conversations.

4.1 HfG Ulm Bus shelter for public transport

In the 50s and 60s, means of transport experienced explosive growth. This development brought new complex demands for design, and those changes were reflected at the HfG. As a result, signalling system, cars, utility vehicles, truck bodyworks, subway and train wagons, and related objects such as petrol pumps, traffic lights and public lights started to be regular exercises at the School (Rinker, 2003a). Projects associated with transportation were carried out at the Building Department: bus stop shelters, ticket kiosks, petrol stations, parking lots and bridges.



Figure 3 Bus shelter. Academic year 1967/1968. Instructors: Herbert Lindinger, Claude Schnaidt; students: Karl Gröbli, Jean-Claude Ludi, Richard Schärer, Michael Weiss.

The bus stop shelter (Figure 3) was developed as a flexible system of independent structures – roof (steel and fibreglass) and sides – that allowed different combinations creating open and closed spaces, and granting the possibility of attaching companion items such as benches, rubbish containers, and others. The advantages of this design are the versatile configuration allowing for simple assembly with removable screws, as well as easy maintenance and transportation.

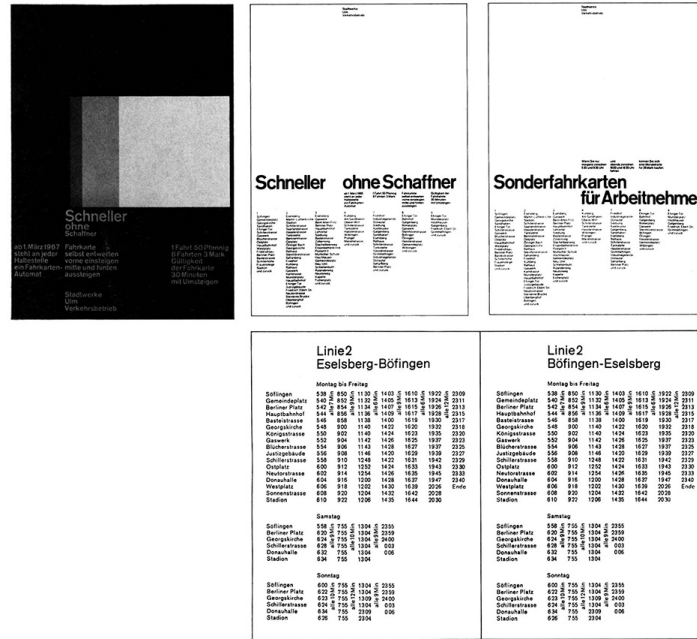


Figure 4 Advertisements and timetables for public transport, 1966/67. Visual communication department, 2nd year. Teacher: Herbert W. Kapitzki. Student: Karl Gröbli.

On the visual communication aspect, some new traffic signs were developed, working on the semantic aspect of them, together with road and transport safety campaigns (Figure 4). Those works focused on the transmission of information on printed material. The designers' research focused on optimising legibility through typography and layout. The local transport company finally implemented these projects as bus posters and timetables (Rinker, 2003a).

The system for petrol stations designed in 1963 by Herbert Ohl and Bernd Meurer (Figure 5) shows, as well, many characteristics of sustainability that can be noted for this analysis. The task consisted of creating a system of industrially manufactured standard units for petrol stations. It focused on the optimum use of grounds including access to roads, smooth running and staff organisation. It also considered the adaptability to various functions, combination and extendibility. The project included strategic, technical and physical analysis and planning, functionality and construction, cost, manufacture, assembly and manuals. Several sustainability concepts are observed in these petrol stations, such as spatial optimisation, accessibility, multifunctionality, or use of natural light. The stations can also be customised according to the size and terrain.

Following these examples, it can be asserted the Ulmer criteria followed scientific research of all factors involved in the design process, use of new materials, the formal and constructive development of the concepts, the rationalisation of resources, the social aspects, and a systemic approach.



Figure 5 System for Petrol Stations. Design: Herbert Ohl, Bernd Meurer, 1963. Photo: ulm 8/9 & HfG-Archiv Ulm, Ulmer Museum.

4.2 D4S Bus shelter for London, a sustainable project by Benjamin & Stedman

Benjamin and Stedman wanted to create and develop a product for public, everyday use (Benjamin, 2017). The goal seemed simple, but to explore sustainable solutions can be complex, as designers can find hidden challenges that will influence their decisions. The concept of “need” was the trigger for selecting what product to design.

Benjamin describes a 2008 competition from Transport for London to design a new city bus shelter provided a chance to give birth to a new product that could be compared to a successful existing one. The shelter is an essential item in a transport system that, with the possibility of moving a vast number of passengers per day, brings several advantages to human well-being and the reduction of carbon dioxide emissions. By enhancing the transport services, the city provides an cost efficient, safe and comfortable option to its citizens.

The shelter design proposals had to include technical specifications as well as indicative costs in order to be considered. Sustainable design was not part of the specifications, but Benjamin and Stedman were committed to present a sustainable shelter. They named it D4S Shelter (with D4S standing for ‘design for sustainability’). Their proposal was shortlisted for further development and received a high score for technical rigour. “We had assumed that a shelter made predominantly from wood was unlikely to progress in the competition due to technical concerns over the material; virtually all urban shelters are made of steel, aluminium or stainless steel. Furthermore, the supply chain for metal (ferrous and non-ferrous) is both sophisticated and mature. Therefore, the cost is reasonably predictable for the high-volume production of extruded and rolled components.” (Benjamin, 2017)

Through the use of Sima Pro, they carried out an LCA to compare the new shelter to the existing ones (Insignia), resulting in less than 10% of the environmental impact of the Insignia Shelter. The overall benefits were substantial, particularly the savings in CO₂.

Both the overview of health, ecosystem and resources analysis and the impacts on human life scored high for the D4S shelter.

Benjamin concludes in a D4S shelter overview that not only was the product excellent, affordable and suitable for the purpose, but it also followed sustainable design approaches. It was suitable for London's streets and intended to last at least 30 years. The selection of materials encouraged people's affection by providing generous seating, lighting, information and security, as well as easy maintenance and good ageing. The modular system will have a good fit for any road's characteristics, allowing a customisable configuration according to the needs.

The principles of sustainable design that can be outlined from Benjamin and Stedman shelter are:

- **Renewable resources with socioeconomic advantages:** use of sweet chestnut wood from a sustainable source.
- **Reuse:** will fit the existing foundations, installation can be performed quicker than the existing one, will save energy and cut costs. Glass panels from older ones to be reused as well.
- **Renewable energy:** solar panels on the roof will generate back-to-grid electricity. Payback of these panels estimated in 10 years of energy savings.
- **Colocation:** information case and flagpole are integrated into a totem to reduce space and avoid the installation of flagpoles, which would include digging and concrete filling.
- **Future-proofing:** a multipurpose area that can be used as seating space, advertising and information touchscreens. Wooden panels allow easy modification and update to other uses.
- **Product longevity:** most components have an estimated service life of 30 years (solar panel, CCTV, infrared detectors and ICT totem and electrics might be shorter). The wooden structure fits in the landscape, as well as having the ability to be easy to repair by non-specialist local woodworkers.
- **Optimisation:** utilisation of all materials was optimised in order to minimise both the number of materials and installation time.

Although the shelter commission was cancelled in the end, the D4S shelter proved to be a sample of sustainable design that will serve its purpose well. The experience helped the designers in the following task, that provided the city of Cornwall with Sustainable Bus Shelters¹.

1 More details on this project on Benjamin & Stedman's website <http://www.naturalshelter.com/>



Figure 6 Hans (Nick) Roericht. TC100 tableware. 1959 thesis project at the HfG Ulm. Photo: HfG-Archiv Ulm, Ulmer Museum.

4.3 Use of systems

The actual sustainability conversation urges to use an integral problem-solving approach as part of the design process. Shedroff emphasises the only alternative to efficient sustainability is a systems perspective, because many things are interconnected, and those connections must be addressed in a design task. This viewpoint involves financial, social and environmental implications. To understand a systems perspective, one must think of a system as a whole, considering all the factors which contribute to a particular activity (Shedroff & Lovins, 2009).

In Ulm, the design disciplines at the School were practised based on planning and systematisation. Marcela Quijano (2003) describes the concept of ‘design as a process’, radically opposed to the assumption that it could be a spontaneous achievement, a creative act, or even spurred on by a moment of inspiration in order to solve a given problem.

Some of the projects developed in Ulm showed systemic approaches, like those in areas such as tableware or food packaging. The projects granted the advantage of stackability, easy washing, modularity, standardisation and reusability.

Hans (Nick) Roericht’s 1959 thesis project (Figure 6) is one of the most well known HfG products, that even made it to the MOMA permanent collection. An industrial product that was transformed into an icon of German “Signature Design” – the antithesis of the HfG Ulm’s conception of design, as Gui Bonsiepe mentions in an interview with Groll (2015). It was licenced for Thomas/Rosenthal, who produced this tableware from 1962 until 2006. In 2010, HoGaKa started manufacturing and selling the set again, bringing the product out of the

museum stand and back to a regular public. It was conceived for gastronomic use in hotels, canteens, hospitals, and cruise ships. The TC100's compact conception covered several needs in a few systematised pieces, achieving rationalisation in production and use. Its concept changed the idea of crockery as pieces of personal artistic expression. It probably was the first set of tableware with the possibility of stacking every piece, even the sugar bowl, as the lids are flat and designed to be stacked on top of each other. The elements of the system belong to a few families of forms – in some pieces, the use of a double cylinder can be appreciated. The double cylinder design (a big one for the upper part and a smaller one for the lower part of the cups) allow a stackability of more than 8 cups, as they lock-in deep one on top of the other. The 120° angle between the base and the sides and the borders also facilitates the stacking.

Moreover, the same principle applies to other pieces. The ground-breaking feature of this set was not only the stackability but the fact that it was compact (in the name TC100, C stands for compact) and saved space when stored. This peculiarity was achieved by modularity, having all the elements following a grid system. For Ulrich Conrads, it was an example of compact-design. He notes that the project "...lies between the two extremes of functionalism (the slogan of which is: what functions well and fulfils the purpose is good and beautiful) and artistic expressionism. Compact-design demands experimental methods as well as the refinement of taste. Compact-design is creative design. Design with an idea" ('Notes on Ulm / Compact Style', 1962). Despite the simplicity of this design, there was probably no life cycle analysis, as would be appropriate today in sustainable design practice. However, instead, there was some thinking behind how to save an employee's time (cafeteria or bar), considering how it would be washed in an industrial dishwasher, dried and stored. Mäntele (2014) describes how, during the industrial production phase, there were *in situ* interventions to optimise the production of cups and other pieces. This dinnerware was produced for over 40 years so it can be considered a successful and sustainable product as well, even if the word wasn't used in the late 50s as it is used today, showing how *avant-garde* these designs were.

Apart from the use of systems, the TC100 set follows, additionally, sustainability principles such as re-utilisation and replacement of parts, against planned obsolescence. Planned obsolescence is criticised from the sustainability approach, both in theory and in practice. Material reduction, increase of product lifespan, part replacement and product repair as well as debating ownership and property are part of sustainable design debates on planned obsolescence (Cooper, 2017; Park, 2017; Tonkinwise, 2017). Hugh Dubberly (2008) draws on the idea of design in the age of biology and speaks about a shift from a Mechanical-Object Ethos – related to manufacturing – to an Organic-Systems Ethos – more connected to software and services. "The mechanical-object-organic-system dichotomy also appears vividly in discussions about ecology. Much of our economy still depends on 'consumers' buying products, which we eventually throw 'away.'" It proposes the idea of products-as-services.

Modules, series, and repetition were topics in the basic course. Starting with basic geometric

shapes, and moving gradually into forms, then 3D and complex structures. As explained by Bonsiepe (2012), the students entered the School with a previous background; they demanded a reason to understand why a design decision was better than another, an argument that is not easy to make. The systemic approach was combined with a structural point of view. The teaching of maths aspects related to groups and combinations was applied to the dimensional and modular coordination. Some examples of these approaches are architectural models showing modular structures whose aim was reducing the cost of housing, an essential goal at the department of architecture. Unfortunately, this hope was for naught because the low cost of construction was overridden by real state speculations on the land. Ultimately, the person in need of a home was not getting a low-cost benefit. This construction approach can be paired with some of the LEED norms such as indoor environmental quality, efficiency in the use of resources, use of innovative techniques and proper material selection.

The Students' housing using modular construction design by Herbert Ohl & Bernd Meurer in 1961 at the Institute for Industrialized Construction, is an excellent example to illustrate what was discussed in the previous paragraph. This HfG project carries several Sustainable Design concepts. For instance, the use of systems, modularity, simplicity, multifunctionality, low cost and ease of building. This idea of construction can be compared to modern green construction norms the purpose of which is to promote highly efficient and cost-saving green buildings. Schnaidt (1964) speaks about the "Prefabricated Hope", and he shows acknowledgement of the housing issues' political implications over technical aspects of building. The use of systems is, by far, not a guarantee of sustainability.

Nevertheless, the systemic vision in this modular housing project offers some advantages like an easy and simple replacement of parts that would age well, allowing a longer life for the buildings as a whole. This vision lowered the construction cost and the material optimisation as well. These are features portrayed in actual sustainable construction.

5. Conclusion

The Ulm School of Design (HfG Ulm) through its discourse, the educational Ulm Model and the projects developed by students and Faculty showed an *avant la lettre* concern and awareness of sustainability. Not having used the term, sustainability was part of the design definition that the school proposed, with a programme that included social equity, resource optimisation and respect for the planet and the environment, which are now considered main pillars for sustainable design practices. The connection between sustainable design ideas and the Ulmer institution could offer a different approach to current design practices.

Transportation is one of the main concerns in sustainability issues, and solutions for commuting are critical for the environment. This topic was highly relevant and extensively discussed in Ulm. The motorisation wave between 1955-1970 caused an automobile growth from 1,693,000 to 13,941,000, transforming cities and demanding new ways of dealing with the transit (Hausmann, 2003). New and complex challenges opened to the design

realm, and echoes of it were heard at Ulm. At the Industrial Design department, they dealt with Signaling systems, utility and personal vehicles, railway wagons, and other supportive products ranging from petrol pumps to street lights. Traffic-related structures such as bridges and parking lots were typical assignments from the Building Department. At the Visual Communication department, assignments include new traffic signs and advertising campaigns related to urban transit.

“Whether they were student projects or commissions undertaken by the school’s commercial development groups these transportation designs serve to exemplify criteria specific to Ulm: the scientific analysis of all design-relevant factors; the use of new materials; the formal and constructive development of space and resource-saving concepts; and systematic thinking in two and three dimensions. Consistent disciplinary cooperation between all the departments of the school resulted in forward-looking developments in the field of transportation.”

(Rinker, 2003a)

Victor Papanek (1971), in the 70s, addressed how the automotive industry in Detroit was pushing for car renovation every three years. That frequency was a response to the factory’s manufacturing part lifespan. The industry kept functioning but created a disposable culture, which smoothly advanced onto categories like clothing, furniture, and electronics. Years later, we see how this disposable culture has taken a toll on the Earth’s health.

Much earlier, in the 60s, the Ulmer thinkers were raising the same issues. Ohl warned not to take the implementation of new materials as a fashion, or as design-oriented to obsolescence, as it was in the consumer goods industry. “Design is a coordinated procedure; design is an activity directed towards balancing all aspects of a problem to be solved.” (Ohl, 1965). Moles first mentioned the concept that actual sustainability targets, *planned obsolescence*, using the term *incorporated obsolescence*. He debated about the crisis of functionalism and the need to produce and sell relentlessly. A way out of this dilemma was “...the technique of *incorporated obsolescence*; artificial breakdowns of function are built into the product which after a certain period of use will collapse...” Moles questions whether functionalism is dead as a design philosophy, as there are severe contradictions with the affluent society, which “...on one side contributes in rationalising the mechanism of affluence, on the other side fights against waste.” (Moles, 1967) This concept is, as well, a principal contradiction in the actual Sustainable Design discourse, and a concern that this paper wants to address.

The use of systems was present in many of the Ulmer projects. System thinking and how to create complex structures using simple techniques were part of the exercises done by students. These ideas were translated into different product categories, as shown in previous sections (stackable crockery design by Nick Röricht, the student’s housing building, the petrol station systems, and other projects).

This brief recap from selected work by Ulmer students and teachers shows how objectively the concept of design contained a sprout of sustainability. Those projects did not bring out environmental concerns that were not present at that time. However austerity,

multifunctionality, use of systems, obsolescence awareness and research practices were considered.

The flexibility and diversity exposed in these examples are characteristics asked of sustainable products. Manzini points out the diversity and complexity of natural systems (often combinations of multiple independent systems) are the basis of their resilience, in other words, their ability to adapt to changes (Manzini, 2013).

However, one of the most exciting aspects of modern sustainability, that separates it from being just an instrument to lower energy consumption and material costs is the idea of a change in behaviour, and not just optimising production. Manzini is promoting a cultural and behavioural gate to sustainability through cultural changes and demeanour (Brooks, 2011). As he asks how a designer can help people change their conduct, he sees that these changes have already started (and there are positive improvements). Therefore, what comes next is how to guide these changes, enhancing this new way of doing and thinking about social innovation with knowledge and appropriate tools.

The promotion of a culture of sustainability (Wolf, 2013) is a crucial tool to encompass sustainability from diverse areas: technological, political-economic, and tradition-innovation. In articles from the *ulm* journal they were also discussing change through behaviour and culture, the acknowledgement of not only a “physical environment but also behavioural environment” (Maldonado, 1965) and a critique to the lack of commitment in the modern architectural practices (Schnaidt, 1967).

Presenting the comparison offered in this paper, we want to revisit some concepts of the past, creating a dialogue with contemporary discussions. Looking at the questions held decades ago, we understand that they are also relevant today. Finally, this conversation could lead to the creation of more desirable futures.

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Over the Rainbow: Sharing a cross-disciplinary philosophy of waste through spectrum visualisation

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Abstract: Waste is a material problem and a cultural condition. Many philosophies and visualisation resources exist for addressing waste such as waste hierarchies and circular economy diagrams. These diagrams, however, are not always enough to represent the intrinsic complexities related to waste systems or the interactions that exist between current and potential interventions. In this paper we contribute an original framework for understanding waste and propose a visualisation of waste as a spectrum of possibilities rather than as a series of discrete, disconnected interventions. The Waste Rainbow invites users to “plot” interventions and to think about these interventions and their relationships with the system on multiple stages of the life of an object.

Keywords: waste; design; circular economy; transdisciplinarity

1. Introduction

From the moment we wake up in the morning to the minute we fall asleep we generate some sort of waste in the world. Be it an annual spring cleaning or the everyday bits of “invisible” disposals such as food scraps, packaging, unwanted objects or body waste. In fact, even when we sleep we are still releasing old skin from our bodies. Waste is a condition of all living things, as part of the cycles of life, we consume resources, process them and dispose of what is not useful. Humans have excelled in this process, extending the consumption and processing of materials much beyond that of the necessities of our bodies and lives. We consume what we need and what we don’t need. Some of what we need is processed and given a lifetime of use, other items are used or contemplated for just a few moments before being disposed of without second thoughts. Social scientists, anthropologists and thinkers from multiple disciplines have warned us and commented on the consequences of the paradigm of growth and overconsumption from as early as 1960’s (Fry, 2009; Humes, 2012; Packard, 1960; Strasser, 2000). Today, consuming and throwing “out” is ubiquitous, desirable, stimulated and feels good. Yet as we consume and throw away our waste accumulates in the outskirts of the cities either in landfills or waiting for a chance to be recycled.



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Although managing waste is a perennial human task, witnessed in ancient middens to modern landfills, in the present day the problem of waste has become far more pressing. As environmental degradation accelerates, waste from overproduction and overconsumption is both a cause and a symptom of unsustainability. The reduce, reuse, recycle mantra of the past twenty years has evolved into the proposition of the circular economy, in which waste must be 'designed out' of the system.

Within this context, we propose a new conceptual framework to understand, visualise and manage waste reduction interventions and policy. Our framework is based on a systemic understanding of waste and we use complexity and resilience theory to explain and visualise the multiple states of circularity of matter before it falls into landfill state—the state of waste from which there is no recovery or the energy necessary for recovery is too high to be feasible. Our framework, the 'Waste Rainbow' embeds the synergy between multiple disciplines that need to work together to tackle the state of waste. It can also accommodate the connections between the different states and different types of waste (whether organic, e-waste, plastic, textiles), which are often tackled separately, but are too intimately connected.

1.1 Context

Queensland University of Technology (QUT) is a major university in Brisbane with a strong focus on applied research. Researchers collaborate as part of the Institute for Future Environments (IFE) from disciplines within science, technology, engineering and mathematics (STEM) as well as disciplines within humanities, arts and social sciences (HASS). Since 2017, a growing community of researchers have formed a shared interest in tackling the problem of waste. Current research projects are focused on various waste streams including plastics, textiles, food and organic waste, e-waste and construction waste. Team members come from STEM disciplines including polymer chemistry, microbial biotechnology, materials science and robotics. HASS researchers are from disciplines including law, marketing, sociology, visual communication and fashion design. Given both the diversity of waste streams and the variety of disciplines involved, research projects are also diverse. Examples include qualitative investigations into government policies around plastic waste, a study on community food waste, numerous engineering projects converting different forms of waste (e.g. agricultural, other organic, textiles) to value-added products, and design-led research with an end-user focus in preventing household plastic waste. As designers, the authors saw an opportunity to map and order the varied activities underway within our transdisciplinary research group under a coherent narrative. The visualisation developed, the Waste Rainbow, is presented in this paper.

1.2 Methods of inquiry

The methods of this paper comprise a literature and contextual review of waste, the circular economy and how these concepts are visually represented; assessment of the efficacy of other visualisations of waste and the circular economy; and design research methods for

development of a fresh visualisation. Visualisations were located through image search engines using the key words of ‘diagram; waste’ and ‘diagram; circular economy.’

Given the context described above, three criteria were developed for assessing the efficacy of a visualisation: (i) the framework should be transferable to a variety of waste streams, (ii), the framework should be able to encompass both HASS and STEM methodologies for waste research and (iii) the framework should allow for the visualisation of connections between multiple interventions.

This paper is structured as follows: First, literature on waste and the circular economy is presented. Second, authors provide a contextual review and assessment of visualisations of waste and the circular economy. Third, the authors outline the design process for the Waste Rainbow, a visual representation of a specific approach to waste research. Last, a short assessment of the framework and its visualisation is presented, highlighting its benefits and weaknesses, through examples of its use in research practice.

2. Understanding waste

Waste can refer to any matter that has become surplus to requirements. Waste can also refer to wasted time, wasted energy, wasted work hours. Every system, whether biological or human-made, creates waste, inevitably by-products or leftovers decay or fall out of usage (Moser 2002). Waste in its physical form, whether waste water, waste plastics, food waste, or human biological waste, is associated with pollution, disgust and damage, and ‘garbage is civilisation’s ... shadow’ (Scanlan 2005, 179). Anthropologist Mary Douglas (1966), in her analysis of society’s need to create systems of order, memorably refers to dirt as ‘matter out of place’. People ascribe value to objects, things, materials for diverse social, economic, historical and cultural reasons. In human society, things become waste when they are seen or found outside of those cultural or economic systems of value and become ‘matter out of place’, unwanted and valueless. Yet waste is not the definitive state of being of that matter, but rather a state into which it has been ‘put’ through human decision-making. Matter can move in and out of this state of waste depending on context.

Within environmental narratives, waste is the by-product of overproduction and overconsumption, a visible marker of pollution and profound environmental damage. It is a symptom of contemporary society (Humes 2012, Strasser 1999). As matter viewed as abject, waste must be sent ‘away’ for others to deal with. Frequently the scavengers, gleaners and the ragpickers, those who deal with waste, are those on the margins of society. In the Global North, waste is exported to the Global South. Yet while out of sight, out of mind, waste still exists somewhere—there is really no ‘out’ for waste.

Waste is often framed as a problem that needs to be ‘solved’ with a range of strategies and approaches to tackle it. In the many ‘R’s associated with waste management, waste must be reduced and avoided through refusing, reusing, repairing, remanufacturing, as well as recycling and reclaiming materials. As cultural theorist Gay Hawkins (2006, ix) writes, the drive for recycling as a strategy for tackling waste “have implicated waste in the formation

of new circuits of guilt and conscience and practices of self-regulation". Individuals are implicated for their wasteful behaviour, even as governments and industry acknowledge that the problem of waste is 'wicked', i.e. an intractable problem that resists solution, and itself is a symptom of another problem (Rittel and Webber 1974).

Design has long been implicated as an activity that is inherently waste-making, in service to an economic system requiring continual consumption of virgin resources. A repositioning of waste comes from industrial ecology and for the past fifteen years has been popularised by the Cradle-to-Cradle concept, in which waste becomes 'food' for new cycles (McDonough and Braungart 2002). A core concept of 'Cradle-to-Cradle' (C2C) is to develop a life cycle for products that emulates the life cycle of nature. McDonough and Braungart propose two streams of materials: 'biological nutrients' and 'technical nutrients'. Biological nutrients are those from natural materials such as wood, plant and animal fibres and materials, manufactured in such a way that they can be composted safely at end of life. 'Technical nutrients' include non-biological human-made components such as steel, glass, plastic to be reclaimed at end of life. The item would be disassembled into its basic parts for reuse into new products. Blends of technical and biological materials are known as 'monstrous hybrids'. Despite the quasi-utopianism of the model in a world crammed full of monstrous hybrids by design, the principles of technical and biological resource streams has become central to the concept of the circular economy.

The concept of the circular economy has its roots in ecological economics and has 'designing out waste' as a core principle. A circular economy is "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes" (Kircherr et al 2017, 224). A circular economy is enabled through streaming materials and keeping them in motion as long as possible, inspired by the life cycle thinking of cradle-to-cradle. Consumption must be reduced overall for a circular economy to be a sustainable system. Critically, if the use of a resource increases due to efficiency gains in recycling, then environmental benefits may be lost (Zink et al 2017). It is important to highlight the role of design in enabling and maintaining these resource continuums, as through design it would be possible to conceptualise products that make use of new materials in a smart way, consider easy disassemble and waste streams, and, better yet, create products that can be designed with longer and more varied lifetime in mind. Design theorist Tony Fry (2009) warns of the danger in this for C2C, which may simply promote further unsustainable consumption.

Waste is a system that has multiple stable and dynamic states as describes in the concept of resilience in systems (Folke et al 2010). Although waste can be tackled instrumentally through the classic 'reduce, reuse, recycle' heuristic, waste must also be acknowledged as essentially a wicked problem, a symptom of the wider unsustainability of the present world economic and social systems. When waste is positioned as part of a complex system, multiple intervention points are required, in full acknowledgment that they may have unintended consequences. In the next section we examine in further detail the frameworks for representing these interventions to address waste.

3. Frameworks for Representing Waste

3.1 Hierarchical Visualisations

The concept of the ‘waste hierarchy’ has its origins in Earth Day 1970, with the three ‘R’s of reduce, reuse and recycle (Byers 2018). Traditional visualisations of waste management strategies are based on hierarchical representations of the different methods of waste management and recovery, usually graphically represented as a pyramid—a triangle. Triangles often represent moving forward, pointing towards something, conversion of factors or energy, and are the most commonly used shape to represent hierarchy.

Hierarchical representations embed the common notion that what is at the top is more important than what is at the bottom of the diagram. They are linear and represent discrete instances of the system. As usually hierarchies have less instances with more importance and more instances with less importance, the triangle is a natural fit for its representations. If any connections are represented, these are usually connections of power. Figure 1 shows an organisational hierarchy, where each position is connected by relationships of power.

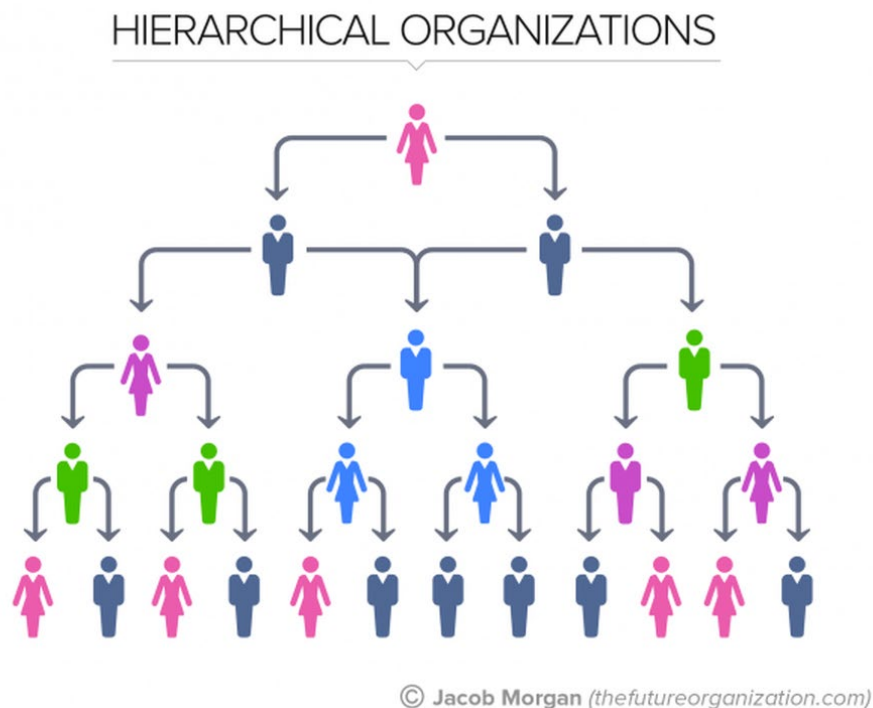


Figure 1 Hierarchical diagram representing organisational structure: more power, less instances on top, less power, more instances at the bottom. Source: (<https://www.forbes.com/sites/jacobmorgan/2015/07/06/the-5-types-of-organizational-structures-part-1-the-hierarchy/#e740d1852529>)

Waste hierarchies usually represent the waste management outcomes, from most preferred to least preferred option (DEFRA 2011). When visualized, they typically come in two forms:

the first and more common one is an inverted pyramid, with the wider part of the triangle on top representing the most desirable outcomes (avoiding, reducing) and the point of the triangle facing down, representing the least desirable waste outcomes, such as landfill or other types of non-recoverable waste (Figure 2). In these diagrams, the size and position of the shapes are equivalent to the desirable amount of waste for each outcome, making them simple and intuitive to read.



Figure 2 The waste management hierarchy, by City of Vancouver (source: <https://vancouver.ca/green-vancouver/zero-waste-vancouver.aspx>)

The second type of waste hierarchy uses a pyramid facing up to show the most desirable options as the small triangle up the top. These diagrams move from a representing a desirable state, to showing the actual volume of waste on each layer. For instance, Figure 3 shows “disposal” at the base of the pyramid as the larger area of the triangle, meaning that disposal is the outcome with the most volume, even though it is the least desirable. It also shows “Prevention” at the apex triangle, the smallest structure in the diagram, showing that, even though it is the most desirable, prevention is the outcome with the least uptake. This turns the pyramid into a good awareness tool, but makes it less intuitive to read. On the other hand, positioning the most desirable actions at the apex of the pyramid evokes a sense of something that is meant to be achieved, a top goal.



Figure 3 The waste management hierarchy, by Carpet Your Life (source: <https://www.carpetyourlife.com/en/about-us/associated-weavers/sustainability/waste-prevention>)

Triangles are a symbol of power and synergy, and naturally highly hierarchical. Triangles are visually stable when sitting on their base, unsettling when inverted and sitting on its apex. Triangular, hierarchical representations of waste evoke a few interesting instinctive feelings: the graphs that show the most desirable as the larger area on top, is the inverted triangle which evokes feelings of non-stability and physical “impossibility”. The graphs that show a stable triangle are the ones where the large area is at the bottom and represents the least desirable option which holds more volume of waste. This is the graph with the geometric form that is stable and comfortable to us, and shows the apex of the pyramid and something difficult or impossible to achieve, or that would need a certain level of effort.

Analysing the waste hierarchies against the criteria presented in Section 1.3, it becomes clear that hierarchies are general visualisations of waste management outcomes and can be used to represent any waste stream, but is specific to none (criterion 1). They represent discrete states, having minimal or no space to demonstrate fluidity of or between management states and outcomes or synergy between actors on each stance (criterion 3), making this kind of diagram limited to its own hierarchical structure and unable to represent any type of connection or circularity. As it is not visualised, when reading the graphic, users are also not stimulated to think about those connections or circularity of waste.

3.2 Circular Visualisations

Circles are the most natural shapes found in nature, and the ones humans are most

comfortable with. Circles are equal, dynamic and closed. They directly evoke the shape of the planet and its closed nature as a system (no out). As such, circles are frequently used in multiple kinds of visualisation, especially the ones dealing with the natural environment or human behaviour. There could be no more appropriate shape to represent systems of production that leave nothing behind.

Circular representations of waste clearly show fluidity and movement between multiple states within the system, and are mostly used to represent the life cycle, or journey, of a certain type of product, material or process. It fits perfectly with the Cradle-to-Cradle philosophy of waste which mimics nature's circles of life, demonstrating reuse, recycling, re-capturing of materials through the process (see Figures 4, 5 and 6).



Figure 4 Example 1 of a circular representation (source: <https://www.toronto.ca/services-payments/recycling-organics-garbage/long-term-waste-strategy/working-toward-a-circular-economy/>)



Figure 5 Example 2 of a circular representation (source: <https://iceclog.com/profitable-shift-to-circular-economy-for-manufacturers-and-retailers-monetize-waste-boost-sales-while-saving-the-environment/>)



Figure 6 Example 3 of a circular representation (source: <http://www.bowleather.com/Sustainability/Zero-Waste.aspx>)

In analysis specific to the circular economy, the circular visualisations vividly contrast with the dysfunctionally-linear economy, leading to waste, and the imperfect loops of the ‘reuse’

economy, in which some waste is recaptured and looped back into the system, while other waste is lost (see Figures 7 and 8). The symmetry and strength of the preferred circular economy, represented by the neat, contained circles adds visual weight to the sense that the circular economy appears to be “intuitively better” (Zink & Geyer 2017). In actuality, the circles are too neat and beguilingly simple.

From a linear to a circular economy

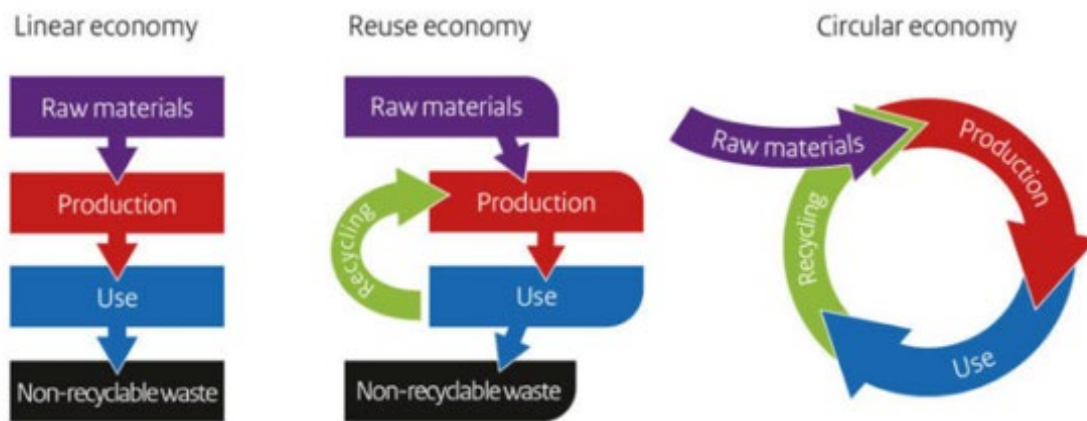


Figure 7 Examples of dysfunctional linear/reuse/circular representations (source: <https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy>)

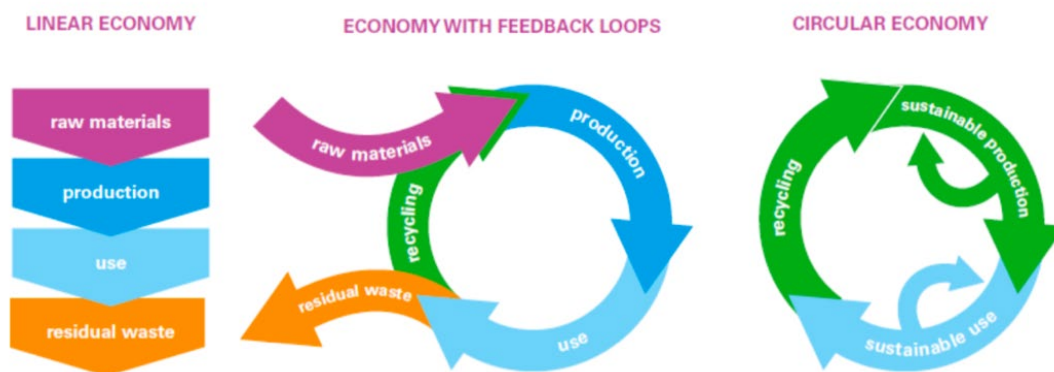


Figure 8 Examples of dysfunctional linear/reuse/circular representations (source: Vanburen, et al (2016). <https://doi.org/10.3390/su8070647>)

Many of the circular representations of waste flows focus on the movement of materials through closed and/or cascading loops of technical and biological materials, respectively. These diagrams visualise the C2C principles either as two closed circles, operating

independently of one another (Figure 9) or with some overlap (Figure 10). These aid in demonstrating the different kinds of interventions required for different kinds of waste streams.

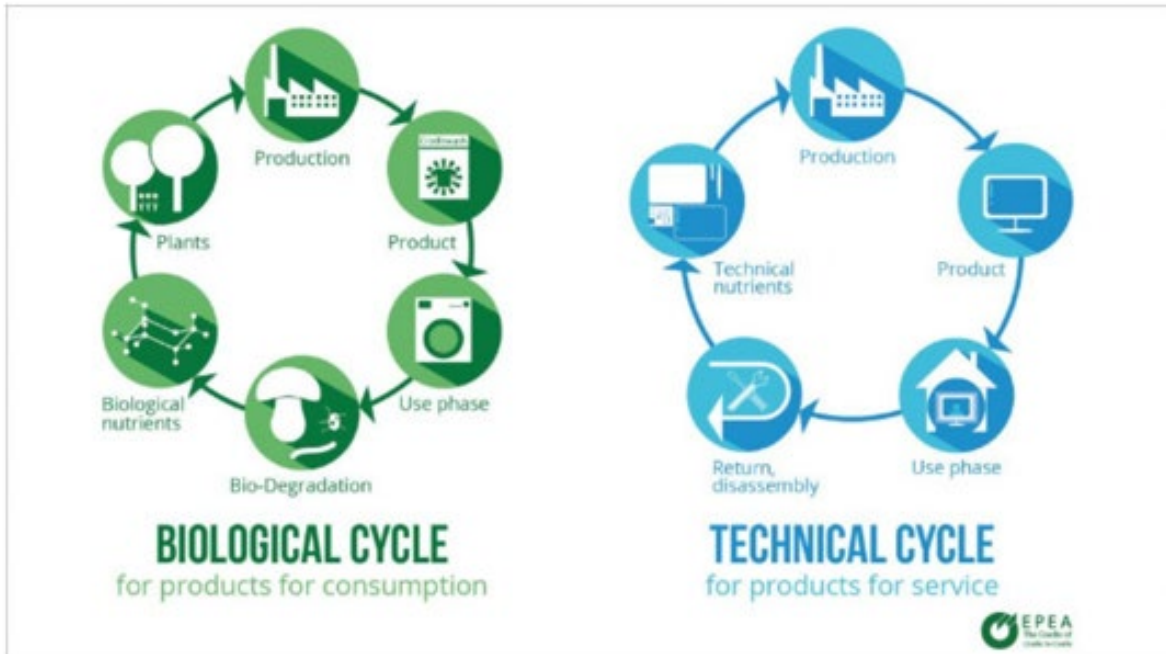


Figure 9 Representation of independently operating circles (source: <https://www.governmenteuropa.eu/is-the-uk-doing-enough-on-the-circular-economy/93304/>)

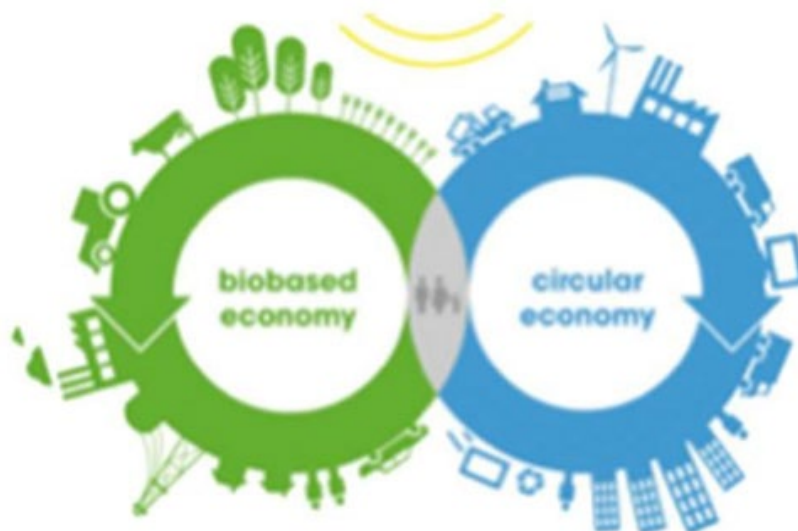


Figure 10 Representation of circles operating with some overlap (source: <https://biconsortium.eu/news/bic-views-waste-package-successful-circular-economy-requires-vibrant-renewable-bioeconomy>)

What the current circular visualisations of waste and economy don't do well is to represent connections between different players and interventions within the system. Figures 11 and 12 visualise greater complexity of circular economy processes as these examples have biological and technical material streams considered, identifying not closed circles but cascading loops showing many pathways to avoid a material becoming waste. The technical materials stream also incorporates the 'R's of the waste hierarchy within it, albeit without privileging one kind of action over another. When this happens it is done by adding extra circles and loops cascading out of the main circle which invariably create graphics that are over-complex and difficult to read (Figures 11 and 12).

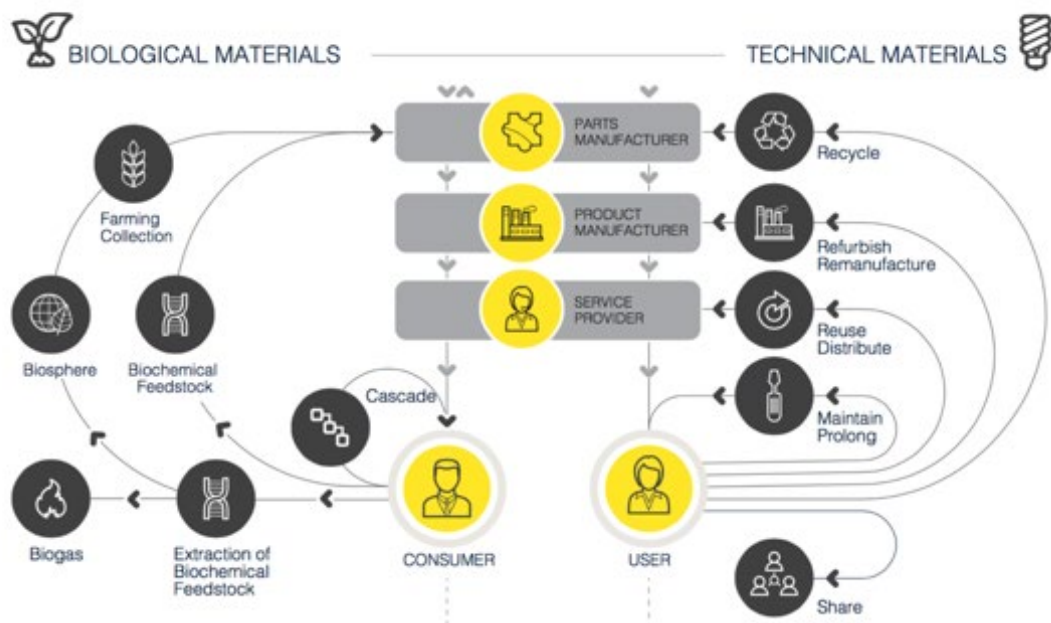


Figure 11 Example 1 of over-complex graphics (source: <https://www.creatingvalue.net.au/circular-economy-defined/>Date accessed: 6 November 2018)

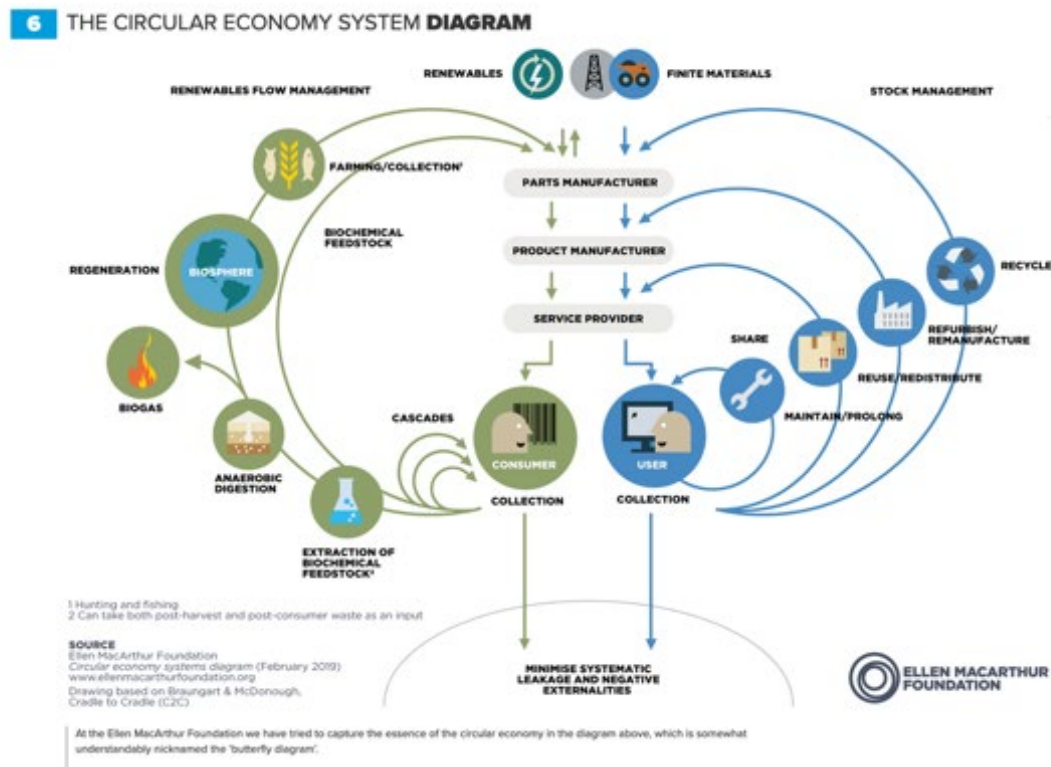


Figure 12 Example 2 of over-complex graphics (source: <https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail>)

Circular representations of waste are frequently used to represent multiple waste streams, sometimes on the same graphics (WVEAC, criterion 1), and are able to demonstrate the role of different disciplines within these cycles (criterion 2), but they fail to represent connections between the multiple actions and disciplines (criterion 3). When these are attempted, it usually breaks the circularity and produces a highly complex diagram.

The danger of the circular representations of economy is the fact that for them to represent true circularity—which usually involves multiple aspects of a complex system—the graphics require a level of complexity that makes them difficult to read, follow, understand and apply to a real-world situation. This defeats the core purpose of visual representations which is to communicate ideas more clearly, more accurately and efficiently.

To try to represent their own cycles in more efficient ways, industry and businesses tend to simplify the circular representation usually showing only one aspect of the system, and sometimes claiming circularity where the circularity does not really exist. Figure 7, for example, represents a reuse economy (Figure 7), or an economy with feedback loops (Figure 8) using a circular visualisation and ignoring the processes that happen beyond the main circle. The problem with not addressing those open loops is that as they are not visualised, they are seen as external to the system and not part of the problem. Similar to what we do with our household waste, the open-ends and unwanted ideas are sent to the outside of the main circles and can be ignored because they are not really our problem anymore. By

representing those open-ended pathways, it makes them part of the problem and therefore considered into strategic and decision-making processes.

What we need today more than ever is a form of visualisation that captures the multiple expertise necessary to understand and intervene in the waste system in an integrated way.

Both hierarchical and circular representations are one-dimensional and usually represent discrete units, interventions or states, as such, they are not able to represent the complex systemic interrelations of the systems around waste and the multiple level interventions.

The visualisation proposed in this paper was born from the need and desire to capture transdisciplinary synergy across multiple states of waste. In a way, we sought to combine the positive aspects of hierarchical visualisations with those of circular visualisations of waste, adding space for capturing interaction between actors and outcomes, as such adding the potential to perceive the dynamics and flows between states of the matter.

4. Designing the Waste Rainbow

Rainbows are optical illusions generated by the combination of three different light phenomena: refraction, dispersion and reflection. When light touches a surface, it is changed by that surface in different ways: some of it can be absorbed by the surface (and transformed into another type of energy), some of which is reflected back to the origin, and some of it might go through the surface, in this case, the angle in which the light hit is usually different from the angle it will have within or through that surface (refraction). In a rainbow situation, the light hits droplets of water in the air and is refracted into a different angle in a way that its wave-lengths become dispersed, showing the multiple colours within white light. These are then reflected out of the droplet, generating on the human viewers, an optical illusion of a 7-colour arch in the sky.

Surprisingly similarly to rainbows, waste also suffers refraction, dispersion and reflection. We create the refraction—the change in angle, change in state of matter—when we make the decision that a certain product is not useful anymore and should go to ‘the bin’. Once waste hits that state, it can be dispersed into multiple waste streams that each have their own characteristics and effects. This dispersion can start in our own houses or the places where the product is consumed, and usually finishes at the MRFs. The part that we often do not realise is that waste is always reflected back to us in one way or another.

The Waste Rainbow was designed with the intention to capture these aspects, as well as the ideas of fluidity, continuum and complexity. What triggered its creation was the authentic need to represent the synergies of transdisciplinary works done in the QUT Centre for a Waste Free World, revealed through team discussions and workshops where the researchers experimented with multiple ways to represent all their active projects and interventions to see how they relate and can work together. What follows is an account of how the authors, together with colleagues came up with the rainbow analogy as a canvas to plot and visualize connections amongst interventions within the waste system.

During the initial stages of working together and setting up the new Centre, the first step was to map existing waste research occurring at QUT. Colleagues worked in building and construction waste, food and organic waste, agricultural waste, e-waste, textile waste, and plastic waste, and came from multiple disciplines such as business, robotics, polymer sciences, law and design. With colleagues, we held a series of workshops to collaboratively formulate our waste research. Initially the organisation of the projects and interventions was done via waste stream (e.g. e-waste, food waste, construction waste, plastic waste, textile waste), but it was soon clear that we needed a more flexible structure that allowed for the multi-streams and “in-betweens” to be captured.

Turning back to Douglas, we framed waste as not a fixed state of matter, but a state that matter passes in and out of as humans ascribe value to it. Immediately, this suggested an approach. Waste is the state to avoid, hence there is a ‘pre-waste’ state, before matter becomes waste, and a ‘post-waste’ state, after matter has been delineated as waste. This in turn suggested a spectrum, just as the pyramid suggests a hierarchy (Figure 13).

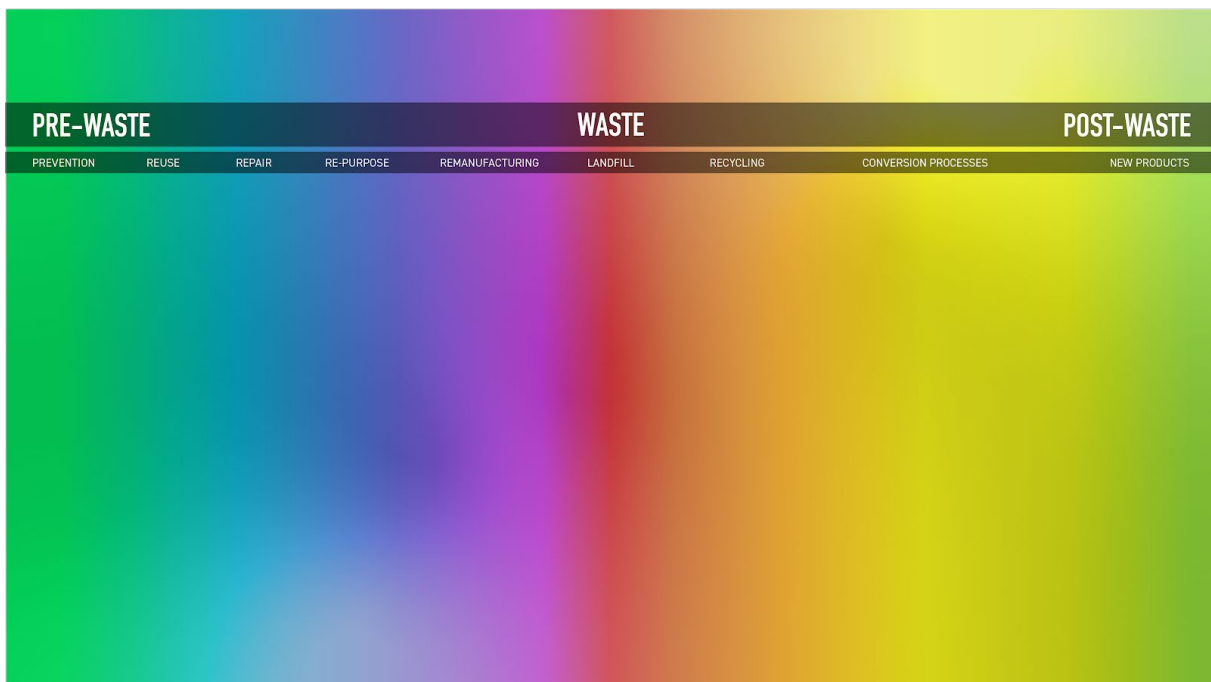


Figure 13 The Waste Rainbow as a canvas to plot interventions

From this process, it was clear that a “canvas” for plotting these synergies was needed, and the spectral representation of the rainbow came as a natural fit for the Centre’s philosophy of waste as it shows no discrete states, naturally representing the fluidity of matter. In order to move away from the ‘waste’ state in the centre, there are a range of interventions. In the pre-waste state, the interventions are drawn from the traditional waste hierarchy including prevention, reuse, repair, re-purpose and remanufacturing. In the post-waste state, interventions include recycling, conversion processes, and then new products. We indicate these interventions on the Waste Rainbow (Figure 13).

As the traditional waste hierarchy demonstrates, there are preferred approaches to managing waste, with prevention higher. Although in designing the Waste Rainbow we have avoided the hierarchical model, through the choice of warmer colours on the right, we have symbolically captured the fact that greater energy is required to transform material from the state of 'waste' into the state of 'post waste'. The benefit of the canvas format is that it offers space for representation of multiple layers of intervention which can be shown separately or in combination. It also allows for any type of connections between those interventions to be represented within and throughout the multiple states of waste.

5. Using the Waste Rainbow

Since developing the Waste Rainbow, with our collaborators we have used it in a number of different ways. Most usefully, it has been a means to structure a philosophy of working together to address waste in which multiple expertise, approaches and perspectives are needed. The word "philosophy" is used here as the Waste Rainbow is the synthesis of a collection of theories and attitudes towards waste that defines the research approaches and values of this group of researchers.

As well as using the Waste Rainbow as representation of our philosophy for working together, we also use it as a means to plot individual projects, visually indicating the part they play in addressing waste (Figure 14). Rather than a hierarchical positioning of interventions, which inevitably implies that some interventions are more impactful than others, our rainbow demonstrates all interventions are needed in working towards the desired goal.



Figure 14 The Waste Rainbow to mark point of intervention

With our colleagues we used the Waste Rainbow as a practical way to capture and sort the varied expertise and projects happening across the university. An example is provided in Figure 15 with our mapping of 'expertise' and two waste streams, plastics and textiles. With our team we have used it to map research across nine additional waste streams. Using the Waste Rainbow concept as a table was an efficient way to capture and organise diverse research and community engagement projects happening across multiple disciplines and faculties. Importantly, the gaps suggest opportunities, it helped identify where further expertise is needed—whether from our own institution, or in collaboration with other

institutions—; how existing expertise applied to one waste stream can be potentially applied to another; etc. In this way the Waste Rainbow revealed synergies and opportunities that were invisible before being plotted.

	PRE-WASTE				WASTE			POST-WASTE
	Prevention	Repair	Reuse	Remanufacturing	Landfill	Recycling	Conversion processes	The products
Expertise	Behavioural economics; marketing; design; law	Design and creative practice		Design and creative practice	Law and policy analysis	process engineering, economics of process, robotics	Industrial biotechnology, bioproducts and biorefining	Advanced materials
Plastic	[Research project 1 - design, law, chemistry]					[Research project 2 - chemistry, law; Research project 3 - robotics, design, chemistry]		
Textiles	[Student project 1 - design, law]	[Creative practice group - repair and making workshops - design]	[Community + student engagement project 1, design]	[Creative practice projects 1-3, design]		[Research project 1 - robotics, law & design]	[Research project 2 - engineering, design, chemistry]	[Commercial partner - research project 2]

Figure 15 Example of mapping research and community engagement projects using the waste rainbow

To provide an example, the mapping of the textile waste area, showcased activities happening in the community engagement space around creative reuse and maker space activities using waste fabric. These workshop activities were also applied to use plastic waste at a university-wide Waste Maker Day. Expertise in industrial biotechnology applied to a textiles research project opened up broader discussions with colleagues in polymer chemistry which in turn led to discussions and potential projects around bio-degradability and compostability. The Waste Rainbow has made visible some potential connections that would otherwise be missed without the visualization process. The aim is to create an organic web of activities that draws upon the Centre’s expertise and contributes to a more circular and less wasteful materials streams through a coordinated mélange of design, science and behavioural approaches.

6. Conclusion

Visualising the complexity of waste is no easy task, and the challenges presented defined the several advantages to our approach. First, it provides a holistic view that privileges prevention as much as recycling and continued material circulation. Second, using the Waste Rainbow can help expose gaps in the research agenda, and can also provide an inclusive view of where different kinds of expertise are required. Third, it shows connections between the interventions, and visually signifies how interventions at one point of the system might interfere with actions happening at the other end.

Nonetheless, a weakness of the Waste Rainbow is its apparent linearity. Looping, circling, and so on are expected in the circular economy agenda. Although this is a visual limitation of the Waste Rainbow, in its simplicity it may be of most use. In future iterations, it could be visualised as a cylinder, joining both ends. Similarly, it could be designed as a three-dimensional surface with 'waste' as the valley in the centre, in line with resilience theories where stable states act as attractors (Folke et al 2010, Gunderson and Holling, 2002, Walker et al 2004). If material reaches this valley, more energy is required in the states on either side, whether to 'pull' material up before it becomes waste, or to 'push' it up out of the waste valley. Mirroring the concept of 'panarchy' (Holling 2001), the Waste Rainbow can be complementary to other visualisations, and ultimately become a synthesis of those, by representing hierarchy into a dynamic system of multiple cycles.

By all means the Waste Rainbow is not definitive, it's apparent simplicity might mistakenly lead users to see the waste system as a simple and direct arena, which is far from the truth. However, some abstraction from the incredibly complex waste system need to be taken in order for researchers and practitioners to make sense of the issues and position themselves as actors and collaborators. In that sense, the Waste Rainbow is a valuable tool to initiate discussions, map interventions and represent a well-defined philosophy around waste research and practices.

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Designerly Living Labs: Early-stage exploration of future sustainable concepts

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Abstract: It is increasingly clear that the sustainability transitions needed to counter climate change depend on lifestyle changes. However, the task of encouraging a shift to more sustainable lifestyles is highly complex. This paper describes an emerging design research method to explore possible pathways towards such sustainable transitions. We describe a living labs-approach based on design practice, developed within Green Leap, a design and sustainability research group at KTH Royal Institute of Technology. We refer to this method as Designerly Living Labs. Based on empirical learnings from four such Living Labs we present eight key characteristics. We then highlight some important aspects that affect how future concepts and solutions can be explored in connection with the lifestyles and material contexts on which they depend. One finding is that ‘living the change’ may be needed to identify potential positive, and often social gains from more sustainable practices.

Keywords: living lab; practice-based design; sustainable transition; sustainable lifestyles

1. Introduction

Everyday routines and choices result from complex connections of lifestyles, identities and societal norms, as well as technologies, societal institutions and structures (see e.g. Jackson & Smith, 2018; Spaargaren & van Vliet, 2000). Transition to a more sustainable society requires a co-evolution of developments within all these fields (see e.g. Loorbach, 2010). In recent years, research has focused on understanding the underlying complexity of real-life contexts in which everyday choices are made, and more or less sustainable practices performed (Cairns et al., 2014; Shove et al., 2015). As Spaargaren has shown (2011), benefits of more sustainable solutions are not likely to be realized if those solutions are designed without considering related user practices.

Designing products, services or policies for sustainable outcomes requires “a higher order of inquiry” on the level of socio-technical systems (Scott et al., 2012). Similarly, drawing on results from the field of transition design research, Ceschin (2013) suggests that real-



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life socio-technical experiments are needed to develop solutions that can lead to more sustainable ways of living. Experiments provide incubation for new concepts or niches, as well as 'safe spaces' for people to try out new behaviors (Sengers et al., 2016; Ceschin, 2014). In recent years, large investments have been made in developing settings for experimentation. Living Labs in various shapes have been described as promising setups (Liedtke et al., 2015; Marvin et al., 2018).

However, early stage exploration of sustainable concepts is difficult. Since this kind of concepts inherently challenge existing structures and lifestyles (Ceschin & Gaziulusoy, 2016), users and other stakeholders are not always willing to try them in the context of their daily lives and current operations. Scott et al. (2012) point out that such experiments require the ability to imagine and construct "entirely new complexes of behaviors, values and things". As these three tend to co-evolve over time, asking people to try out future things today can be challenging, and especially if this is in conflict with their current values and practices.

In this paper, we describe an emerging approach to Designerly Living Labs as experimental settings for early stage exploration to inform the development of concepts that may enable more sustainable practices, and to explore potential use and integration of such concepts in society. This approach differs from common descriptions of living labs, and we argue that it is especially useful when there is not yet enough knowledge or stakeholder support to set up more targeted innovation infrastructures. We provide intermediate empirical findings from four implementations, aiming to answer the following research question:

What characterizes real-life socio-technical experiment setups that are suitable to inform early-stage development of future sustainable concepts?

Drawing on several different perspectives on how disrupting everyday practices may facilitate user experimentation, reflection and change, we develop guiding principles for planning Designerly Living Labs. We end this paper by providing some suggestions for how this method can be further developed.

2. Background

2.1 Practice-based and practice-oriented design research

Cross (2001) describes "designerly ways of knowing", and how designers are known to approach problems in ways that differ from most other professions: Design is constructive, and designers create knowledge by doing and making in that they "bring ideas to life in ways that encourage speculation and 'what if?' questions." (Coyne, 2005). By prototyping and visualizing things that do not yet exist, designers may engage in reflective dialogue with proposed objects or scenarios (Schön, 1983), thereby exploring and iteratively improving the situation at hand (Simon, 1996). It has been argued that such "designerly" approaches are well suited to tackle complex and open-ended questions (Coyne 2005; Buchanan, 1992), often referred to as 'wicked problems' (Rittel & Webber, 1973). In the face of complex societal issues and challenges, there has been rising interest in designerly approaches to

perform research, using terms such as Research through Design and Practice-Based Design Research (see e.g. Koskinen et al., 2012; Redström, 2018; [authors], 2019).

Co-design can be described as a deliberate effort to enable co-creation (Sanders & Stappers, 2008) actively involving stakeholders as experts (Björgvinsson, Ehn, & Hillgren, 2010).

Design can facilitate co-creation by making physical artefacts that help users make sense of a situation and create ideas (Sanders & Stappers, 2014; Vaajakallio & Mattelmäki, 2014). However, user-centered and behavior-based design have been described as inadequate approaches to design for sustainable outcomes (Shove et al., 2007). Viewing human behavior as static or given, and therefore designing around human behavior is limited as this does not take into account the dynamics of how “design, production and consumption are embedded in and constitutive of contemporary routines and habits” (Watson & Shove, 2008, emphasis added). User needs depend on existing practices and norms, which can be influenced by design.

Many have argued that practice-oriented design holds opportunities for addressing sustainability issues (see e.g. Hesselgren, 2019; Kuijer, 2014; Shove & Watson, 2006).

Designerly Living Labs build on both these design research perspectives.

2.2 Current Living Labs typology and definitions

The term ‘living labs’ has come to include a collection of very different approaches. Described by Cheyne (2013) as “a nebulous term for a number of different approaches which do not share much in common other than they seek to develop knowledge through experimental, practical application”. Burbridge and Morrison (2017) define a living lab as “a real-life place for user co-creation of innovations in knowledge, products, services and infrastructures”.

The European network of Living Labs (EnoLL) also define living labs as a user co-creation approach, but highlights their role as collaborative platforms set “in real life communities and settings” or “open innovation environments attracting inwards investment”¹. In this view, the “lab” may be a city or a region, hosting a collaborative project to engage citizens and diverse stakeholders in creating and testing solutions to selected societal issues.

The SusLabNWE project (Sustainable Labs North-Western Europe) proposes Sustainable Living Labs (SLL) to engage academia, citizens and other stakeholders in co-creating solutions to reduce environmental impacts of our society. SLLs have this far centered on understanding how users appropriate technologies (especially ICT in the home) potentially enabling more sustainable lifestyles (van Timmeren & Keyson, 2016; Romero Herrera, 2016). SLLs place a strong focus on Product Service Systems (PSS) as a promising approach to reduce material consumption, and Liedtke et al. (2015) describe a three-stage method for developing such PSS. SLLs have a user-centered approach inspired by design, with an emphasis on users self-reporting their practices and taking some part in co-creating solutions (ibid., see also Romero Herrera, 2016a).

1 See <http://www.enoll.org/> Retrieved on 2019-10-18

In literature describing EnoLL and SusLabNWE, references are often made to niche-management (Markard et al., 2011; Schot & Geels, 2008) and socio-technical experiments, as described by Ceschin (2012, 2014). Living labs are described as open innovation infrastructures for such experiments. Similarly, in a recent anthology describing Urban Living Labs (ULL), these are defined as not being “a stand-alone set of interventions”. Instead, a city or region may use a portfolio of experiments to govern urban sustainability development (Marvin et al., 2018). Also, all these similar approaches often emphasize later stages of the innovation process, using terms such as “test facilities”, “pilots” and “upscaling” (ibid.).

In the design field, Scott et al. (2012) describe small-scale explorative living labs based on practice-oriented design and “enabling practitioners to challenge existing norms”. The proposed Designerly Living Labs share many similarities with this approach.

3. Designerly Living Labs

Our approach to setting up living labs has aimed to explore possible sustainable futures and communicate their potential. As described in section 1, when designing for sustainability, users’ behaviors and needs cannot be regarded in isolation, but must be explored in conjunction with lifestyles, as well as social and material contexts. All four living labs described in this article have aimed to explore different perspectives on sustainable mobility, but living labs to explore sustainable transitions in other fields have also been discussed and one such living lab is currently being developed.

The four Designerly Living Labs have all been based on interventions into people’s everyday lives. These interventions have been the introduction of possible future technologies, regulations or services, but not with the purpose to test or validate these innovations. Instead, we consider the interventions ‘provisional concepts’ that function as starting points for learning, and their detail design is not a central issue.

The four living labs have all been designerly, using practice-based design research approaches, and with research activities carried out by design practitioners.

3.1 Introducing the four Living Labs

LIVING LAB 1: “A CAR-FREE YEAR” (HENCEFORTH CAR-FREE)

In this living lab, three carefully selected and highly motivated households agreed to live without their car for one year. Instead, they were supported by the project to replace it with various rented Light Electric Vehicles (LEVs). All their travel was logged using a mobile phone app (Moves2) and the participants reflections were supported by printed travel diaries. The resulting travel data was visualized and used as trigger material in a series of in-depth interviews. The aim was to explore the transition to car-free lifestyles, in order to identify perceived barriers, as well as changed practices and possible value gained.

2 An activity tracking app developed by Facebook. Discontinued in July 2018.

LIVING LAB 2: “KTH LEV-POOL” (LEV-POOL)

This living lab was centered around offering a workplace pool-service using LEVs during six to nine months. Employees at two workplaces were recruited as “caretakers” which included leasing a LEV (a quadricycle) using it freely for travel in their spare time, as well as to and from work. The cost of the vehicle was subsidized by the project since colleagues could book and use the vehicles for travel during the workday. The living lab aimed to explore the new service concept and emerging practices from several perspectives, including caretakers, daytime users, employers and the pool service operator. One specific point of interest concerned whether the service would support daytime users to leave their own cars at home, and go to work by public transport.

LIVING LAB 3: “FUTURE PLAYING-RULES FOR EVERYDAY MOBILITY” (PLAYING-RULES)

Nine randomly selected participants were introduced to three types of economic incentives, designed to encourage more sustainable mobility choices. For six months, all their travels were logged using a mobile phone app (TravelVU3). Furthermore, the app functionality was also extended to present the actual, full cost of driving their private cars, after each ride. The incentives were designed so that more sustainable mobility choices would lead to savings, that were duly repaid using monthly bank transfers. The living lab aimed to trigger reflection and experimentation with changed travel practices, to explore underlying factors that influence mobility choices. Travel data was visualized and used to create scenarios to facilitate reflection.



Figure 1 From Living Lab 4. Work-hub participants from several different employers.

LIVING LAB 4: “WORK CLOSER AND TRAVEL SMARTER” (WORK CLOSER)

In this living lab, a local office space (work-hub) was set up in a suburban residential area and access was offered as a service to people with long daily commutes. This study is still ongoing at the time of writing, with 62 active participants. The work-hub was designed as a fully equipped office with 14 desks, 3 phone-booths and a meeting room. Booking of desks and rooms was made available in a web-app where the service is offered in combination with various accessibility and mobility services. The aim is to explore individual, social and professional aspects of working closer to home, as a way to reduce travel.

Table 1 provides data about the living lab setups and research designs.

Table 1 Short facts about the research design in the four Designerly Living Labs.

Participants	Participant recruitment	Data-collection methods	Duration and place
“A Car-Free Year”			
3 families. In total 5 adults and 6 children.	Self-recruited through advertising on Facebook. 3 out of 72 applicants selected for motivation and contribution to heterogeneity of sample.	6 rounds of bi-monthly semi-structured in-depth interviews, travel-diaries used as trigger-material, travel-data collection app.	12 months 2014-2015. Stockholm, Sweden.
“KTH LEV-Pool”			
2 separate setups at two large Swedish employers, with a total 16 caretakers and approx. 70 active service users.	“Care-takers” were self-recruited using internal communication channels. The service was open for all employees and used by approx. 10 and 7 % of employees	2x2 rounds of semi-structured in-depth Interviews, 2x2 user and stakeholder workshops, facilitated production of user-created short-movies	2 x 12 months, in 2016 and 2017. Stockholm and Älmhult, Sweden.
“Future Playing-Rules for Everyday Mobility”			
9 individuals in 7 suburban households with different accessibility options. All owning a private car.	25 individuals randomly approached outside the main food-stores in selected suburbs. After mapping all travel for one test-month, a heterogenous group was selected.	2 short structured interviews to get basic data. 3 semi-structured in-depth Interviews using scenarios and other trigger materials. Use of travel-data collection app	1 + 6 months, 2018. Stockholm, Sweden.
“Work Closer, Travel Smarter”			

Participants	Participant recruitment	Data-collection methods	Duration and place
62 participants at the time of writing. All with full-time employment and relatively long commutes.	25 users self-recruited through advertising in a local Facebook-group. 42 were recruited through three large employers, offering the service to employees living near the work-hub.	2-3 rounds of participant Interviews. Data from travel-diaries and booking-app, Stakeholder interviews and 2 stakeholder workshops (planned).	18 months, 2019 - 2020. Stockholm, Sweden.

4. Main characteristics of Designerly Living Labs

In this section we present eight characteristics of the four Designerly Living Labs. Together, they describe the approach, when, why, and how it is used, and what separates it from the common, open-platform-type living lab approaches outlined in section 2.2.

4.1 Early-stage

We suggest Designerly Living Labs as experimental setups for early-stage exploration to inform the development of concepts or policies that may lead to more sustainable behaviors. All our living labs were designed as part of a longer chain of developments, and next steps have been planned. The labs have aimed at identifying issues for our own further research, generating input for the development of new service concepts, or been part of working towards scaling up the results.

4.2 Explorative

We propose that Designerly Living Labs are distinctly explorative. In line with Pierce et al. (2015) we found that as our interventions were not designed based on user needs, it was of little interest to evaluate them as such. We have not aimed to answer specific and well-defined questions. Instead, our living labs emphasize open exploration of pathways to change, and how new solutions may fit in the context of everyday practices.

4.3 Interventionist

We position Designerly Living Labs as an interventionist approach. The interventions were not solutions to be tested and validated, but instead served mainly to trigger responses – encouraging user experimentation and reflection. Trigger materials or probes are frequently used in design practice to elicit reflection and responses from users (Kankainen et al., 2012; Mattelmäki, 2008). The interventions served to explore future concepts and the participants' responses, as well as possibly unknown factors that affected people's ability to adapt or change their practices.

4.4 Holistic

The living labs' real-life settings means having to include (and deal with) the full complexity of everyday practicalities and the surrounding society. This makes a Designerly Living Lab inherently holistic (e.g. planning the work-hub in Work Closer, required handling as diverse issues as municipal policy, workplace regulation, activity-based offices, e-meeting and Wi-Fi technologies). Furthermore, all the labs have shared a stated ambition to explore not just user responses to a new phenomenon, but also business aspects, social consequences, side-effects and rebound.

4.5 Participatory

We argue that Designerly Living Labs are participatory. Participants were invited as "collaborators in discovering new meanings and values" (Pierce et al., 2015). Drawing on Brown, Reeves, and Sherwood's (2011) conclusions from field trial methods, we consider the living lab participants not as passive subjects to be studied, but as "active investigators of their own practices". This requires facilitating participant reflection, as well as securing an open dialogue and to act on participant feedback during the living lab.

4.6 Flexible and open-ended

Being an explorative approach, the research design of all four living labs was deliberately held mostly open-ended. We find that Designerly Living Labs must be flexible, as unexpected findings or practical problems have in several cases lead to changed research questions, design of new interventions or data-collection methods. This is supported by Russel's (2010) claim that in open and critical inquiry, flexibility is required to let the study "remain open to revisions in response to new information".

4.7 Close

The Designerly Living Labs have aimed to facilitate an open and trustful relation with the participants. For this, we found that a well-coordinated research team and personal level of communication was needed. The interventions also required many practical engagements with the participants, including the provision of physical resources, instructing and facilitating. The desired level of closeness would be difficult in an open innovation arena or infrastructure where many stakeholders take part. Furthermore, actively involving commercial stakeholders has proven difficult, as early-stage exploration of an issue rarely connects with their core operations.

4.8 Longitudinal

Finally, we propose Designerly Living Labs to be set up as longitudinal studies. In the common European practice of open-platform-type living labs, the research infrastructures are long-lived, but the experiments or demonstrations included are in many cases shorter. To allow iteration and still give new practices time to evolve and become part of everyday life, all four

Designerly Living Labs have stretched 6 months or more. This has proved to be important, as in several cases distinct behavior changes have occurred after several months, and seasonal lifestyle changes have proven to have a major impact.

5. Learnings – how the Designerly Living Lab characteristics have emerged and been handled in practice

In this section we present findings regarding how the living labs unfolded. We expand upon some of the key characteristics and describe how variations in living lab methodologies may have influenced research results.

5.1 Interventionist approaches of disturbing and triggering

The interventions were designed to explore motivations, opportunities and barriers to change, by intervening in, or disturbing participants current practices. The idea of disturbing practices to facilitate experimentation and reflection is a recurring theme in many different research areas from psychology to experiments in social sciences (Kurz et al., 2015).

Within the design field there are many similar interventionist approaches: Sengers et al. (2005) describe Reflective Design as “[expanding] on reflection-in-action by not waiting for surprise to occur but intervening to create or stimulate these reflection triggers”, and ‘technological probes’ as using new technology “as a stimulus or probe for understanding larger social practices”. Junginger and Sangiorgis (2009) describe Service Designers as taking “[the role of] ‘enabler’, ‘facilitator’ and ‘connector’ for certain behaviors and configurations to emerge”.

In Social Practice Theories, Reckwitz (2002) describes disturbance strategies as generating potential “crises of routines” aiming to make people consciously reflect on their behaviors. Spaargaren (1997) describes ‘de-routinization’, as events that allow an individual to examine routine behaviors from a new perspective. Kuijer (2014) further develops the use of Social Practice Theories in design, and describes an elaborate method for the design of ‘proto-practices’. This essentially means facilitating the co-creation of alternative ways for “how things could work”. For Kuijer, proto-practices take a disturbing role: “a proto-practice should trigger non-everyday instances of improvisation or experimentation” (ibid.).

The interventions in our Designerly Living Labs took a similar role by enabling and triggering the participants to invent or imagine new practices. Hence, the interventions were not proto-practices per se, but enabled and facilitated proto-practices to emerge.

5.2 Different ways to balance strict and soft interventions

Our interventions were designed to trigger reflection and experimentation, challenging otherwise unconscious habits, norms and understandings. As described by Hesselgren et al., (2017) we found that the level of strictness of the interventions was a crucial factor for the level of experimentation.

In Car-Free, the participants agreed to have their cars removed for a full year. This very strict intervention left them with no choice but to adapt to the new situation. This required experimentation with new modes of travel, and in some cases changing or giving up travel-dependent practices. Car-Free participants also described finding it hard to go against the norm, e.g. when they received help from car-owning friends and could not reciprocate (Hesselgren et al., 2016). Strict interventions thus require large efforts from the participants. In the case of Car-Free, this was possible since the self-recruited families had strong, personal motivations to get rid of the car (ibid.). In LEV-Pool, the “caretakers” volunteered to take care of and use a LEV, which proved to be a very strict intervention. The vehicle had to be taken to work every day since colleagues may have booked it and left their private car at home. The LEV-Pool study duly identified this responsibility as a barrier to wider uptake (Sopjani et al., 2020), and the concept was adjusted when the service concept was later scaled up commercially.

In contrast, Playing-Rules was designed to explore everyday mobility by use of soft, behavioral interventions. During the living lab, the participants were informed of the full cost of each car-trip, and offered discounts and monetary rewards for more sustainable travel choices. In this living lab it was deemed important that the participants did not volunteer for the study (e.g. not to recruit for engagement in environmental issues). Therefore, a more random recruitment method was selected (see table 1). Since these interventions were soft, and as travel is deeply integrated with other practices and lifestyles, very few changes were made. Two participants made limited attempts to obtain the discount offered for using public transport off-peak. However, without making more substantial changes to their daily routines, they could only avoid the peak hour either going to or from work, but not both ways. In this case, the price model constructed for this intervention resulted in very limited savings, and they returned to their previous routines. In Playing-Rules, it was also clear that alternative solutions that still included a car, such as carpools or buying a smaller car, were considered when other alternatives were not. Likely because alternatives that still involve a car would allow other practices such as shopping habits and kids activities, to remain unchanged. In Playing-Rules, soft interventions and little personal motivation to change current practices led to very limited experimentation. The participants still reflected deeply upon their travel-habits, misunderstandings of travel costs and possible alternatives, but there is likely potential to learn more about a projected future if the participants do experiment with new practices. In Car-Free, on the other hand; to accept a strict study design that required substantial changes to their practices, motivated forerunners had to be specifically recruited. (This was also the case in a similar study in Finland, see Laakso, 2017).

In Work Closer, the local work-hub was offered as a way to reduce travel. The participants were self-recruited to ensure that the service offering would be used. This intervention was also of a softer nature. Before joining the work-hub, participants typically worked from home one day a week. Interviews revealed that in many cases the only change to their weekly routine was to spend that day at the work-hub, leaving their daily practices largely unchanged. The new service would only be used to improve their comfort or working

performance, without challenging workplace norms and policies, and likely with little effect on lifestyles. To counter this, we have tried a different method, provisionally called 'Challenges'. This means that a researcher, in a personal way, asked participants to try changing a current practice more substantially for a limited time-period, while taking notes of learnings such as problems encountered, or adaptations needed.

Results of the challenges are not yet fully analyzed, but one preliminary finding involves identifying value gained. In Car-Free, the participating families faced many challenges to cope without the car, but also found unexpected values, such as kids becoming more independent when learning to use public transport, or quality family-time on the train to the country house. In Work Closer such positive gains have been prominent, and participants have described having time and energy left after work, for visiting elderly parents or to go out for a run. Many have mentioned reduced stress-levels and allowing for more time with their children as positive value gains. A preliminary finding from the Challenges is that some positive gains were connected to changing surrounding practices. We find that positive gains, like rebound effects, can result from unanticipated chains of changes and are therefore hard to foresee without actually 'living the change'.

5.3 Challenges building closeness in larger living labs

As previously discussed, Designerly Living Labs are participatory and as such require some efforts from the participants. In all four living labs many personal contacts were needed during recruitments and set-up. Through the labs we have strived to be open about the purpose of the research, thus intentionally involving the participants as co-researchers. Finally, in three of the living labs the number of participants was small. These factors allowed building closeness: a closer relation and a sense of responsibility that prompted the participants to perform their part diligently.

in Work Closer, the number of participants recruited was much larger than in the earlier labs, to ensure the work-hub would be populated. This in turn required using web-based application forms, resulting in less personal contacts during the recruitment process. Also, the research team was larger, and an employed host was added as a service layer between the work-hub users and the researchers.

There are indications that this has led to lower levels of involvement. In Playing-rules, the nine participants spent a lot of time correcting faulty data in the tracking app, and in two cases volunteered to take notes when it temporarily did not work. One participant could not take part after an app update did not support her old phone, but asked to re-join the study after having purchased a new phone. In Work Closer, seemingly smaller app-related difficulties caused several participants to voice irritation, and a few skipped using the service at all. Also, compared to the earlier three labs, it has been harder to book interviews, and fewer participants have taken the time to fill in a provided travel-diary in detail.

Limited involvement in larger groups is described as 'diffusion of responsibility' in psychology (Darley & Latane, 1968). For example, it has been shown that employees email responses are

more helpful and elaborate when they are personally addressed (Barron & Yechiam, 2002).

We found that the participants' engagement and level of effort to fulfil expectations depend on a close relation with the researchers, and whether participants are addressed as individuals. Also, being addressed as co-researchers has led to higher levels of engagement and reflection, connecting the participatory and closeness characteristics of the labs.

5.4 Early-stage experiments encounter and identify structural barriers

Staging a possible future societal change or service concept is not a trivial matter. As described earlier, the real-life setting means having to deal with the complexity of the surrounding societal context, which makes Designerly Living Labs inherently holistic.

In most cases the interventions have required detailed planning and several months of practical arrangements. Setting up future service concepts such as LEV-Pool or Work Closer involved challenges similar to managing a start-up company. As described in the introduction, these services fit Ceschin's (2014) description of sustainable PSS as inherently radical innovations. As such, they encounter – and thereby identify – barriers on both cultural, corporate and regulative levels. For example, a corporate research partner in Work Closer needed a several months long internal process to allow employees to work at the hub. Workplace-safety regulations and union agreements were found to influence corporate policies for working from home, and were therefore investigated.

As our interventions have in several cases been perceived as radical concepts challenging existing structures it has often been hard to involve stakeholders' core operations. Instead, our early-stage exploration helped establish contacts, and often revealed barriers to more active engagement. We have found that corporate structures may limit the experimentation and learning processes needed to reach sustainability goals, which may be a barrier to reaching sustainable results (see e.g our earlier project, developing mobility services at a large Swedish corporation, Hesselgren et al., 2019).

6. Conclusions

The knowledge produced in Designerly Living Labs is rich in qualitative detail and shares some general characteristics. Prototypes in early phases of a design process are often designed to be generative rather than evaluative. As a 'fuzzy front end of research', we find that our living labs produce generative and actionable results, suitable to inform development in next steps, specifically mapping out barriers and opportunities. Also, we find that Designerly Living Labs tend to uncover many unanticipated issues, often reframing challenges and connecting to several different fields of research. This may require a multi-disciplinary research team to effectively analyze and evaluate the results.

As opposed to the approaches described by Scott et al. (2012) and Kuijer (2014), Designerly Living Labs do not aim to design proto-practices as such. Instead, new concepts and solutions are designed to disturb, thereby learning from the participants' reflection

and experimentation. Still in line with this distinction, we see opportunities for more participatory approaches: In an upcoming living lab we consider asking participants to partake in envisioning and co-creating new concepts and solutions, with the specific aim of enabling more sustainable practices.

Hesselgren et al. (2017) have described soft interventions as adding, and strict interventions as taking away. Considering all four labs we find that other aspects need to be considered. The level of strictness must be balanced against the degree to which an intervention challenges current lifestyles and values, which is in turn connected to participant motivation and therefore, recruitment strategies. Structural interventions like the LEV-pool or the work-hub may enable new and more sustainable practices, but when the LEV-pool has a strict design requiring a caretaker to use it daily, the work-hub was merely an offer. In *Work Closer*, to learn more, we have tried Challenges: simply asking participants to use the service more than they would otherwise have done.

All four living labs have been aimed at exploring more sustainable practices, which in many cases are at odds with current lifestyles and norms. Strict interventions have led to challenging experimentation with new practices – but also to unexpected positive, and often social value. This supports the view that pro-social and pro-environment lifestyle choices could be connected (Jackson & Smith, 2019). In *Playing-rules*, changes were never made, which may be a reason why the participants viewed more sustainable travel practices as merely limiting or inconvenient. Sustainable lifestyles are commonly associated with reducing, cutting down, and withdrawing from common behaviors (see e.g. Spaargaren, 2011). We believe Designerly Living Labs are well positioned to meet calls to explore and create richer images of sustainable lifestyles.

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When behaviour change is about hot air: home systems should change behaviour to fit practices

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Abstract: Existing residential housing has to become more sustainable to meet global CO₂ reduction goals. Zero energy home refurbishment is one approach to achieve this. Rather than the currently common behaviour change approach, this study investigates residents' experiences and practices with regard to their home environment. The study consists of interviews in 11 residents' own homes. The residents live in homes in various levels of refurbishment, including zero energy. The study focuses particularly on ventilation. Ventilation is an issue that is understudied yet known to affect homes' energy performance as well as residents' comfort experience. The study reveals many issues with trust, understanding and unfavourable associations of ventilation systems. The study then presents a number of exemplary design directions that could address these issues. The implications are that practices should be studied more to reveal such issues, and that there is a need for better home systems design approaches.

Keywords: sustainability; practices; home systems; zero energy

1. Introduction

Existing residential housing has to become more sustainable to meet global energy goals (Silvester et al., 2017), yet the challenge is to integrate energy-reducing refurbishments with the way people already live in the homes. To establish zero energy consumption the energy demand for cooling and heating is minimized. The remaining energy demand is met from renewable sources generated with heat pumps, solar panels, wind turbines or solar water heaters (Li, Yang & Lam, 2013). Zero energy (ZE) homes are often air-tight to minimize heat loss through uncontrolled ventilation and are equipped with a balanced ventilation system with heat recovery. Good functioning of such systems is of increasing importance, considering that people typically spend 90% of their time indoors (Lohani & Acharya, 2016). Often, indoor air is five times more polluted than outdoor air (Kim, Paulos & Mankoff, 2013). Polluted air has negative effects on productivity, health, and comfort of residents



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and can cause allergies, inflammation, infections, and asthma (Dimitroulopoulou, 2012). Numerous materials and activities can pollute the air with gasses and particles such as fine dust, CO, CO₂, odours and water vapor (Behar & Chiu, 2013). Some indoor activities can quickly increase the concentration of pollutants: for example, cooking, lighting a fireplace, laser printing or cleaning (Kim & Paulos, 2009). Besides, building materials and furnishings can be a source of pollution: for example, pressed wood furniture (Kim et al., 2013). People are often unaware of air quality and pollution sources, since identifying air quality is very difficult. Physically people cannot sense changes in air quality since pollutants are often invisible and odorless (Kim et al., 2013).

1.1 Balanced ventilation

Balanced ventilation systems use mechanical components like air handling units, ducts and valves to supply clean and extract polluted air. Generally, air is extracted in 'wet rooms' of the house: the kitchen and bathroom. Fresh air is supplied in 'dry rooms': the living room-and bedroom. Some mechanical systems recover heat from used air to preheat fresh air before supply (Dimitroulopoulou, 2012). Furthermore, systems can be equipped with sensors like CO₂ and humidity to regulate airflow.

1.2 The residents' role

The residents' interaction with ventilation systems impacts indoor air quality and energy usage. Residents' activities have been shown to affect the success of ZE housing: the activities partly cause what is known as the performance gap, the difference in expected and actual energy usage of buildings (Behar & Chiu, 2013; Paone & Bacher, 2018). For example, residents sometimes use ventilation differently from how it was designed to be used: they open windows while heating is on, disable ventilation or block vents (Behar & Chiu, 2013). Furthermore, maintenance like replacing filters, which is crucial to maintain the capacity of a ventilation system, is often not performed (Soldaat & Itard, 2007). This impacts not only energy goals (Behar & Chiu, 2013) but can also result in decreased comfort and unhealthy situations.

1.3 This study

The work presented was carried out in connection with the 2nd Skin ZE refurbishment project (Silvester et al., 2017) and is based on the first author's graduation project that focused on ventilation practices of residents who experienced a ZE refurbishment of their homes. The graduation project was supervised by the other authors. Practices are particularly important in the context of ZE refurbishments of rented houses as residents stay in the same house while they are expected to adjust their practices. The aim is to support residents to transition their practices so that they can benefit from their ZE homes in terms of health and comfort but also financially. With a research through design approach (Stappers & Giaccardi, 2017) this study simultaneously generates new knowledge on ventilation practices and design directions to support a transition of practices. In this way, the study generates knowledge

on designing home systems from a practice-oriented perspective. Through supporting a transition of practices, the generated design solutions contribute to decreasing the performance gap.

We first describe the practice of maintaining indoor air quality to identify points that hinder a transition of the practice. We show that the lack of feedback of the ventilation system makes residents insecure and makes it hard to understand. Besides, associations that mismatch the new material make residents reluctant to use the ventilation system. Residents struggle to integrate the new system into their practices. We then propose design directions that could address these issues.

Research questions were:

- What practices do residents have in relation to indoor climate?
- What material, skills and meanings are attached to residents' practices (Kuijer, 2017)?
- To what extent do residents transition their practices after refurbishments?

1.4 Practice-oriented approach

We take a practice-oriented approach in this research. Practices are routinized ways of doing (Shove & Watson, 2006). The advantage of this approach is that it broadens the analysis away from specific product-user interactions (Kuijer, 2017). By understanding the residents' routine actions, we can identify points for intervention to support a desirable reconfiguration of practices in their refurbished house. Practices are things people do and regard as normal. Cooking is a practice. However, cooking on a camping trip is quite different from cooking at home. This demonstrates the distinction between 'practices as an entity' and 'practices as a performance'. Cooking is the overarching entity; the different observable ways of cooking are the performances (Kuijer, 2017). Practices are described as a configuration of the following elements: skills, material, and images (Kuijer, 2017). In the cooking example, material are pans and knives, but also the air, experienced as fresh or not. The skill is knowledge and routinized actions required for cooking, for example ability to boil an egg. Images are the meanings people attach to cooking, for example on what is healthy or sustainable food and what is a pleasant kitchen environment. In the context of home systems, a practice-oriented approach facilitates designing for what people do in their homes, rather than designing for a fictional user who is primarily interested in the technical performance of their home, also referred to as "Resource Man" (Strengers, 2014).

TRANSITIONING PRACTICES

Practices are not fixed; they are dynamic and can transition over time. In the process some materials, skills, and meanings become useless and new ones are added. The practice of maintaining warmth is used to illustrate this. With the introduction of gas, coal sheds and the skill of creating a fire became obsolete. Meanwhile, pipes and skill to regulate temperature using knobs became needed. At the same time, the related image changed as the amount of

work involved decreased (Kuijjer & De Jong, 2012). Transitioning practices has been a matter of attention in the design field, especially in the context of sustainability (Jégou, Liberman & Wallenborn, 2009; Kuijjer & Jong, 2009). Whereas the goal is often to transition practices to become less resource intensive (e.g. using less water), this study has a different primary aim: it aims to support residents in the integration of new elements, the new technologies, the new materials that enter their ZE houses.

2. Method

The first author conducted interviews with residents in their own dwelling. The interviews were semi-structured and consisted of open-ended questions. The set-up of the interviews was inspired by the path of expression: sharing current experiences, recalling memories and concluding by defining possibilities for the future (Sanders & Stappers, 2012) as well as by method insights by Boess, Silvester, de Wal & de Wal (2018) who employed a listening-first approach in ZE refurbishment. This framework was used for the set up because it would support residents to not only share current practices but also explore and express desirable futures. The following method and analysis part is the first author's description.

2.1 Approach to the interviews

The interviews took approximately an hour and took place in residents' homes. Some were preceded by residents filling in reflection booklets ahead of the interview in order to become aware of the topic, which made experiences and practices relating to air easier to discuss (Sleeswijk Visser, Stappers, Van der Lugt & Sanders, 2005). During the interview, I asked residents to explain what they filled in and I then asked questions about it. The structure of the workbook followed the path of expression and also alternated between Make, Say and Do. The interview concluded with a Dolls' house toolkit which the residents used in order to create and express desirable futures. The other, more exploratory interviews started off by covering past and present experiences using stimuli like a timeline, ambiguous pictures and prepared questions to induce stories and memories. Future scenario statements were presented to uncover what residents consider important or desirable for the future. A statement was for example "with a heat pump it is efficient if the temperature is constant and not too high, for example, 21 degrees". These interviews concluded with a home tour, where residents often shared anecdotes about how they manage indoor comfort. In the interviews with residents living in ZE houses, I used statements on current life rather than future scenarios to find out what the residents regard as normal. Information that addresses or challenges people's beliefs can support them in critically reflecting on practices and revealing thoughts (Scott, 2008). A statement was for example: "I always open the window, because it makes me feel more connected to outside".

2.2 Participants

Eleven residents took part in the study. Interviewees differed in age, gender, living situation

and type of property (Table 1). Having a diversity of residents participate supports observing a variety of configurations of a practice (Kuijer, 2017). The visited properties were equipped with different ventilation technologies (Table 2). By visiting residents living with different material, I could study to what extent the material influences the practices.

Table 1 Overview of 11 residents interviewed and their housing, gender and living situation

Nr	Set	Age	Gender	Living situation	Sort of property
1&2	Explorative	± 35	Male&Female	Couple	Two story house
3	Explorative	± 40	Female	Alone	Zero energy ready apartment
4	Explorative	± 55	Female	Alone	Zero energy ready apartment
5	Explorative	± 45	Female	With adult son	Zero energy apartment
6	Explorative	± 67	Male	Alone	Zero energy apartment
7	Explorative	± 40	Male	Partly together	Zero energy apartment
8	In-Depth	22	Male	Alone	Student studio
9	In-Depth	27	Male	Alone	Student studio
10	In-Depth	23	Female	Alone	Student studio
11	In-Depth	19	Female	Alone	Student studio

Table 2 The visited houses and their different material for ventilation

Zero energy	Zero energy ready	Student Studio	Two story house
Well insulated	Well insulated	Well Insulated	Poor insulation
Apartment	Apartment	Studio	Two story house
Balanced ventilation with heat recovery	Mechanical exhaust natural supply	Balanced ventilation with CO2 and humidity sensors	Minimal mechanical extract, natural supply

2.3 Analysis

The analysis combined qualitative data of both the explorative and the in-depth interviews and used visual thematic clustering (Figure 1). The sense-making moved along the DIKW dimensions (Ackoff, 1989): from data to information to knowledge. The qualitative data set, gathered in interviews, included pictures, reflection booklets and transcripts. To turn this into information, I read through the transcripts, marked interesting quotes and wrote their interpretation on post-its. Thereby, I gave it an interpretation and attached meaning to it. Thereafter, I moved towards the level of knowledge and clustered and sought for patterns. In clustering, I kept in mind practice theory and grouped insights into the different elements: images, material and skill. Intermittent with this individual analysis, I organised team sessions in which all the authors reviewed the results. From the analysis and these sessions, key guiding ideas were derived that served as input for design directions.



Figure 1 Visual thematic clustering of insights

3. Results

Residents of ZE (ready) housing struggled to incorporate the balanced ventilation system in their practices, because it is difficult to understand what the system does and hard to develop trust in the system. This disintegration in practices is a key finding, considering that ventilation becomes increasingly important with houses that become more airtight. The ventilation system is of great importance for comfort, health, and energy.

3.1 Associated practices

The practice of maintaining indoor air quality is interconnected with many other practices (Figure 2). Showering, cooking, drying laundry and cleaning are polluting and causing an increased need for air. Sleeping and cleaning are associated with the need for fresh air. Furthermore, images are linked to the following practices: maintaining a comfortable indoor climate, managing energy loss through windows, managing energy bills and keeping the house safe. The insights are clustered into material, image and skills to maintain indoor air quality.



Figure 2 The practice of maintaining indoor air quality is connected to many other practices

3.2 Insights related to the material to maintain indoor air quality

In non-refurbished housing, the following material supports maintaining indoor air quality: windows, doors, the extractor hood, cracks, trickle vents, ventilators, air fresheners, and plants (Figure 3).

1. WINDOWS, TRICKLE VENTS AND DOORS ARE REGARDED AS THE MOST OBVIOUS AND IMPORTANT MATERIALS TO VENTILATE.

In non-refurbished housing, cracks create uncontrolled ventilation with the outside, which is often unnoticed by residents. With refurbishments, material changes. Improved insulation makes uncontrolled infiltration impossible. Furthermore, new material like supply and exhaust channels, a ventilation control panel and sensors are installed (Figure 3).



Figure 3 First columns: ventilation material in pre-refurbishment housing. Last two columns: ventilation practice material in ZE (ready) housing.

The interviews with the residents showed that those living in refurbished, ZE housing felt that the system's feedback and feedforward poorly communicated system functioning and its functions (Figure 4).



Figure 4 A collage from a reflection booklet showing annoyance and insecurity about the ventilation system, described as slow, unexpected, irritating and lacking control.

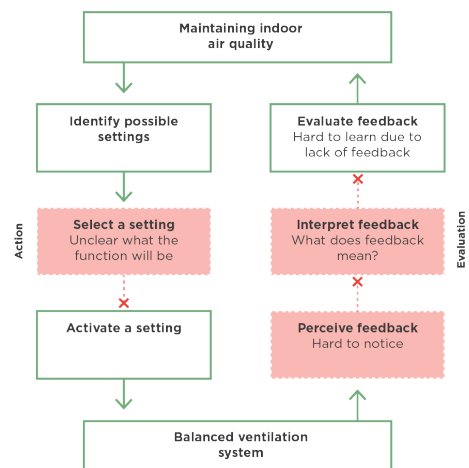


Figure 5 Seven-stage action cycle to operate a balanced ventilation system

To analyse the operation of the ventilation system in a ZE home, I applied the model of Norman (2013) (Figure 5) describing the use of products in action cycles. On the action side, residents struggle to select a setting. In the ZE homes visited, residents have to choose from 1,2,3 and boost (Figure 7). Residents have to learn the settings and when to use them. In interviews, they often recalled the instructor who had explained the system to them. Residents that had automatic ventilation combined with a boost control were insecure about what the control did. This also had to do with the system's feedback, because it is difficult to perceive what the system does and therefore hard to evaluate the performed action. Overall residents feel insecure and frustrated when selecting a setting (Figure 4). Due to lack of feedback residents lack trust in the system's functioning.

"As Sue [the instructor of the system] said of course, I have to keep it on level two; she mailed what the impacts are on air quality. So now I put it on three when cooking."

"But it is unclear what it is doing, really. They say that it will turn on if you press the control once and increase intensity if you press twice. Maybe you can also turn it off using the control, but I don't know about that."



Figure 6 The installation room in a ZE house. It houses the equipment, but is a black box to residents.



Figure 7 Selecting the function suitable for the situation: no indication of the setting the control is currently on.

2. RESIDENTS OFTEN RELY ON NATURAL VENTILATION, BECAUSE THEY PERCEIVE THE EFFECT BETTER

It is difficult to sense an effect with balanced ventilation. Linking back to the seven stages of action (Figure 5) (Norman, 2013), natural ventilation allows for an evaluation phase by feeling the airflow and lower temperature of incoming air. With balanced ventilation evaluating the effect of the action is difficult because no temperature difference or airflow is felt. The system does not compensate for the lack of natural feedback.

"But if it is warm and a bit stuffy I would rather open a window, because it feels like it has a quicker effect. I would not press the button."

3. THE NEW INSTALLATION ROOM IS A TECHNICAL BLACK-BOX TO RESIDENTS

To fit all equipment belonging to ventilation and heat pump an installation room is made on the balcony of ZE houses (Figure 6). Although the room is part of their house, it is not designed for resident interaction – yet they are expected to clean the filters.

“Where that technical stuff is, no girl. That door remains closed... I don’t have anything to do with that”.

4. RESIDENTS DO NOT REALIZE THE IMPACT AN AIR-TIGHT HOUSE HAS ON VENTILATION

With refurbishments houses become air-tight, therefore ventilation becomes increasingly important. However, some residents did not seem to be aware of this change. One resident of a ZE home mentioned rarely opening a window and had the ventilation on a low setting. This is not healthy due to the increased air-tightness of the house.

3.3 Insights into images related to maintaining indoor air quality

Indoor air quality is something most residents are hardly mindful of: air is always there. Only at the moment of entrance, people are briefly sensitive to it. Also when signals like damp, smell and warmth are felt, residents become aware for a short period. Sometimes they take action to improve indoor air quality. In the absence of signals, people generally quickly adapt and forget about it.

1. QUALITY OF INDOOR AIR FELT TO BE IMPORTANT FOR HEALTH

Residents mentioned sufficient oxygen and the right level of humidity as important for their health.

“Yes air is important for my health, for example, sufficient oxygen is necessary to live.”

“Since I have skin problems it is very important for me to have fresh air. Not too damp, not too dry air. Well, just nice and fresh.”

2. GOOD INDOOR AIR QUALITY IS FELT TO BRING COMFORT

Mainly unpleasant smells were mentioned to decrease comfort. Residents also recognize that pollen and a lack of oxygen can make them feel less fit (Figure 8).

“That window is open all day, because it will get damp and smelly if I don’t. And well, I don’t like that of course”



Figure 8 This collage expressed discomfort from indoor air quality as feeling tired and sneezing from pollen



Figure 9 This collage from a resident shows she wants to be able to feel the air like with an open car window

3. MAINTAINING QUALITY OF AIR IS CONNECTED TO ENERGY CONSCIOUSNESS

By ventilating through windows, heat is lost. Therefore, for residents it is associated with energy consciousness.

“And if it then gets really cold actually, I close the open windows on both sides. Because you would be heating the outside air if you didn’t.”

4. AIR QUALITY IS IMPORTANT DURING SLEEPING

During sleep residents find ventilation important, not only to have healthy air but also to have comfortable cool temperatures.

“If I go to sleep, I always find it pleasant to open a window. To notice a bit that there is fresh air coming in”

“Yes, I indeed always have my bedroom window open. Yes, I find it.. I like it better if it is nice and cold than when it is hot in the bedroom.”

5. THE PRACTICE OF MAINTAINING INDOOR AIR QUALITY IS PART OF A TRADITION

Residents perform practices as part of a tradition.

“My mother told me open the window and exchange air. I was told.”

6. AIR FROM OUTSIDE IS CONSIDERED AS HEALTHY AND FEELS PLEASANT

“Well, I do really enjoy the air from outside. The smell and the freshness of the air. And usually I don’t like the airco. Maybe they could fake air at the window, but I can’t imagine that would work.”

“I find it pleasant that even when the window is closed semi-fresh air is coming in with the ventilation system. But well, I do notice that it is a different experience in my room, when the window is open. “

7. INCREASED INSULATION AND BALANCED VENTILATION RESTRICT THE FEELING OF BEING CONNECTED TO OUTSIDE

Sounds, air, and smell make residents feel connected to outside. Due to the mechanical supply of air and insulation, this changes: residents hear fewer sounds, smell less and feel less of the airflow.

“At (X’s) parents they have insulated the place so incredibly that it seems like you live in a vacuum. I think ...you do have to hear something from outside. To have a bit the idea, at least I find it pleasant to have the idea that things are happening around me...”

8. AIR FROM BALANCED VENTILATION FEELS LESS CLEAN BECAUSE IT IS INDIRECT

“Well, with ventilation it is like there is old air circulated in the room. While with an air grill, you know it is air from outside. So maybe an air grill would give me a fresher feeling.”

9. THE VENTILATION SYSTEM IS SOMETIMES REGARDED AS A WASTE OF ENERGY

Residents with automatic ventilation mentioned they find it unnecessary that the ventilation is always on. They regard it as a waste of energy when they have their windows open or when they are not at home.

“I think it is wasteful that it is always on and that you can’t control it the moment you want to, that is a waste of energy. On those moments when I am not here, the air here does not have to be ventilated.”

10. IN ONE MOMENT A BREEZE IS EXPERIENCED AS PLEASANT, WHILE IT IS UNPLEASANT AT ANOTHER MOMENT

In some moments residents enjoy the feeling of incoming air: the movement and its temperature. However, at other moments residents experience the same breeze as an uncomfortable draught.

11. OUTSIDE AIR HAS MORE POSITIVE ASSOCIATIONS COMPARED TO BALANCED VENTILATION

“They say that you can leave the windows closed in summer, in theory, that sufficient air is coming in. But personally, for my own feeling it is in some way nicer to have the window open. Not needed, but well...” (Figure 9).

3.4. Insights into the skills needed to maintain indoor air quality

Typically, residents act upon indicators of pollution. Pollution motivates residents to do something about indoor air quality. Pollution is often hard to sense, only if there is a direct comparison (e.g. when entering a room). Residents with natural ventilation make use of the following skills: creating airflow, balancing noise pollution and the need for fresh air, and balancing fresh air and a comfortable indoor climate. When equipped with balanced ventilation after a refurbishment, residents need to develop new skills to select settings, manage energy usage of the system, clean the filters and limit heat loss through windows.

1. USING VENTILATION CONTROL IS BOTHERSOME AND CONFUSING

Once ventilation controls are installed during refurbishment, they should be discoverable and learnable for residents and they should be able to develop practices incorporating them. In the visited ZE homes residents had to decide whether setting 1,2,3, or boost is proper for the situation (Figure 6). Setting '1' is intended for situations where residents are not at home, however, residents tend to select this setting because they assume that it is more silent and energy-efficient. The control demands of residents to recognize situations with an increased need for air. When there is a party, for example, residents should increase ventilation. Residents have to learn these situations by themselves. This knowledge is not required for residents with automatic ventilation. However, it is unclear for those residents what the boost does and how long it is active. They also doubt how manual control and automatic function together. They are insecure about whether they should take action.

"Here, it has apparently, an orange light could come on and that should mean that air quality is poor I believe. But I am not sure whether I have to turn the ventilation on myself, or whether that happens automatically."

2. RESIDENTS DOUBT SYSTEMS FUNCTIONING BECAUSE THEY ARE UNABLE TO PERCEIVE IT
Feeling the decrease of temperature and airflow are means to observe ventilation through windows. Both means of feedback are absent in the balanced ventilation system. As nothing makes up for this feedback, residents doubt the systems' functioning.

"yes, then I put it to level three, but you don't feel anything from that"

"Here is the ventilation control. There, I pressed it. I hope it works, but I do not know, really"

3. RESIDENTS LOSE INTEREST BECAUSE THEY EXPERIENCE A LACK OF CONTROL
Residents experiment with the controls at the start, but if they do not perceive changes or the system does not meet their wishes they lose interest (Figure 10). The ventilation system will continue to work, but residents only incorporate natural ventilation in their practices.

"and you get used to the way it is. At one point you just accept the way it is. I have researched the system and tried what I can do. It ends at one point and then you make time for other things."



Figure 10 In the interviews this resident showed the control. She had lost interest and placed a clothes rack in front of the ventilation control



Figure 11 Residents are expected to clean the valves. But cleaning them without adjusting configuration or mixing up valves is a challenge

4. RESIDENTS ARE NOT AS CAREFUL WITH THE CONFIGURATION OF THE VALVE AS THE DESIGN DEMANDS

The configuration of the valves is very delicate and specific for the room where it is installed because it determines the amount of air being added. Residents are unaware of this. Besides, they are expected to clean them. By cleaning the configuration can accidentally be adjusted and during cleaning, valves from different rooms can also be swapped as valves of all rooms look similar (Figure 11).

In the interview, one resident said that he sometimes completely closes the valves of the ventilation to decrease noise pollution.

“For example, when my mother comes to stay for the night. She is annoyed by the noise of the system, so then I sometimes rotate it to close it off.”

3.5 Synthesis

A lack of system feedback, unfavourable associations and unmet needs currently lead to the fact that residents are unable to integrate balanced ventilation sufficiently into their daily practices. Due to the lack of feedback that the new material provides, the ventilation system is experienced as a black box. Residents become insecure about the systems functioning and as a result of the poor feedback residents lose interest (Figure 10). Besides, residents hold associations which make transitioning practices more difficult. For example, they regard air from ventilation as less fresh, because it is indirect. Also, ventilation is associated with high energy consumption, rather than saving energy. Furthermore, the new system does not meet the desire to feel airflow and the need to feel connected with outside. The experience of balanced ventilation should match residents’ needs. As long as it does not, they are likely to use the windows. To summarise: the lack of trust in the new systems and of understanding of

the system's functioning is caused by a lack of system feedback (Figure 12)

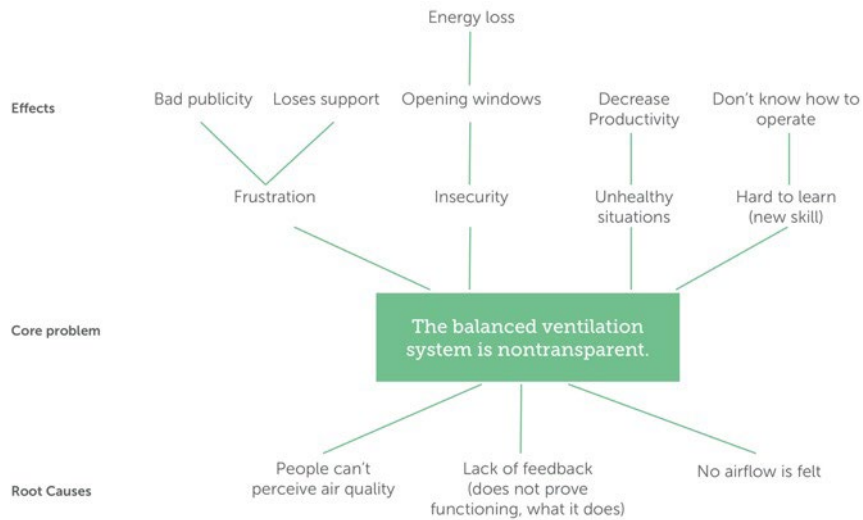


Figure 12 Problems summarised: a lack of feedback is a root cause of the system's non-transparency.

3.6 Design directions

In order to target the key issues of trust and understanding, particular images and skills are targeted that could be evoked when the overall goal is to support residents to integrate the new ventilation system (material) in their practices (Figure 13).

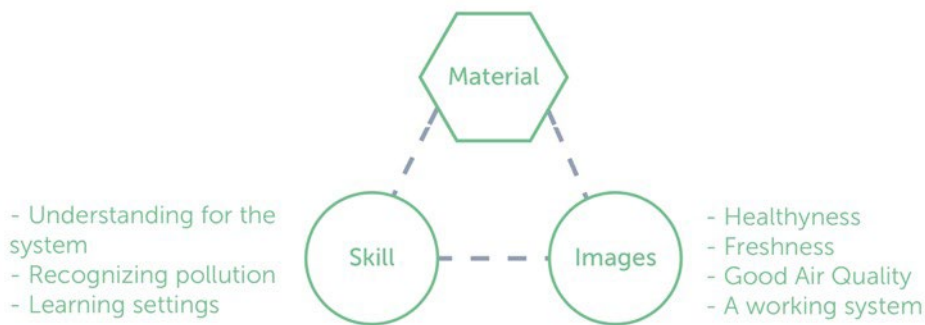


Figure 13 Targeting trust and understanding: images and skills that could be evoked. The overall goal is to support residents to integrate the new ventilation system (material) in their practices. Image adapted from Shove and Pantzar (2005).

Feedback is not only considered as feedback on action, but also a general proof of functioning and air quality.

In the following, a number of examples illustrate design directions how ventilation feedback and transparency could be embodied in the home context to improve trust and understanding.

When behaviour change is about hot air: home systems should change behaviour to fit practices

AUDIO FEEDBACK

This example welcomes the resident with a breeze to foster associations that the system is present and healthy. Audio feedback is used to communicate what the system is doing (Figure 14).

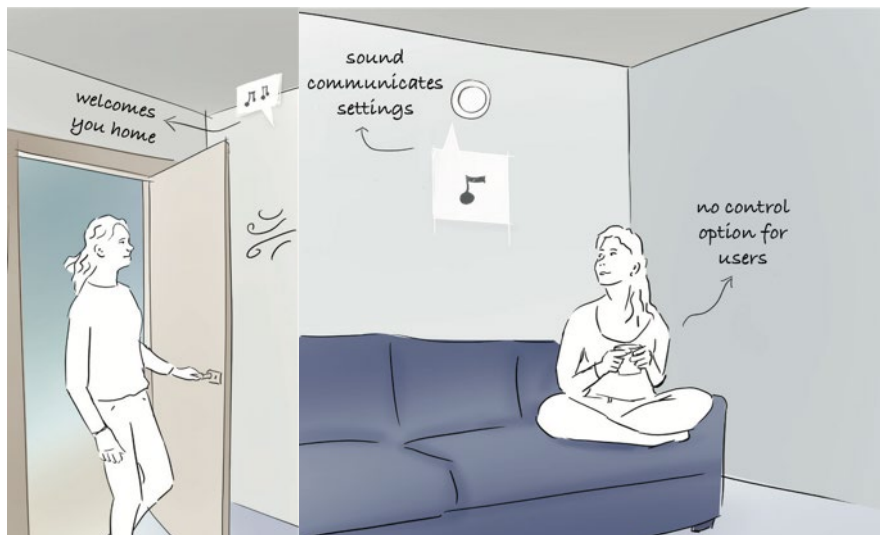


Figure 14 Welcoming the resident with a breeze to foster associations that the system is present and healthy.

SMART DOORS

This example uses the doors to provide information on indoor air quality. Residents can access more information in a second layer of information. Information on air quality proves the quality of air and supports learning about pollution (Figure 15).

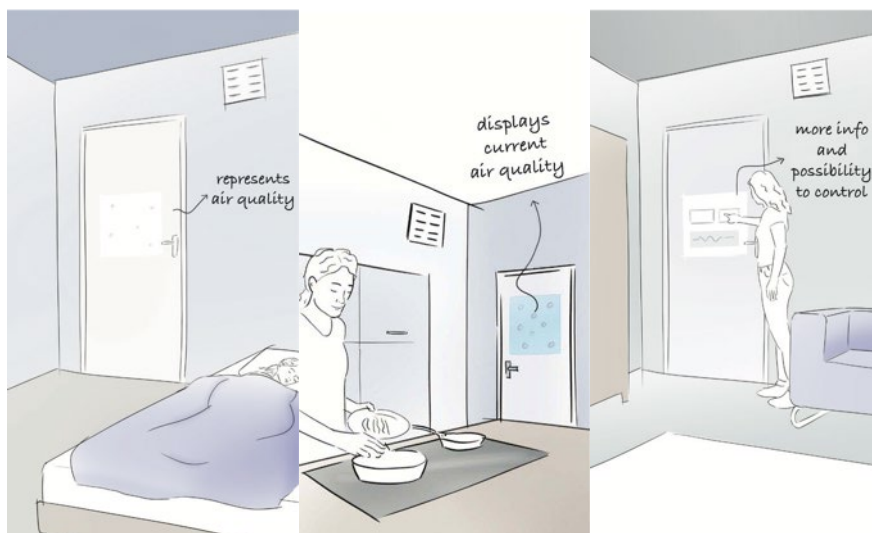


Figure 15 Smart doors to provide information on indoor air quality.

VISUAL SUPPLY

This example uses the supply valves to prove the system is working and show what it is doing. Through increased trust and understanding for the system it supports integration in practices (Figure 16).

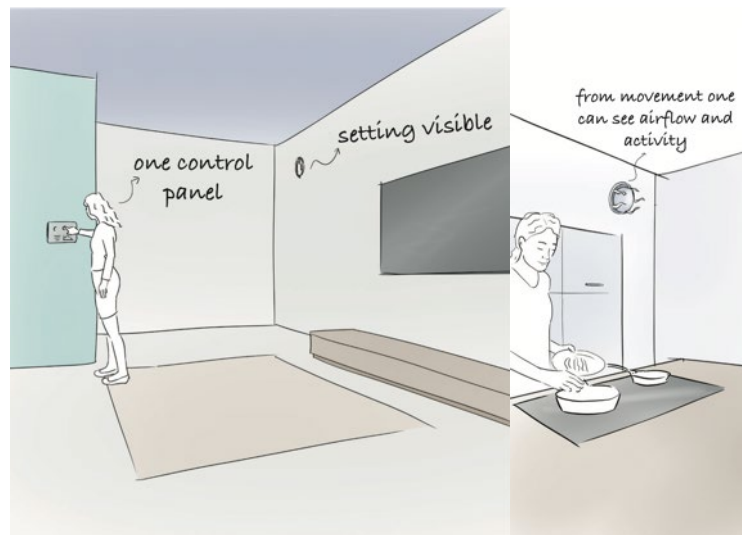


Figure 16 Using the supply valves to prove the system is working and show what it is doing.

FEEDBACK VALVE

This example shows that the need to clean valves could be indicated right at the place of the valve itself. Additionally, the valve could be designed in such a way that it can only be re-mounted after cleaning in the way that provides the right amount of air. Showing the need to clean can help residents develop a practice around it like cleaning curtains or windows (Figure 17).



Figure 17 Indicating the need to clean valves right at the place of the valve itself.

4. Discussion

This study investigated residents' ventilation practices to identify starting points for supporting residents to transition their practices in ZE homes. We have shown an example of how a practice-oriented research approach (Shove & Pantzar, 2005) reveals a lack of system feedback, unfavourable associations and unmet needs. An added detail analysis of system operation (Norman, 2013) adds understanding to the practices perspective of where the breakdowns occur that impede integration of new systems in residents' lives. Lastly, we provide exemplary design directions to better support resident practices. Based on these findings, future research may need to start by engaging with residents' existing and potential practices and then designing system behaviour change to correspond with that, rather than the more common approach in this domain of designing home systems and then resident behaviour change.

Studying practices in field research revealed that residents struggle to develop new practices that incorporate the balanced ventilation system. We described the associated practice of maintaining indoor air quality in order to identify points that hinder a transition of the practice. We found the lack of feedback makes residents insecure and makes it hard to understand the system. Besides, associations that are mismatched with the new material make residents reluctant to use balanced ventilation systems.

In addition to the analysis, we proposed design directions to illustrate how feedback could be improved and desirable associations with the ventilation system fostered. This could help residents trust that the system is working, understand what the system does and develop appreciation for it. The design directions could serve as input for the design of new product-service-systems and the design of touch points for them. Ideally a ventilation system should be self-explaining, because owners and residents change and there is often no introduction or manual available.

We have seen that the design directions involve modifications to installation components such as valves, which also has implications for the system balance as a whole. It is important to get stakeholders like general contractors and installation components manufacturers excited about the potential of solutions in this domain. The design directions developed in this project so far only address understanding and trust of the system, but even more links could be made between the technical functioning of systems and practices and positive experiences at home.

In conclusion, both the design directions and the insights generated can contribute to a transition of residents' ventilation practices in ZE homes. Overall, the study shows that studying practices helps design better home systems. The generated insights about ventilation practices could be used by general contractors to design the touchpoints and communication in the ZE refurbishment process. Besides, ventilation component manufacturers could use design directions as input for the design of future ventilation systems. In this way, the study supports residents to transition practices in both current and future systems.

Hence, it can contribute to decreasing the performance gap (Behar & Chiu, 2013; Paone & Bacher, 2018) and increase residents' comfort after a refurbishment.

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Design Innovation Management SIG

Overview of papers in the Design Innovation Management SIG highlights

Editorial	822
Erik BOHEMIA, Blair KUYS	
185. Expanding industrial design's contribution to manufacturing SME's in Hong Kong by introducing a Balanced Scorecard for industrial design management	824
Sonny Yip Hong CHOY, Blair KUYS, Gianni RENDA	
251. Product standards as a barrier to innovation: the case of jockey's safety vests	838
Lisa GIUSTI GESTRI, Carolyn BARNES	
286. Research on the value of CMF design in industrial products	853
Ying LIU	
204. The inherent value of design research for industry: An impact case study using low-cost 3D printing for high-value commercial products	866
Blair KUYS, Mark STRACHAN	
272. A pilot study used to better construct a research direction to understand where industrial design fits within the 4th industrial revolution (Industry 4.0)	887
Christoph KOCH, Blair KUYS, Gianni RENDA	
358. Sharpening Critical Thinking in Problem Identification in Design and Technology Education	899
Wei Leong LOH	



DRS2020
BRISBANE, 11–14 AUG
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Editorial: Diversity of Design Innovation Management research – the Design Innovation Management SIG

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Papers included in the Design Innovation Management Special Interests Group's section cover a spectrum of topics such as trying to develop a measurement to benchmark design's strategic impact in manufacturing companies, or exploring external barriers hampering safety product innovation and exploring critical thinking elements in educational settings. The included papers in the DRS2020 conference proceedings illustrate the wide level of diversity related to design innovation management research.

In the first paper (paper 185) by Sonny Yip Hong Choy, Blair Kuys and Gianni Renda titled 'Expanding industrial design's contribution to manufacturing SME's in Hong Kong by introducing a Balanced Scorecard for industrial design management' outlines a rationale to develop a tool named 'Balanced Scorecard' to measure performance of 'industrial design management' within manufacturing SMEs. The development of the 'Balanced Scorecard' tool is part of a doctoral research project. The 'Balanced Scorecard' has been inspired by Kaplan's and Norton's initial work in 1992 and the idea is to extend the measure to 'industrial design management' and how it informs SMEs' strategy and in return, it is anticipated that the information can be used to improve the performance of the 'industrial design management'. The doctoral candidate plans to test the 'Balanced Scorecard' with manufacturing SMEs located in Hong Kong.

In the next paper (paper 251) by Lisa Giusti Gestri and Carolyn Barnes titled 'Product standards as a barrier to innovation: the case of jockey's safety vests' explores how design innovation which is related to personal safety can be hampered by national product standards. The authors propose that in order to stimulate product design innovation a wider network of stakeholders need to be considered. For example, in their review of jockey's safety vests in Australia they identified that beside the jockeys, both medical, as well as product standard experts, should be involved in the innovation process.



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The third paper (paper 286) titled 'Research on the value of CMF design in industrial products' by Ying Liu argues that the fastest and most efficient cost reduction can be realised by changing the Colour, Material and Finishing (CMF) scheme. Liu proposes that the CMF design concept is related to the International Council of Societies of Industrial Design (ICSID) 1980's definition of industrial design. Ying Liu suggests that CMF can also be used to develop business strategy. Thus, the author concludes that future designers should be trained using CMF as part of their practices.

The next paper (paper 204) by Blair Kuys and Mark Strachan outlines a research-led design project undertaken with a lighting company and how it stimulated the company's innovation by enabling it to access expertise of using CAD and 3D prototyping technology. The technological expertise was used to progress the aesthetic development of a new range of products, as well as their structural and functional elements.

The fifth paper (paper 272) titled 'A pilot study used to better construct a research direction to understand where industrial design fits within the 4th industrial revolution (Industry 4.0)' by Christoph Koch, Blair Kuys and Gianni Renda argues that industrial designers are largely unaware about 'Industry 4.0' benefits. They suggest that the lack of understanding is potentially hampering innovation to support companies to take advantage of Industry 4.0.

The last paper (paper 358) by Wei Leong and Leon Loh titled 'Sharpening Critical Thinking in Problem Identification in Design and Technology Education' explores critical thinking elements as used by Design and Technology students located in Singapore. The authors propose that the contextualising students' critical thinking can support teachers to improve how they guide students' design projects. They concluded that the students who participated in the research have achieved positive outcomes related to critical thinking.

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Expanding industrial design's contribution to manufacturing SME's in Hong Kong by introducing a Balanced Scorecard for industrial design management

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Abstract: Manufacturing small-to-medium enterprises (SME's) in Hong Kong utilise the Hong Kong industrial design profession as a source of competitiveness. However, the contribution of industrial design to these objectives falls short due to mis-aligned priorities and unmet manufacturer needs. This paper and associated literature review discusses the background and context for the creation of a Balanced Scorecard for industrial design management framework. The framework's intention is to provide a robust solution to Hong Kong manufacturing SME's to deal with business volatility and increased competition globally. The context of Hong Kong manufacturing is explored while the foundations and potential benefits of this new and novel framework are discussed.

Keywords: balanced scorecard; industrial design; hong kong sme; manufacturing sme

1. Introduction

Hong Kong manufacturing SME's want to become more strategic in their operation as part of elevating their business model from Original Equipment Manufacturer (O.E.M.) to Original Design Manufacturer (O.D.M.), Original Brand Manufacturer (O.B.M.) and Original Strategy Management (O.S.M.). However, they find the industrial design services available in Hong Kong are mismatched to these objectives. As highlighted by E. C. Yim (2018), industrial design in Hong Kong is under-utilized and doesn't contribute with its full potential. In fact, Yim identifies four aspects on which the two professions mismatch, thus creating a need for rectification.

This conceptual paper discusses the problems, contexts and reasons why a new and novel framework named the Balanced Scorecard for industrial design management may offer



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one effective solution. It focusses on how this framework can potentially help Hong Kong industrial design profession become more valuable and connected to manufacturing SME's in Hong Kong. It discusses the potential benefits and illustrates ways of making marked improvements to Hong Kong's industrial design profession.

This paper is contextualised for Hong Kong manufacturing and industrial design, however, the learnings from this could transfer to similar geographic and economic contexts globally where manufacturing SME's play a role in the economy. Also, modifications to this framework may potentially benefit other design professions which also aim to make significant contributions to business performance.

The following outline provides a brief introduction on the areas covered within this paper. The Balanced Scorecard for industrial design management framework is currently being developed as part of the requirements of doctoral research in industrial design. As such, the framework is yet to be fully created and will not be presented here. Empirical research is required to create and validate this framework which would be done in later stages of the doctoral research. Rather, this conceptual paper and review of literature will discuss the problems, context and influences surrounding its creation. This paper first discusses problems observed in Hong Kong related to a mismatch between manufacturing and industrial design, giving rise to the motivation for this research. It then explains the Balanced Scorecard (BSC) framework which is a business tool fundamental to this research. A brief history is offered and the main aspects of BSC are described, giving insights as to why it is chosen. The paper then discusses how industrial design increases its relevance in firms and how this new and novel framework enhances industrial design contribution. Discussion is made on how the benefits of BSC framework may carry across to Balanced Scorecard for industrial design management and why this new framework represents one solution to the problems in Hong Kong. What follows are deep dives into two scholarly works which also form foundations for this new framework and explains why these works are significant. Reasons why industrial design is key to SME success is then explained by further review of literature. The Balanced Scorecard for industrial design management is then briefly introduced before the paper is concluded by discussing how further research into the creation of this framework will proceed. The message this paper provides for other design researchers is a greater understanding of a Balanced Scorecard for industrial design management. The conceptual paper and subsequent literature can be used for other researchers to determine if a similar framework could/should be considered for organisations relevant to this field.

2. Hong Kong's mismatch problems

E. C. Yim (2018) discovered that Hong Kong industrial designers have weaknesses in manufacturing knowledge, technology knowledge, organisational behaviours and business knowledge. Hong Kong manufacturers require those skills and knowledge from their industrial designers. As highlighted, Yim notes the Hong Kong industrial design profession

fails to meet all the needs of Hong Kong Manufacturing SME's. Other scholars have noted that Hong Kong industrial design profession is not fully addressing manufacturability in the industrial design process (Li et al., 2018). Industrial design in Hong Kong focusses less on manufacturing aspects of product and more on aesthetics and the user's perceptions of products (Lam, Liu, & Yee-Nee Lam, 2016; E. C. Yim, 2018). In addition, the Hong Kong industrial design profession attempts to create value by advocating "for the significance and value of reapplying traditional design wisdom to solve contemporary design problems" (Zheng, 2014). These approaches do not align perfectly with Hong Kong Manufacturing SME's practical and commercially oriented design needs. On the most part, Hong Kong's current industrial design education has left Hong Kong manufacturers frustrated by offering a small array of industrial design strategies (E. C. Yim, 2018). This creates a need for change in the Hong Kong industrial design profession and asks how they can better meet Hong Kong manufacturers' needs.

At the same time, Hong Kong SME's can benefit from a more strategic approach (E. Yim, 2015). However, on an individual firm level, many SME's lack a clear strategy (Rompheo, 2011), let alone one to lead them to a more competitive state. Their diversifications into realty, the volatile business environment, increasingly selective tastes of customers and advancements in manufacturing technologies (E. C. Yim, 2018), not only leave them in a weakening position, but the lack of proactiveness in being more strategic only amplifies the disabling nature of the problem. These gaps in alignment are widening and the need for a more strategic approach are of utmost importance. Manufacturers are not making the most of industrial design strategies to contribute to firm performance and create value (E. C. Yim, 2018).

This conceptual paper reviews relevant literature that contributes to creation of a new framework named Balanced Scorecard for industrial design management. The framework combines BSC with industrial design strategies to potentially become a robust solution substantiated by over 25-years of research. The new framework not only allows firms to create and plan a firm strategy, it also ensures every member of the firm is acting to deliver what is in the firm's best interests.

3. Balanced Scorecard (BSC) background

The BSC was developed by Kaplan and Norton in 1992. In their Harvard Business Review article, the researchers likened the BSC to "dials in an airplane cockpit: it gives managers complex information at a glance" (R. S. Kaplan & Norton, 1992). It is a business performance management and strategic planning tool that is highly effective at creating financial and non-financial firm improvements. In literature (BSI, 2008, 2018; Coe & Letza, 2014; R. Kaplan & Norton, 1996; R. S. Kaplan & Norton, 2001, 2005), BSC has been applied to a wide range of firms with great success. BSC measures a firm's performance through four important perspectives: financial, customers, internal processes, and learning and growth perspectives. These four perspectives exist as both financial and non-financial aspects. This is a strength of the BSC since it overcomes "limitations of managing only with financial measures"

(Davig & Brown, 2004) and managing with a “narrow and incomplete picture of business performance”(R. S. Kaplan & Norton, 1992) when relying purely on financial measures.

BSC combines important business areas which can be “disparate” into a single managerial report. The holistic view of the firms’ overall strategy prevents errors by showing managers “whether improvement in one area may have been achieved at the expense of another” (R. S. Kaplan & Norton, 1992).

Literature relating to both the BSC and SME’s became more popular during the first decade of the 21st Century. Before this period, a literature review was not in existence (Sousa, Aspinwall, & Guimarães Rodrigues, 2006; Taticchi, Tonelli, & Cagnazzo, 2010). Early on, SME’s were neglected somewhat with regards to BSC and importantly for this study, there has been very little literature on the link between a BSC approach and industrial design.

BSC “translates mission and vision statements into a comprehensive set of objectives and performance measures that can be quantified and appraised” (Bain, 2019). A key aspect of BSC is to “balance lagging indicators with leading indicators” (Mair, 2002). Lagging indicators describe what has happened, while leading indicators “attempt to quantify future results based on current actions” (Mair, 2002). Kaplan and Norton suggest the ideal BSC has “lead and lag indicators applied horizontally within the areas and vertically between areas” (R. S. a. Kaplan, 1996).

Mair (2002) was able to identify critical success and failure factors in implementing BSC for SME’s. Success factors include mobilising change through executive leadership; making strategy a continual process; aligning organisation to the strategy; making strategy everyone’s job; monitoring and reporting progress regularly; getting an objective (external) opinion on the developed BSC; and treating the BSC as a dynamic document, adjusting it to changing conditions. The pitfalls discovered include failing to communicate and train; having no accountability; measuring that does not focus on strategy; measures that are tied to compensation too soon; employees not being empowered; and having too many initiatives. Literature notes that training is clearly tied to effective BSC implementation (Sitkin, Sutcliffe, & Schroeder, 1994; Walton, 1986). This was evident from Sousa et al. (2006) who found UK SME’s focus most on this area when implementing BSC.

Fernandes, Raja, and Whalley (2006) investigated a manufacturing SME with little familiarity with BSC and some level of scepticism as well as reluctance toward BSC’s implementation. To meet this challenge, a robust 8-step implementation was devised to emphasised firm buy-in. Heavy input and involvement from the researchers replaced the traditionally top-down implementation approach (Papalexandris, Ioannou, & Prastacos, 2004). Part of the their insight was that Individual departments need to be held accountable if true buy-in can be achieved (Jude Fernandes, Raja, & Antony, 2001). Since M. B. Beverland, Micheli, and Farrelly (2016) highlight departmental conflicts as a barrier to increasing industrial design’s contribution and status, the implementation model of Fernandes et al. (2006) will greatly help to smooth out such conflicts.

Rompho (2011) is a scholar noting a fault with BSC in SME’s. He cited “frequent strategy

changes that require revision of the BSC is another important factor that determines the success or failure of implementation.” Although this research was based on a single case study, it does point toward some problems in similar ways to Hudson, Smart, and Bourne (2001). Pekkola, Saunila, and Rantanen (2016) cites inflexibility and involved implementation as reasons making the BSC unsuitable for SME’s in turbulent environments.

R. S. Kaplan and Norton (1992) highlight how BSC allows a firm strategy to be formulated with the best interests of the firm at its heart. It also plots a course for individual departments and even individual colleagues to join hands and deliver on this strategy from the highest to the lowest levels of the firm. BSC is not only a strategic plan, it is also a performance measurement and management tool that ensures what a firm sets out to achieve is quantitatively measured and successfully implemented over time. The simple, holistic and practical nature of BSC are some of its great strengths.

However more recently, Heinicke (2018) conducted systematic literature review of performance management systems (PMS) in SME’s and family firms. The review featured examples and evidence of effective BSC deployment in an SME context, lending support for BSC’s use in SME’s. Malagueno, Lopez-Valeiras, and Gomez-Conde (2018) offers quantitative data that shows BSC leads to improved financial performance for SME’s. In particular SME’s which are more established as opposed to start-up SME’s. The researchers found that BSC enhances organisational efficiencies without apparent reductions in firm flexibility. This discovery is important since it refutes earlier researchers suggesting BSC implementation required a higher level of firm structure in order to be successful (Pekkola et al., 2016; Rompho, 2011; Taticchi et al., 2010). As such, the affirmations for BSC usage in SME’s support the creation of a Balanced Scorecard for industrial design management framework which targets Hong Kong SME’s.

4. Industrial design strategies for SME’s and how these can be complemented by this framework

There is extensive literature exploring how industrial design can create and capture customer value. These industrial design strategies cover a wide array of opportunities for Balanced Scorecard for industrial design management to enhance through measurement of performance and management by firmwide strategy. For example, contributing to scientific experiment design to ascertain a better research direction (Thong & Kuys, 2012), using “inclusive design principles to develop appealing assistive products” (Kuys & Renda, 2013), improving design outcomes through special focus on design brief formulation (Yang & Renda, 2019) or use of “frugal innovation” (Rao, 2018; Weyrauch & Herstatt, 2017) to create new product concepts cheaply and rapidly. The framework in this research can support these strategies by integrating them into one which involves the entire firm and appends appropriate measures that quantify staff contribution. Regardless of whether the strategy (or strategies) occur at the front-end of the product development process, or represents a firmwide paradigm change, industrial design strategies can be integrated into this framework

to create a firm wide strategy.

Industrial design strategies involving higher degrees of firm participation may include work on a firm's "value creation design" where its business model and value networks are designed for increasing profit (Schneider, Mittag, & Gausemeier, 2017). Or, industrial design could capture value through the use of design thinking to enhance innovation of products, systems and services (Kleinsmann, Valkenburg, & Sluijs, 2017; Tabeau, Gemser, Hultink, & Wijnberg, 2017). These types of high involvement strategies can be very well supported by a Balanced Scorecard for industrial design management because of its ability to clearly delegate responsibilities and involvement to each member of staff. It clearly allocates measures to these staff so that they are aware of how they can achieve the required results. For example, one measure within a learning and growth perspective may be to evaluate the adoption of design thinking in the firm after six, 12 and 24-months. Another measure may be to evaluate the number of new product ideas generated since the introduction of design thinking to the firm.

A knowledgeable framework implementer may pair this framework with any type of industrial design strategy. For example, a firm engaging in design-led innovation to improve a business model, repositioning the business and its offerings in the market to become more innovative (Townson, Matthews, & Wrigley, 2016) would require an implementer who is well versed with such a transformation. He/she would be tasked with determining the right set of measures for the process together with management and staff. Another example may involve designing for manufacture and assembly (DFMA) to reduce part-costs (Bin Ahmad et al., 2018) or the "servitization" of products by offering "services in combination with their products" (Kuijken, Gemser, & Wijnberg, 2017).

There are many examples of how industrial design strategies can contribute to firm performance. What is discussed here is a small selection with due respect to the limitations of this paper. When implementing this framework with various industrial design strategies, a list of benefits exists for firms.

5. Benefits of BSC that are potentially shared by Balanced Scorecard for industrial design management

Balanced Scorecard for industrial design management can be matched with any industrial design strategy listed above. This unrestrained flexibility of the framework is one of its great strengths. It achieves this by measuring any industrial design strategy from four financial and non-financial perspectives found in BSC. Thus, manufacturers can implement this framework no matter what their goals, objectives or intended choice of industrial design strategy is.

The framework allows a firm to adjust its strategy over time, too. During implementation, the firm's chosen strategy can be adjusted, combined with other strategies or altered to address the changing business environment. Since the resultant Balanced Scorecard for industrial design management document is designed for ongoing adjustments, firms can use it flexibly to free itself from limitations rising from changing business environments.

The heart of Balanced Scorecard for industrial design management is its ability to bring clarity and transparency to the contributions of industrial design. It holds actors in the firm accountable to their allocated measures and allows management to see exactly what is achieved in each component of an industrial design strategy. The benefit of this framework is that industrial design can now be measured across the entire firm down to the individual employee. Benefits include quantification of performance for decision makers and the elevation of industrial design to the forefront of management's attention.

Firms in Hong Kong managing industrial design can benefit from using this framework by quantifying how industrial design adds to firm performance. Since the framework makes explicit the contribution of each perspective, mapping industrial design to these perspectives clarifies its contribution, where measurable performance can be managed (Ridgway, 1956).

By integrating disparate business areas into a single report, industrial design is integrated into a firmwide strategy, thus potentially raising its level of importance in the firm. By identifying lag/lead indicators in the context of industrial design, time versus value creation/capture reveals an added dimension to understanding the contribution industrial design has on a firm.

For Hong Kong SME's, it represents an attractive option that may support its navigation through a volatile/uncertain/complex/ambiguous (VUCA) business environment (Cousins, 2018) which they find themselves in.

To summarise, all benefits experienced in a typical BSC implementation can potentially carry across to this new framework. The work will need to be done in the doctoral research to determine the degree to which this is true.

In literature on increasing the contribution of design, different models and frameworks can be found. For example, various models have similarly considered design as capability or as resource (Acklin, 2013; DDC, 2003; Kootstra, 2009; Westcott et al., 2013), as a contributor to branding and firm strategy (M. Beverland & Farrelly, 2007), as requiring cross-firm acceptance and cross-functional collaboration (Bilson & Aitchison, 2016; Micheli, Perks, & Beverland, 2018), and as process guided by design maturity models with various measurement metrics (Acklin, 2013; DDC, 2003; Kootstra, 2009; Westcott et al., 2013).

Micheli et al. (2018) found critical success factors for increasing industrial design contribution to a strategic level to include: top management support, leadership of the design function, generating awareness of design's role and contribution, inter-functional coordination, evaluation of design, and formalisation of product and service development processes are all necessary ingredients.

For Balanced Scorecard for industrial design management framework, achieving these types of success factors is integrated into its conceptualisation. For example, when a firm's management commits to this framework it will inherently accept that industrial design will play a major part in the firm's competitiveness. It will involve commitment and buy-in from management down to individual staff and will require different departments in the

firm to work toward the same goal. The great advantage of this framework is that design is consequently formalized and permeated throughout the firm. Once performance measures are in place for each department, the firm can focus on delivering the strategy that will bring them success.

Potential applications for this framework may include helping inexperienced firms to introduce industrial design to their business in a transparent and measurable way, supporting a firm's elevation in design maturity to become more competitive, increasing the performance of an existing industrial design department or measuring the effectiveness of increased investment into industrial design over the short/medium/long term. Beyond strictly industrial design related applications, the framework can be adapted to facilitate similar results for other professions. For example, the framework can measure fashion design contribution to firm performance for a fast-fashion brand, manage architectural design client expectations (Wong, Lam, & Chan, 2009) or to improve civil engineering sub-contractor selection (Ng & Skitmore, 2014). Further to this, synergy can be created through this framework by integrating inter-disciplinary design efforts into a single cohesive strategy map. The map would clarify how each design discipline would contribute to positive performance in such synergistic projects. For example, by including a sustainability measure (Wang, Chang, Williams, Koo, & Qu, 2015) to BSC in projects geared toward environmental benefit to society, synergy between multiple design disciplines can be integrated into a single cohesive strategy map and performance measurement plan.

6. Balanced Score Card and Design Value

Mozota (2006) created a conceptual framework which combines design and management. Seeing misalignments between the two professions yet both having to operate in firms together, Mozota offers a single holistic framework to combine the work of both parties. "A value model in design management" aligns the "four powers of design" with the four aspects of Kaplan and Norton's Balanced Scorecard. Besides this, Zizlavsky (2016) created an original conceptualisation called the Innovation Scorecard which is based on the stage-gate process and the Balanced Scorecard. These two frameworks serve well to measure and manage design/innovation performance. The referencing to these two frameworks represents two separate but equally valid versions of the BSC for industrial design management. Although they are conceptually similar, the purpose of this research is to create a suitable and effective framework to help Hong Kong manufacturing SME's. As such, these two versions hold much validity and contribute to the creation of this framework.

7. Reasons why industrial design is key to SME success

To benefit SME's on a long-term basis industrial design can become more strategic in its approach, "influencing decisions and setting direction on issues related to long-term sustainability and competitiveness" (Luchs, Swan, & Creusen, 2016). Raising industrial design's level of influence brings benefits. It is instrumental to the creation of new markets

(IDSA, 2019) and adds value to SME's (Mak, 2018). Strategic industrial design "drives innovation, builds business success, and leads to a better quality of life through innovative products, systems, services, and experiences" (WDO, 2015). Through engaging with industrial design, firms can achieve greater competitive advantage as well as support innovation (Hernandez, Cooper, Tether, & Murphy, 2018).

8. The beginnings of an integrated solution

The Balanced Scorecard for industrial design management aims to deliver a robust framework for performance measurement and performance management to Hong Kong Manufacturing SME's. The framework is based on a commonly understood strategy statement which is permeated throughout the entire firm. The robustness of this framework improves businesses no matter the sector or size. It gives firms a clear and explicit way to achieve improved firm performance in a step-by-step manner. Once the system is set in place through a tailormade implementation plan, the firm carries out the required tasks and iterative progress until improvements become evident over time. The main differentiation between the traditional BSC and Balanced Scorecard for industrial design management include the following:

1. BSC looks at measuring the entire firm's performance based on general performance improvements whereas this framework starts with the premise that industrial design will take a strategic lead by dictating the direction of the firm. Thus, all other departments within the firm contribute to increasing competitiveness through high deployment of industrial design.
2. BSC is a performance management tool which measures a firm's performance down to the individual level whereas this framework also does this but has the capability to raise industrial design to a strategic level, increasing the firms design maturity.
3. BSC uses a generic firm strategy which is based on the firm's competitive competencies, whereas this framework creates a business and design strategy allowing performance measurement using best practice design metrics and measures.

By proposing the Balanced Scorecard for industrial design management as a solution to the mismatch between the Hong Kong industrial design profession and Hong Kong SME's expectations, Hong Kong gains a reliable framework for leading SME's to a better future and greater competitiveness. Hong Kong's leading position in the Greater Bay Area of China has been seriously challenged by the rapid rise of neighbouring Shenzhen (Heaver, 2016). What is being proposed leading out of this conceptual paper and literature review, is a new and novel framework that enables industrial design to enhance Hong Kong SME competitiveness.

9. Conclusion

The Balanced Scorecard for industrial design management — a new conceptual framework — refers to the knowledge areas reviewed in this research. A robust framework that takes advantage of what Hong Kong industrial design profession has to offer through a diverse range of value adding methods and techniques. Industrial designers can implement any one or combination of these strategies to generate value for Hong Kong Manufacturing SME's. By moving up the value chain, the Hong Kong industrial design profession can help Hong Kong Manufacturing SME's step up in strategic focus from O.E.M. to O.D.M., O.B.M. and O.S.M.. The Balanced Scorecard for industrial design management framework provides a clear and 'easy to use' performance measurement and management framework for Hong Kong SME's to achieve increased strategic focus and become more competitive.

Through implementing this new framework, design maturity and contribution of industrial design for Hong Kong Manufacturing SME's is raised as a consequence; with benefits such as "cost savings, revenue gains, productivity gains, speed to market, and brand and market position improvements through their design efforts" (InVision, 2018).

Importantly, when a firm commits to increasing the contribution of industrial design and attracting more value from the market, they will have a robust and proven method for doing so. The framework will help limit risk with industrial design engagement, as well as an increased understanding of the impact industrial design can have on a firm. In the same instance, since many SME's are not endowed with a thorough strategic plan (Rompho, 2011), and strategic directions change often, a clear mission and vision that is translated into a workable and executable strategic and performance plan is all the more necessary. This would help SME's navigate the VUCA business environment.

Moving forward, the doctoral research will use empirical research methods to create, implement and review this new and novel framework with suitable research subjects. This research will propose questions related to this framework's effectiveness and suitability to addressing problems found in Hong Kong manufacturing SME's. It will seek to create a thorough and well considered framework that would be robust and adaptable to the many firms which require such a solution.

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Product standards as a barrier to innovation: the case of jockey's safety vests

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Abstract: Innovation is key to enhancing product performance and customer benefits, with designers having a core role in conceiving and actioning innovations in response to evolving conditions of use and customer needs. This paper discusses the scope for innovation in jockey's safety vests in relation to the constraint of official product standards. The Australian standard for jockey's safety vests, ARB 1.1998, has not been appreciably updated since the early 2000s despite a consistent rate of serious injuries to jockeys, grown in the number of females and the rise of smart wearable technologies in other sports and health. For this product category, those setting standards seem habitually unable to revise their norms, limiting product development to styling. We complete the paper with a snapshot of results from a program of user research, which shows how jockey's needs and perspectives contest the existing standards for safety vests and could significantly inform product innovation.

Keywords: jockey's safety vests; personal protective equipment; product innovation; safety standards; design innovation

1. Introduction

Product standards have limited innovation in the design of jockey's safety vests in Australia despite consistent rates of serious and fatal injuries to jockeys and the growing participation of female jockeys in the sport. This case study reflects on the barriers to innovation in jockey's safety vests. Firstly, we clarify the nature and purpose of safety equipment in sport. Secondly, we provide brief literature reviews on race injuries to jockeys and the effect of product standards on innovation. Thirdly, we report a qualitative study on the perspectives of jockeys in their use of safety vests to highlight the scope for innovation and limitations of current product standards. Here, we identify the previously unconsidered status of medical staff as an additional user group, whose role in racing accidents is pivotal to the wellbeing of jockeys. We conclude the paper by considering how smart technologies could advance innovation in this product category.



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2. Background to horse racing and PPE

Personal protective equipment (PPE) plays an essential role in preserving athletes' safety when participating in sport. Because of the diverse nature of sports and sporting injuries, PPE is a broad product category that includes helmets, body protectors, gloves, goggles and mouth guards, with athletes often required to use a combination of equipment to offer full protection (Daneshvar, Baugh, Nowinski, McKee, Stern, and Cantu, 2011; Graham, Rivara, Ford, and Spicer, 2014). The PPE literature discusses how design innovation and advanced materials have been applied to PPE design to offer enhanced protection to athletes, although there is no specific literature on the design of jockey's safety vests. According to Sports Medicine Australia (2008), about 50% of sports injuries are preventable with appropriate and properly fitted protective equipment, clothing and footwear. Race riding is well-acknowledged as a risky activity. Regardless of a jockeys' training and skill, it is not possible to prevent a fall; horses are unpredictable animals that have evolved to use agility and speed to escape danger; riding them at speed is inherently dangerous (Miko, 2017).

Despite it being compulsory for jockeys to wear gloves, helmets, goggles and safety vests, jockeys are daily exposed to high risk in races and training gallops, knowing they are likely to experience falls and consequent injuries during their career (Polkinghorne, 2016b). Indeed, former jockey Brian Rouse describes race riding as *"like driving a car with no brakes. If you make a mistake, you can't rectify it in one stride"* (Quoted in Oakley, 2013, p. 288). In Australia, an average of 200 jockeys are injured annually, 89% of falls requiring medical assistance with 40% of jockeys being unavailable to ride for an average of five weeks a year due to injury (National Jockeys' Trust, 2017). The most common injuries to jockeys are fractures and soft tissue damage, but the most serious are head and spinal damage, which can cause permanent, debilitating injuries and even death (Mackey-Laws, 2016; Aitken, 2017; Johnston, 2017, O'Connor, Warrington, McGoldrick, and Cullen, 2017). The catastrophic injuries often suffered by jockeys in the torso area following falls (Filby, Jackson, and Turner, 2012; McCrory, Turner, LeMasson, Bodere, and Allemandou, 2006) highlight the poor level of protection offered by safety vests.

The major international industry that provides clothing and equipment for riders is an interesting case in what motivates product development. Horse riding is often a pursuit of social elites, with *fashionability* being a significant consideration for the design of riding attire and equipment. This is followed by comfort and lightness, with all three played off against protection from injury. For example, the expensive helmets worn by female dressage and show riders often feature detailing in luxury materials such as python skin and Swarovski crystals in the aim of creating a glamorous appearance for the rider, with protection from injury being a secondary factor.

Even where PPE for equestrian sports is not dominated by fashion, effective design can meet significant constraints. The market for PPE for equestrian sports and leisure activities sees the proportion of amateur riders vastly outnumber professional riders. Jockeys form a small niche group within the totality of riders who might need or want to wear a safety

vest. Jockeys' safety equipment needs to be especially light and also accommodate jockeys' very light build and small stature. The weight that horses carry in a race is limited to enable them to perform without being overly taxed. Jockeys work hard to keep their body weight as light as possible, ideally between 49 and 54kgs, while they ride horses that weigh between 500 and 600kgs. In handicap races, varied weights are allocated to horses based on past performance to equalise the horses' chance of winning and make wagering on races less predictable. For example, the minimum weight allocated for handicap flat races such as the Melbourne Cup and Caulfield Cup must not be less than 50Kg while the top weight must be not less than 58Kg (Racing Australia, 2020, p.79-80), the total comprising the weight of the jockey, their gear and the racing saddle.

3. Injuries in race riding and the introduction of safety vests

In race riding, jockeys ride horses galloping in a group at a speed of around 60 K/h (Miko, 2017). Jockeys' precarious riding position presents an added challenge, seeing them adopt the "Martini glass" posture where their centre of gravity sits over the horse's shoulders to minimise the effect of the jockey's weight on the horse's forward momentum (Figure 1). To achieve this, jockeys ride with very short stirrups attached to a miniscule saddle. This sees them perched on top of the horse in a crouch position with only their lower legs in contact with the horse's body. When an incident occurs, jockeys are extremely vulnerable to falls. In addition, multiple horses can fall at the one time, exposing jockeys to the risk of being crushed or trampled by their own horse or those following (Navarra, 2015).

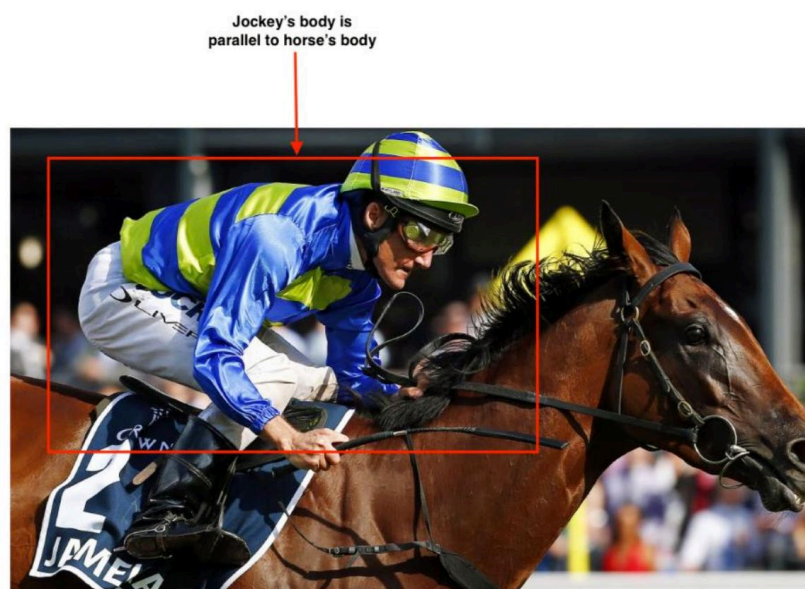


Figure 1 "Martini Glass" riding style during a Caulfield Cup (Stewart, 2016)

In Australia, jockeys who ride in flat races experience an average of one fall every 240 rides, with a third of falls resulting in injury (Hitchens, Blizzard, Jones, Day, and Fell, 2009). Approximately 200 riders are injured annually on Australian racetracks, the combination of

race riding and track work producing around 500 falls per year; the average work time lost due to falls will exceed 500 hours per incident; over their careers, 9% of Australian jockeys experience more than 20 falls, with 5% of falls resulting in career-ending injuries (National Jockeys' Trust, 2017). Due to the risks that jockeys face, doctors and paramedics attend all race meetings to monitor the wellbeing of riders. During races, ambulances follow the field on an adjacent track. These are staffed by a doctor, two ambulance officers and a registered critical care nurse ready to immediately attend to jockey following a fall (Racing, 2008; Australian Harness Racing, 2015; Wilson Medic One, 2015).

To try to reduce the severity of jockeys' injuries, in 1995 the Australian Racing Board commissioned a collaborative study between doctors and engineers to investigate how best to protect jockeys (Gibson, 1996, 1998; McLean, 2004). Based on this study, in 1998 the Australian Racing Board made the use of safety vests compulsory and introduced the Australian standard ARB 1.1998 to which safety vests had to conform. ARB 1.1998 is closely aligned with the European Standard EN 13158, developed in 1986 to address wide variation in jockeys' safety vests, thus establishing minimum standards for coverage of the torso, manufacture, product testing and performance. The reason for developing a separate Australian standard was the perceived climatic differences between Australia and Europe. ARB 1.1998 is certified by Standards Australia. It determines that safety vests are made of perforated foam strips of varying thickness, covered with mesh polyester. Adjustable strips or Velcro® sections at the shoulders and waist keep the vests tight on the jockeys' bodies. Within ARB 1.1998, only two safety vests templates are available, these having to accommodate male and female jockeys of varying body types and sizes.



Figure 2 Level 1 jockeys' safety vests approved by ARB (Giusti Gestri, 2019)

Notwithstanding the reduction in the number of jockeys' deaths since the introduction of the compulsory use of safety vests, their effectiveness has come under sporadic criticism. Roe et al. (2003) call for the efficacy of safety vests to be evaluated alongside a safety education program being introduced for all horse riders. Doubts about the validity of the product standards for PPE for jockeys were raised in 2011 by an Australian report that analysed the injuries and risk factors suffered by jockeys (Foote et al., 2011). It noted a paucity of data about the incidence and type of injuries sustained by jockeys in thoroughbred racing. While confirming the importance of wearing safety vests and helmets, Foote et al. (2011) criticised the variety of standards covering PPE for jockeys. Today, safety vests for jockeys must comply with ARB Standard 1.1998 or European Standard EN 13158, while jockey's helmets must comply with AS/NZS 3838 2006; EN 1384:2012 or EN 1384:2017; ASTM F116 3-04a (2011), ASTM F1163-13 or ASTM F1163-15; PAS 015:2011; VG1 01.040, Recommendation for Use, 12/12/2014 (Racing Australia, 2020, p.63).

3.1 Product Standards

Geng (2019) notes the problem of product standards that span both national treatment and mutual recognition across national borders. Such arrangements mean companies need only observe the lowest common denominator in product standards: Geng questions how different principles in product standards agreements are chosen and, most critically, whether "*these choices [are] well-founded from a welfare perspective*" (2019, p. 1258). Geng observes that product standards established in high income nations and trade blocs — where consumers expect high product quality — can raise product standards in other jurisdictions and lessen the negative impact of products, but he argues that harmonising standards is difficult. Because the two main safety products used by Australian jockeys need to conform to a range of standards, there is inherent potential for negative interference between standards. Stipulations for one product category can affect the design and performance of the other, this interaction building complexity into the delivery of user-specific solutions for individual products. How the neckline of safety vests interacts with helmets due to jockeys' typical riding position is an example.

In the case of safety vests, the Australian standard ARB 1.1998 has had minimal revision since its introduction, significantly limiting the scope for improvement and lessening the need for manufacturers to compete through product innovation. Minor changes have not greatly benefitted users, the standards review process revealing no appetite for innovation. For instance, no new advanced technologies developed since the introduction of the standard such as smart fabrics or sensors have been integrated into its criteria or into vest designs for jockeys. Changing contextual factors suggest the need for significant revision. High among these is the fact that the number of female jockeys has risen significantly since the introduction of ARB 1.1998 (Norton, 2015; Parke, 2018). The prediction is that at some point between 2018 and 2028, female jockeys will outnumber male jockeys (Cook, 2018). This alone indicates a strong need for attentiveness to the ergonomics of vest design, existing product standards for jockeys' safety vests failing to allow for alternative designs to fit male

and female bodies.

3.2 Vests regulations as a barrier to innovation

Since 1998, jockeys' riding style has continued to evolve to see them use ever shorter stirrups, exaggerating their crouched position, something rarely cited in literature. Climate change has increased the risk of heat stress and discomfort for Australian jockeys when wearing vests, extending discomfort experienced over more of the year. Despite the recent introduction of inflatable vests as PPE for horse riders in general, these devices have not been considered for race riding. Although they have received evaluation, only a small number of riders wear them (Meredith, Ekman, and Brolin, 2018), suggesting resistance from riders to innovation, perhaps due to the constraints on change in PPE because of product standards.

A number of studies on the frequency and nature of injuries to jockeys call for more effective safety vests (e.g. Moss, Wan, and Whitlock, 2002; Yim, Yeung, Mak, Graham, Lai, and Rainer, 2007). McCrory et al. (2006, p. 618) specifically argue that safety vests do not protect the spinal column from the compressive injuries often experienced in race falls. A pilot study by Brolin and Wass (2016) assessing the protective capacity of jockeys' safety vests in a range of scenarios found that the vests offered good protection against horse kicks, with the chest withstanding 125 to 175Ns compared to no vest worn at 225Ns. However, the vests tested provided no protection in rotational falls where a horse lands on top of a rider, a common accident in racing. In simulating the condition of being trampled by a horse, Brolin and Wass found that the risk of injury was far higher for hoof impact close to the sternum compared to more lateral locations, which had up to 25% less risk.

3.3 Need for safer vests

A range of articles call for specific consideration of the *design* of safety vests for jockeys (Gibson, Thai, Saxon, and Pollock, 2008; Foote, McIntosh, V'Landys, and Bullock, 2011; Safety Solutions, 2014). The vests in use are described as bulky and stiff, and thus restrictive and uncomfortable to wear with a need for jockeys' perspectives to be feed into product development being recognised. Although wearing PPE is seen to have reduced the number and severity of impact injuries to the jockey's to an extent, the literature identifies that in an emergency situation — where jockeys need medical attention on the track following a fall during a race — PPE can obstruct access to the chest, face and head, interfering with the ability of medical crews to properly stabilise jockey's spine or head. Here, Casa and Stearns (2015) highlight the problem of obstruction where immobilisation on a spine board is needed.

A two-year investigation into the protective capacity of safety vests funded by the Australian Racing Board and the Rural Industries Research and Development Corporation produced the report, "*Evaluation of Safety Vests – Health and Safety in Australian Racing*" (Foote, Gibson and McGauran, 2014). It determined that of international standards for safety vests, ARB

1.1998 offered the lowest level of protection although its testing for impact performance was the most complete. The report recommended improvements in safety vest design and revision to the Australian standard based on Australian weather conditions and the type of injuries sustained by Australian jockeys. The report included insights gained from an anonymous survey of Australian jockeys, which indicated their dissatisfaction with the performance of the vests in terms of protection, heat retention, their restrictive nature and lack of flexibility due to the materials used. It concluded that to foster improvements in the design and performance of safety vest more research was required, including specific input from jockeys. Hitchens (2014) and Andres, Bushau-Sprinkle, Brier and Seger (2018) make similar arguments. Despite such conclusions, no changes have been made to ARB 1.1998 to address these perceived deficits.

4. User Research: A catalyst for breakthrough innovation?

In response to the constraints on innovation in the design of jockey's safety vests, the first author conducted a program of field research in 2016/17 to understand jockeys' and medical first-responders' perceptions of the safety vests mandated for use by Australian jockeys. The study used a flexible, qualitative research design incorporating semi-structured interview, focus group and observation. The research design was informed by Forlizzi's (2007) concept of product ecology, of which she writes:

The Product Ecology framework articulates all of the factors that evoke social behaviour around products. The factors in the framework can be used in a generative manner to scaffold the selection of design research methods for understanding current experience and generating new products to change that experience ...[It] provides an alternative way of understanding the complex physical and social context of use around a product, and a means for suggesting change within the current state of the world. (p. 18)

For Forlizzi, application of a Product Ecology framework can expand the sense of what a product *is* and what it *could be*, hence its value in being applied to develop insights to contest the representation of a product in a long-established product standard.

4.1 Research method

To create a deep understanding of how jockeys experience safety vests and what they mean to them, data gathering involved the primary users of the vests, the group of participants being comprised of apprentice jockeys (n=6), fully qualified jockeys (n=9) and former jockeys (n=2). However, drawing on Forlizzi, a secondary user group was included — the medical staff who handle the safety vests when jockeys are injured. Two doctors and one intensive care paramedic were included in the study for a total of 20 participants. 16 of the 17 jockeys interviewed had experienced at least one fall during their career when wearing a safety vest (see Table 1). The three medical professionals had significant experience in treating jockeys' injuries after falls. They considered that making safety vests compulsory had been beneficial for jockeys, but their involvement offered unique insights into design limitations in the current vests resulting from their experience in attending to jockeys in the critical period

after a fall when quick decisions had to be made about whether to remove the vest from an injured jockey.

Table 1 Participants' racing and fall experiences

Participant Code	Category	Gender	Experience in years	Falls	International Races
AJ 01	Apprentice Jockey	M	5	Yes	No
AJ 02	Apprentice Jockey	F	4	No	No
AJ 03	Apprentice Jockey	M	2	Yes	No
AJ 04	Apprentice Jockey	M	3	Yes	No
AJ 05	Apprentice Jockey	M	3	Yes	No
J 01	Jockey	F	6	Yes	No
J 02	Jockey	M	21	Yes	Yes
J 03	Jockey	M	24	Yes	Yes
J 04	Jockey	F	28	Yes	Yes
J 05	Jockey	M	30	Yes	Yes
J 06	Jockey	M	18	Yes	Yes
J 07	Jockey	F	5	Yes	Yes
J08	Jockey	F	18	Yes	Yes
D 01	Doctor	M	28	n/a	n/a
ICP	Intensive Care Paramedic	M	3	n/a	n/a
D 02	Doctor	M	10	n/a	n/a
AJ 06	Apprentice Jockey	M	3	Yes	No
J 09	Jockey	M	16	Yes	Yes
JR 01	Retired Jockey	M	28	Yes	Yes
JR 02	Retired Jockey	M	12	Yes	Yes

Once individual semi-structured interviews were completed, a preliminary analysis of the interview data was undertaken (Attride-Stirling, 2001). This used thematic analysis with the assistance of NVivo software. The findings of the preliminary analysis informed the conduct of the focus group. This provided a form of member checking by testing the trustworthiness of the interview results with the research participants (Dey, 2003). In the light of the interview and focus group results, participant and non-participant observation was conducted at three major city racecourses in the state of Victoria, Australia, in order to develop deeper understanding of the design context and jockeys' and medical first responders' experience of safety vests. The first author was able to watch the participants in their normal environment around the track, in the jockeys' room, the press room, the main community room and the weights room. More observation was performed at Victoria's Apprentices School and at fitness sessions at Exercise Research Australia (ERA). Observations were recorded with notes and some photographs.

4.2 Field research and observations

Such is the constraining effects of the product standard ARB 1.1998 that the participants were surprised that they were being asked about their experience of safety vests, commenting that they had often tried to provide feedback on them, but had been ignored. They were enthusiastic about sharing their stories with a researcher about their falls, injuries and discomfort while wearing the vests, as well as their perceptions of the limitations of current vests. The jockeys were conscious that their profession was extremely risky. They also accepted the products on the market, even if they did not guarantee their safety. As one jockey explained, *“For what we do there is always no guarantee And again, the perception is not that we expect the vest to save our lives All we want it to do is to help us, not hinder us in a racing incident”*. The jockeys described in detail their feelings of restriction when wearing the vests, attributing this to a system that had not paid attention to their concerns or involved in the development of standards for vest design. As indicated in the jockey’s comment above, limited movement is a serious problem for jockeys. They need to bend their heads, turn to look around for other horses, talk to each other during races and be able to roll into a ball in the case of a nosedive fall — a common form of tumble where jockeys can be flung forward into the ground.

4.3 Data analysis

Most of the participants reported that the vests were uncomfortable due to their rigidity and felt hot and even heavy to wear. The female jockeys commented that the safety vests worn during track work, which are not covered by ARB 1.1998, are more comfortable than those required for racing. They explained that those worn for track work are heavier, but softer. This increases their comfort because the vests tend to mould to their body shape. As one female jockey explained,

“From a female’s point of view or perspective, I think definitely they need to have a male and a female vest. That’s my opinion. They do it with all the motorbike gear and all that sort of stuff. The only reason I know is because I used to ride a lot of dirt bikes when I was younger. There’s a big difference with the female body suits compared to the male’s body suit. Obviously, we’ve got our breasts and our hips and stuff – our curves [motorbike gear] was all fitted. It was completely different”. With the safety vests worn during racing seen as a source of discomfort, several participants reported wearing the safety vests differently to how they were meant to be worn, for instance, leaving the vest a bit looser on the sides or even wearing them backwards.

Many of the participants highlighted the problems they encountered as the vests came into contact with their race helmets, highlighting an issue with the interaction of standards. Most helmet manufacturers have no connection with those producing safety vests. The standards to which helmets must adhere do not take into account those used for safety vests. The lack of research into the conditions of use has created the risky situation that during a race, the top of the safety vests can into the back of a jockey’s helmet. Most participants reported that the vests interfered with their helmets, leading to bigger problems such as their vision being impaired while riding. As one participant explained,

"I am not watching where I am going because I have to look with my eyes up instead of my head up ... I can feel it pinching on the back of the vest, so it is just half an inch, so it is stopping me from extending my neck forward. Jockeys cannot extend forward properly because vest and helmet bump together."

This effect becomes most critical during the last 400 metres of a race when the jockeys urge their horses up to their maximum speed to try to win, with a pack of horses jostling each other to get to the finish line first.

The jockey's perceptions and experiences lead them to express doubts regarding the knowledge of those who established and maintained the safety vest standard ARB 1.1998. Jockeys with more years of experience were the most critical as they had encountered the problems with the vests for the longest time without anything changing. One simply stated, *"I don't know how they do the standards."* while another expressed clearer doubt in commenting, *"I am not convinced the standards are right."* A third participant voiced their perception of the source of the problem in stating,

"The people doing the test might be engineers and experts in testing equipment, but they are not experts in riding, racing, or dealing with the animals or what we deal with. They are only dealing with numbers, facts and obviously video footage, but they are not the people actually riding, or the ones actually falling in it."

The medical professionals discussed the nature and severity of the injuries they treated and the ways in which the safety vests interacted with their actions. They reported that after a fall, the time a jockey spends lying on the turf is crucial. Here, medical attendants need to act fast and with accuracy. Unfortunately, the vests' design represents an impediment to the rapid supply of aid because they are hard to remove. The medical participants showed curiosity for the research process because, finally, someone was trying to investigate such an important matter, with scope to bring improvements to how they carried out their work. Both the jockeys and the medical staff considered that the most dangerous place to be fall was at the starting barriers or at full gallop while perched above the saddle. The medical participants observed said that the vest designs were not exactly fit for purpose, because during a fall, a jockey's chin often came forward and caught in the top of the vest, thus adding to a jockey's injury.

4.4 Results and insights

Generally, the jockeys regarded safety vests as compulsory items rather than essential and desired equipment to guarantee their wellbeing. To balance safety and comfort in the provision of safety vests, there are two options: 1) to use current technology to improve an existing product design or 2) employ a radical approach. Each of these choices has its advantages and disadvantages (Fullagar, 2015). An incremental innovation approach has the advantage that the product remains competitive and acceptance of any change is easier in being delivered via an already recognisable product. Revisions to an existing design can be implemented at a reasonable price and if successful can be marketed to a large market of recreational and competitive riders in addition to jockeys.

In the design of safety vests for Australian jockey, the opportunities for incremental improvement span addressing the:

- basic and rigid design;
- paucity of ergonomics;
- lack of advanced materials and technologies;
- the spinal area not being adequately protected;
- absence of a user-centred design approach to enhance marketability;
- providing alternative designs for male and female jockeys.

A radical innovation approach offers the opportunity to create whole new products and markets, opening the door to new innovative PPE companies to enter the marketplace. Eventually, radical product innovation may be the only answer to most of the deficits that jockeys attribute to safety vests as the current designs enabled by the current standards may be too compromised to be sufficiently adapted. Reflecting an aim of the application of the Product Ecology Framework, a key consideration in the opportunity for radical evolution in safety vest design is in approaching them not simply as personal protective devices, but as first aid tools for treating medical staff.

The term “wearable technology” refers to accessories and garments created to incorporate electronics. These products can collect and monitor data about a user or the surrounding environment through their proximity to the human body. The high demand for smart technologies has seen analysts forecast the sale of 411 million smart wearable devices in 2020 at a value of around US\$34 billion (Lamkin, 2017). Smart wearable products are successful when they achieve a balance between interaction design, technology, comfort and purpose. If these criteria are satisfied, a product that adds value to users’ lives is achieved. In the case of the re-conception of jockey’s safety vests through the application of sensors, there is potential for critical information on the location and severity of impact in a fall or contact between the horse and jockey to be transmitted to the attending medical officers at the track, thereby permitting faster and more informed medical assistance. Such information could also be sent ahead to emergency department staff at a hospital waiting to receive an injured jockey.

5. Conclusion

Race riding is a dangerous occupation, yet in Australia, current safety vests are inadequate to the task of preventing jockeys’ injuries. Jockeys want and deserve safety vests that incorporate the best possible mix of comfort and safety. Achieving this outcome involves ongoing scope for new designs to be introduced to the market, this being especially likely in the light of constant innovation in materials and digital technology. Nowadays, wearable technologies are making strong inroads into sports, being associated with enhanced functionality and design. Yet as our paper has argued, neither incremental nor radical product innovation is currently possible in Australia because of the constraining effects of the product standard ARB 1.1998, its criteria being only minimally and rarely revised over the

past two decades. Introducing a new design could offer a higher level of safety and comfort; a revision of the neck cut (both front and back of the vest) represents a scenario in which the standards would be reinterpreted to develop related standards for vest and helmet. Product innovation may bring benefits to the medical professionals in reducing the time in removing vests from injured jockeys. Our paper has identified the additional problem of a lack of alignment between standards for products that interact during use as well as the challenge of adapting international standards to reflect local conditions such a climate and turf conditions in the case of safety vests for jockeys.

Most significantly, the application of the product design framework to the ethnographic research identified that more than one category of user should be considered as active in the product context. Not only was the significance of differences between female and male jockeys in their experience of safety vests identified. A new category of vest user was revealed in the form of medical staff. These users cannot be adequately characterised as secondary, which is to say lesser users relative to jockeys, nor as stakeholders. Their role in the ecology of use and the fate of jockeys following a fall is crucial. Their inclusion in the future improvement of vest designs and related product standards is critical. Hence, they are more properly characterised as co-dependent, or even co-primary users, in the successful use and evolution of jockey's safety vests.

Innovation is clearly required to enhance the function and experience of safety vests for jockeys. Our paper has argued that research informed design should include jockeys and medical staff as the main protagonist, not only to deliver improved vest designs, but to serve as a catalyst for the revision of safety vests' standards in ways that are dynamic and context specific.

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Research on the value of CMF design in industrial products

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Abstract: With the development of information and IoT (Internet of things) technology, the product form gradually flattened, resulting in the design space of physical hardware becoming smaller and smaller, and the traditional industrial design method seems to enter the bottleneck period. CMF design, as a new product derived from the subdivision of industrial design industry, is different from the traditional industrial design ideas. It takes color, material and finishing process as the breakthrough point to carry out product design innovation. This paper first discusses the value and importance of studying CMF design from the perspectives of product appearance, user experience, manufacturing, cost control and business strategy, and puts forward suggestions that enterprises can try to find innovation opportunities from the perspective of CMF, so as to realize the competitive advantages of low cost, short cycle and fast update speed through CMF, and better promote the development of industrial design industry.

Keywords: industrial product design 1; cmf design 2; design value 3; industrial design industry 4

1. Introduction

CMF (color, material, finishing) can be understood literally as color, material and finishing process. In the field of modern design, "it refers to a new knowledge system, design method and profession, that is, CMF design method and CMF designer profession, which are widely used in automobile, home appliance, electronic consumer goods and other industries, with product color, material and finishing process as the breakthrough point." (Li, 2019, P.2)

The concept of CMF design may be new to many people, but its related content can be traced back to the Bauhaus period. "...Johannes Itten (1888-1967), an important teacher of Bauhaus, once discussed form, color, material and texture through practical work..." (He, 2019, P.114). In the 1980s, "...with the rapid development of electronic industry and manufacturing industry, household appliances, electronic products and automobiles gradually become an important part of human life..." (Li, 2019, P.3). Limited by the slow



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update of core technologies, the homogenization of most products' functions, the inability to make essential breakthroughs in appearance modeling, and the self-requirements of enterprises to continuously launch new products, the new design thinking with color, material and finishing process as the starting point has gradually become an important factor in improving the competitiveness of industrial product appearance design. With the development of time, more targeted and more commercialized CMF design concept is emerging.

In some enterprises, in order to better complete the design scheme, the work of industrial design is gradually subdivided, and then a clear and fixed CMF design post emerged. At the end of the 20th century, Volkswagen, Philips, Motorola, Samsung and other international enterprises took the lead in establishing their own CMF design team. At the beginning of the 21st century, some large enterprises in Asia began to realize the importance of CMF design. Haier, Lenovo, GAC, Midea, Hisense, Siemens (China), Gree and other companies have set up CMF designer positions. In recent years, we can even see some professional organizations providing CMF design consulting services. All of this shows that as a new product of the design industry, CMF has been paid more and more attention by enterprises and gradually stepped on the path of professional development.

2. Definition of CMF design

Although CMF design concept appears relatively late, it is closely related to industrial design. According to the definition of industrial design given by the International Council of Societies of Industrial Design (ICSID) in 1980, "industrial design refers to the mass-produced industrial products that give new quality and specifications to materials, structures, forms, colors, surface processing and decoration by virtue of training, technical knowledge, experience and visual experience." (Wiki pedia,2007) It can be seen from this definition that in fact, half of the early work of industrial design is related to CMF design, but at that time, there is no clear and accurate definition of CMF design in the industry.

With the increasingly professional development of the industry, now the concept of CMF design can be clearly and accurately defined :

"CMF is a highly integrated design method and work category integrating creativity and management, which is different from the way of traditional industrial design. CMF design is based on aesthetics, material engineering, economics and management, closely related to popular trends. It takes color, material and finishing process as the breakthrough point to carry out innovative design, and creates innovative products that meet the design needs and user experience by achieving a high degree of unity of art and technology." (Design wind,2017,Para.4)

In addition to the three elements mentioned in CMF literally, there is also an important element that potentially affects CMF design, namely pattern. The four elements of pattern, color, material and finishing process are inseparable, which jointly act on the product and play an important role in meeting the function needs and improving the user's sensory experience. In brief, the following aspects should be paid attention to in the process of

design and production transformation of these four elements:

- Color: “Color is the most intuitive and emotional element in the appearance of products.”(Hsiao, 2014, P.613) The elements that affect color design include hue, lightness and saturation. In the design work, designers need to follow the relevant color matching theory and method, master the popular trend at all times, and then combine the brand’s market positioning to design, and finally convert the color scheme into the production language to the factory.
- Material: “Material is the material basis of product form and the carrier of product function and structure.”(Ferro, 2020, P.2) In the field of industrial design, the commonly used materials are metal, plastic, rubber, wood, ceramics, glass, etc. The selection of the main materials of the product should generally meet the strength requirements of the structural design.
- Finishing process: Finishing process here mainly refers to the surface treatment process, “specifically refers to the process operation of mechanical, physical and chemical treatment of the surface layer of the material after processing and forming.”(Brian, 1999, P.34) Common surface treatment processes include cutting, grinding, polishing, stamping, sandblasting, etching, coating, plating, etc. This requires that CMF designers not only understand the professional knowledge, but also have rich factory site experience, and can communicate well with workers.
- Pattern: Pattern can be brought by the material itself, or it can be the result of the two-dimensional pattern or three-dimensional texture formed on the product surface after the surface treatment process, which is specially designed according to the requirements of decoration or function. Pattern is an integral part of CMF design, which can improve the user’s visual and tactile experience (Figure 1).



Figure 1 Pattern and texture applied to the surface of various products

In the practical work, according to the work content and requirements of CMF design, the design process can be divided into three stages, namely, trend research stage, design proposal stage and production transformation stage. Its main task is, first of all, the designer studies the industry trend, and gets an insight into the future market opportunities to develop a trend research report. Then, according to the trend report and the company’s positioning, the product definition is made and the design scheme is proposed. Finally, the

factory implements proofing, quality monitoring and schedule control for the plan, and finally produces the products in batches.

To sum up, it can be thought that CMF is a subdivision industry of industrial design. It is a new design method and profession integrating trend research, design, engineering and supply chain. "It relies on the market development trend and user demand, pays attention to practice, science and art, and helps the product form a unique competitiveness..."(Li, 2019, P.7), and brings greater business value to the enterprise.

3. Why should designers conduct research on CMF design

Although it can be seen that some of the world's leading industrial design enterprises or companies have established professional CMF design teams, this is far from enough. On one hand, the scale of research on CMF design is not large enough, which shows that most enterprises and design practitioners are still not aware of the importance of CMF design. On the other hand, it is also the most important thing that with the development of information technology and the increasing demand of users for product functions, the trend of the development of science and technology products becomes to use touch screen interaction or virtual interaction as the main way to achieve functions. Therefore, the focus of most product research and development has shifted to software development, leaving less and less design space for product physical hardware, so more and more product models tend to be flat, simple and homogeneous.

In view of the current situation of this industry, the following questions must be considered: Is there still room for innovation in industrial design? Or is it necessary to carry out innovative design of product appearance? In order to answer these questions, this paper attempts to analyze them from the following two aspects.

3.1 From the perspective of product appearance design

Take the mobile phone as an example. If the smart phones of the mainstream brands in the current market are put together without lighting the screen, most of the mobile phones are similar "black boxes" in appearance, so it is difficult to identify the brand of the mobile phone at a glance. There is a fact that people can't forget the impact of the fashionable, simple and unique appearance design of the iPhone 4 when Apple launched it in 2010. This work can be regarded as a milestone in the history of industrial design, but also triggered a new trend of modeling design. However, in the next few years, it is hard to see which mobile phone can bring such a shock in the appearance design. It shows that conventional industrial design ideas have begun to appear powerless.

At the end of 2018, Huawei launched the P20 mobile phone with gradual Aurora color on the back of the mobile phone for the first time (Figure 2). Different from the way in which the design focus is always on Modeling and structure, Huawei P20's appearance design focuses on color, material and finishing process, and adopts "...the advanced PVD (physical vapor Deposit) vacuum gradient coating technology (Figure 3) creates a charming gradient "Aurora

band” on the back of the phone...”(Baidu Encyclopedia, 2018, Para.3) which is a design idea never appeared in the history of mobile phone design. Therefore, within ten seconds after the P20 conference, “Huawei’s sales volume of more than 100 million yuan has become understandable...”(Home of mobile phone, 2018, Para.1). And with the passage of time, it has also shown a long-term and better market performance in the product market of the same period. At the same time, Huawei has successfully achieved the uniqueness of the brand through this new design scheme. When you see someone walking on the road with a mobile phone which has gradually-changing blue and purple color you can quickly decide that is Huawei P20 without checking the brand logo.

Of course, the success of Huawei P20 in business may have other factors, “but it is undeniable that its innovative design in CMF has brought inspiration and new ideas for traditional industrial design, and also brought huge innovation space for designers.”(Chen, 2019, P.110)



Figure 2 Huawei P20

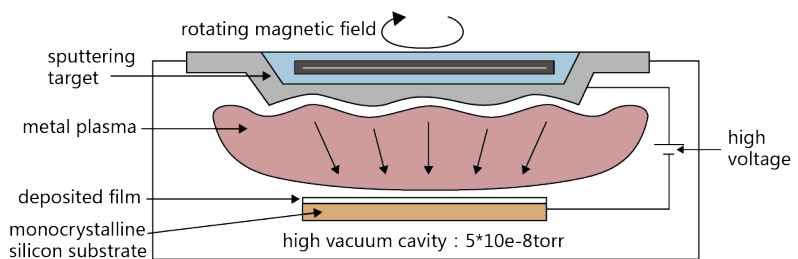


Figure 3 “PVD vacuum gradient coating process drawing” drawn by CMF design team(CMF design corps, 2018)

3.2 From the perspective of user experience

Data shows that facing a wide range of products, “users only need 7 seconds to determine whether they are interested in this product.”(Wang, 2015, P.310) The detailed chart shows (Figure 4). In just 7 seconds, 32% of the people will take function as the main purchasing factor, 20% will choose price, the remaining 8% will be affected by other factors, and 40% will choose products according to appearance. Generally, color, material and finishing process are the most important and intuitive elements that affect the appearance. This shows that before using a product, “users will judge whether they are interested in it through the color, material and finishing process of the product.”(Liu, 2017,P.133) Facing the same product function and price, most consumers will determine their purchase behavior based on the appearance of the product and our subjective feelings. Therefore, it can be thought that CMF is the most expressive part of a product and the most infectious element for users.

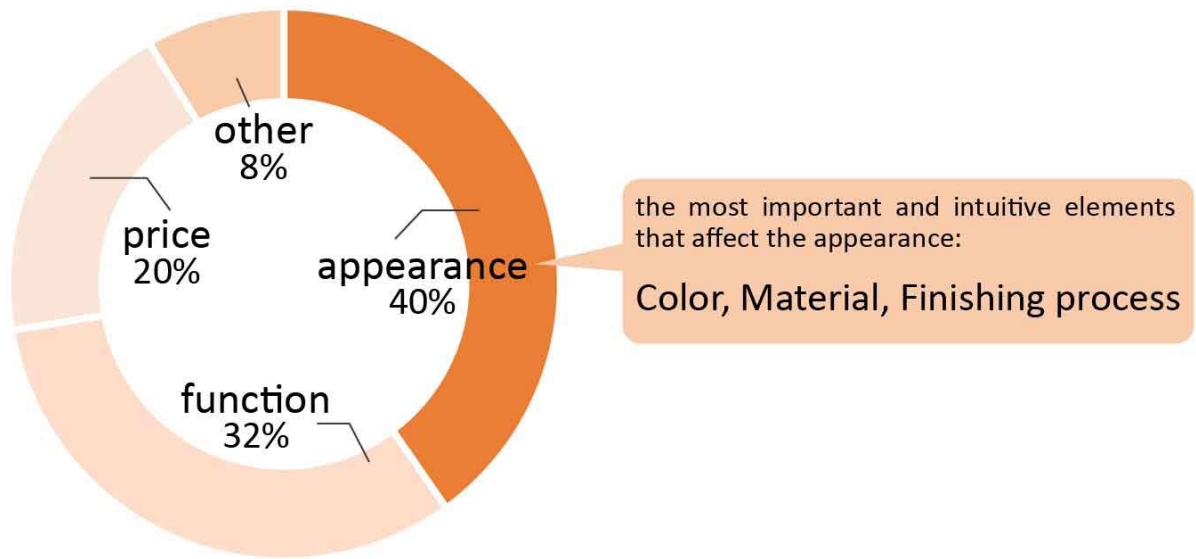


Figure 4 Factors Influencing Consumers' purchase behavior

Of course, CMF not only gives the product durability, beauty and quality, but also brings deep emotional experience to users. These experiences come from visual, auditory, tactile and olfactory senses. For example:

- In mobile portable devices, the application of sanding technology on the surface of parts contacting with the palm of the user will bring people a sense of security (increasing friction can make the portable products not easy to get rid of their hands).
- Office products with high brightness and low saturation can bring a sense of relaxation to white-collar people who are anxious and stressed. Statistics show that "people will feel depressed when they are in a low brightness color environment for a long time, and will always feel excited when they are in a high saturation color environment for a long time." (Hsiao, 2008, P.911)
- Using wood or cloth on electronic products can reduce the sense of technology and increase the affinity (Figure 5).



Figure 5 Application scheme of CMF design for different products

This kind of delicate and suitable CMF design method on the product hardware appearance will always inadvertently strike a chord among users, make the user get used to and rely on this feeling, and then achieve the effect of improving the user stickiness of the product. This kind of delicate and deep emotional design thinking is just what is easy to be ignored in the traditional industrial design.

4. The value of CMF design

In the process of product production and development, CMF design can not only solve some practical quality problems, but also help enterprises reduce production costs, and strategically bring a lot of business value for enterprises.

4.1 Control product quality through CMF design

In the process of product development, due to processing technology and other reasons, there are often some expected effects that can not be achieved, which will affect the overall quality of the product. For example, as is known to all that most mobile phones with metal body often shield the mobile phone signal and affect the call quality, so the common practice is to divide the metal and embed a thin rubber strip in the gap to reduce the interference of metal to the mobile phone signal. But this will destroy the original continuous and concise overall sense of product modeling, which can be said to be "...the aesthetic concession made in the process of pursuing product realization in order to meet the functional requirements..." (Das, 2019, P.441) (such as iPhone 6, Huawei mate s, shown in Figure 6).

But from the perspective of CMF design, we can still control the appearance quality of products without changing the overall plan. For example, a piece of rubber can be "metallized" through color, material and finishing process to reduce the difference between it and surrounding metal materials. The realization method includes two paths:

1. Electroplate and spray on the rubber strip to make its surface metallized.
2. When making rubber strip, mix pearlescent powder or metal powder into it to make it look closer to metal texture.

Specifically, designers can realize the control of product aesthetics and quality by forming visual metallization on the rubber strip through CMF design ideas (such as Meizu Pro 5, Huawei EF 7, shown in Figure 6).

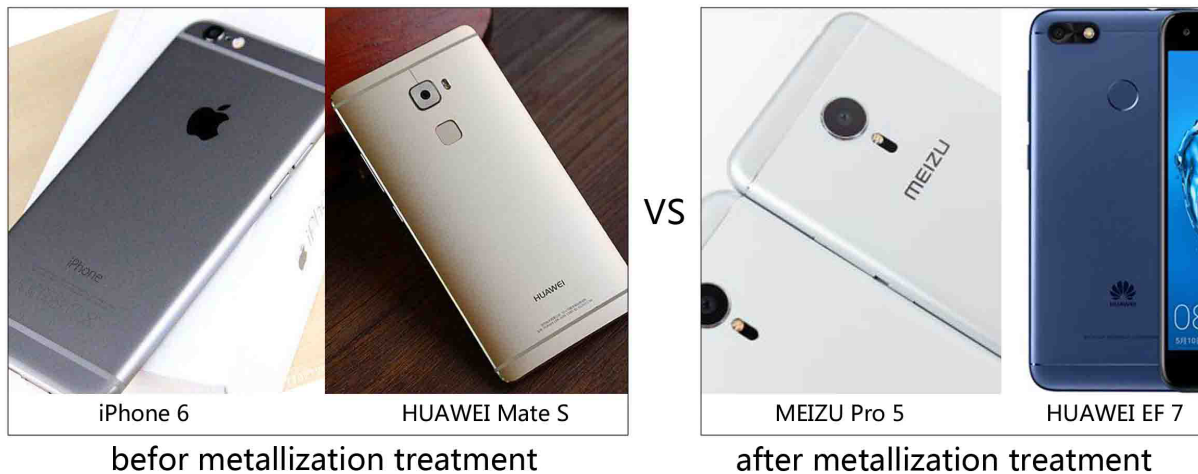


Figure 6 Effect comparison of rubber strip before and after metallization treatment

4.2 control the cost and time of research and development through CMF design

In the later stage of product development, if cost reduction is needed, it will basically be realized by changing the CMF design scheme, which is also the fastest and most efficient way. For example, “the material of the product used to be metal, and later it was found that the plastic can also meet the structural strength through the handboard test, so there is a chance to change it into plastic material.”(Nellippallil, 2018, P.11) Or, “before the surface treatment of the product, it was electroplated, and later it was found that painting can achieve the same effect.”(Polyanskii, 2014, P.13) Because electroplating is more expensive than painting, in order to save cost, it is possible to replace painting process.

For a product with a long life cycle, sometimes the product designer of the project is basically off the case. If there is a new market demand at this time, CMF designers can directly make color scheme, then take it to the customer for confirmation, and then reverse it to drawings for direct production. This not only reduces the workflow, saves time, but also greatly reduces the design cost and increases the competitive advantage.

4.3 CMF design helps enterprises develop business strategies

In addition to brand positioning, in order to use resources more safely, effectively and reasonably, designers can make different design strategies for products in different fields from the perspective of CMF design. For example:

- Home appliance industry: the focus of home appliance products is plasticity, security and durability. Then the main body of the product will be made of plastic material (about 80% of the whole body material), because the plastic is insulated and has high plasticity; some parts that are often in contact with keys and fingers are mostly made of metal (about 20% of the whole body material), because the corrosion resistance should be considered due to the high frequency of use (Figure 7).



Figure 7 CMF design strategy of household appliances

- Electronic consumer goods industry: most of the electronic consumer goods pursue texture, intensity and sense of technology. Taking mobile phones as an example, from the perspective of cost, medium and low-end mobile phones will use plastic body (about 40% of the market), because plastic is cheap and light, and easy to bring a sense of intimacy; The high-end mobile phones usually use a metal integrated body (about 30% of the market). In addition to the strength and sense of technology brought by the metal itself, processing technology is also more difficult which make the mobile phones made of metal materials more valuable. The rest of the mobile phones will use ceramic and glass materials for its design strategy (about 30% of the market, Figure 8).



Figure 8 CMF design strategy of consumer electronics

- Automobile industry: as a large commodity, automobile has always been an important carrier for consumers to reflect their personality, taste and identity, so they will be extra cautious when purchasing. Due to different factors such as age, occupation, gender, education level, living environment and culture of consumers, everyone has different feelings and needs for cars. Taking color as an example,

a successful automobile appearance color design can not only help automobile enterprises to well divide the consumers, but also help enterprises to reasonably allocate and use resources, and focus limited human, material and financial resources on the market segments. At the same time, it can also form the brand's unique color symbols and give full play to the maximum economic benefits. For example, according to the purchasing power of users, the automobile market can be divided into high-end, middle-end and low-end markets. Statistics show that “the high-end market prefers low saturation and neutral colors such as black, white, gray, brown and blue.”(Hsiao, 2016, P.104) The number of hue and color saturation in the middle-end market will increase, while the color in the low-end market is the most abundant. (Figure 9).

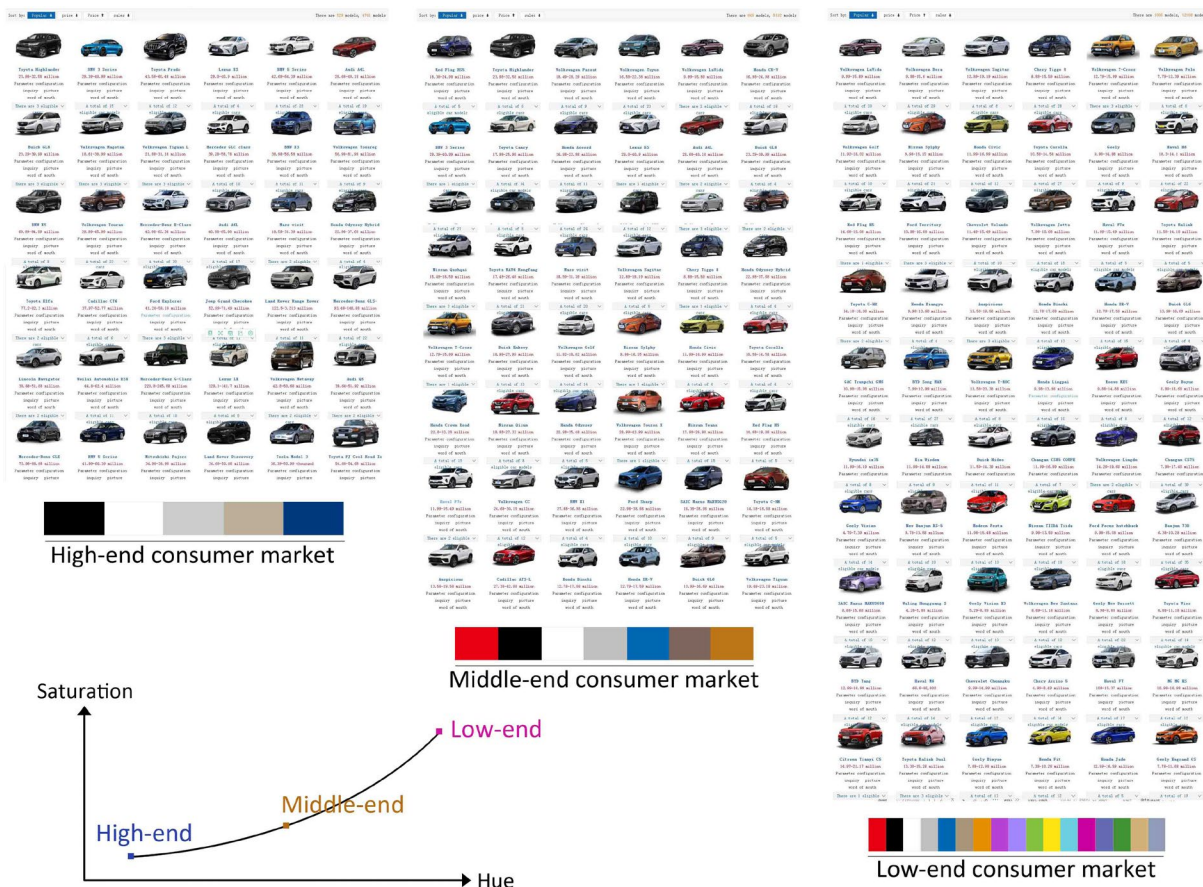


Figure 9 Color design strategy of automobile. Roughly calculated and drawn by the author referring to Sohu automobile website and the price unit in the figure is yuan (Auto.sohu.com, 2020)

Another effective approach is that enterprises can also stimulate the consumer market by updating the CMF design scheme. Data statistics show that the marketing activity of a new product is usually only 3-5 months. Stimulating the consumer market and mastering the initiative in the market competition can be achieved by updating the product CMF design. For example, Apple launched the iPhone 7 in September 2016, but the market performance

was weak. So five months later, Apple launched a red iPhone 7 that works with a public welfare project called red. The new red version iPhone has injected new vitality into Apple's sluggish sales, not only expanding the brand's influence, but also driving Apple's share price to a new record. This is an effective way to stimulate the consumer market by changing CMF program.

5. The future and challenges

With the development of CMF design research scale and specialization, the division of labor in CMF design industry becomes inevitable. Due to the complex discipline background involved in CMF design and the different work contents and requirements of design procedures in different stages, new changes may occur in the industry, including: 1. There are a large number of independent trend research institutions specialized in the research of color trend, material trend, process trend, pattern trend or product trend, which provides opportunities for some small and flexible entrepreneurial companies. 2. The leading research and development of new materials will become more and more valuable, and CMF material suppliers will become more and more active, gradually changing from the role of cooperation to the role of joint development in the business cooperation with the brand side.

In terms of processing technology, with the development of material technology, spray free materials may one day be able to directly complete the surface treatment process of products through 3D printing. Combined with the characteristics of 3D printing without mold and rapid prototyping, the surface of industrial products may not need to be processed again to obtain a variety of exquisite texture, which can improve production efficiency and reduce environmental pollution.

In the education industry of colleges and universities, with the emphasis of enterprises on CMF design, more and more colleges and universities will undoubtedly begin to set related disciplines or professional courses. Only by continuously cultivating a large number of CMF design talents, the CMF design position gap can be continuously filled in the enterprise. However, various processing technologies and production methods are needed to be familiar with to carry out CMF design research. But most colleges and universities do not have such facilities and conditions. This is the problem and challenge that colleges and universities must face if they want to develop CMF design education.

6. Conclusion

With the rapid development of information and IoT technology, the product form is gradually flattened into the trend of industrial design in the information age, and CMF design undoubtedly provides a broader innovative prospect for the limited space of industrial product appearance design.

Of course, the development of CMF design is not to overthrow the traditional industrial design. For users, CMF design is concerned about the emotional consumption needs of users.

It will not replace the role of modeling design, structural design, functional design and user interface design in traditional industrial design, instead on their basis, it can give products more delicate quality and use experience. For enterprises, “CMF design can not replace the important role of conventional industrial design in the development of enterprises, but it can effectively make up for the competitive disadvantage of slow product iteration speed in the conventional design mode.”(Li, 2019, P.19) Enterprises can try to find innovation opportunities from the perspective of color, material, finishing process, pattern and so on, and finally realize product innovation through the competitive advantages of low cost, short cycle and fast update speed.

However, there are still many imperfections in the current CMF design industry. It needs more responsible and powerful groups to join in. At the same time, the industry also needs to give more tolerance and help new entrants or those who are about to enter the industry. In this way, we can help the industry progress by internal and external cooperation and multi party cooperation, so as to promote the better development of the industrial design industry.

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The inherent value of design research for industry: An impact case study using low-cost 3D printing for high-value commercial products

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Abstract: Often published literature in design research explores theoretical content to advance the way we look at a design discipline but in Australia, it rarely bridges the gap between scholarly work done within a university and design work done for industry. There is an overwhelming sense of importance put towards industry-university engagement in Australia to improve funding mechanisms for research within universities, but also to ensure the research being done has impact for industry. This paper details a successful impact case study, which utilised the professional skills of a design team within a university to successfully tackle a challenging commercial project. By operating within a research framework, the gap between research theory, research practice and the generation of high-value outcomes has been bridged with demonstrable impact.

Keywords: industry-university engagement; low-cost 3d printing; research-led practice; industrial design

1. Introduction

This paper refers to a successful product development team within an Australian university that established a program based on ‘academic research-led industrial design practice’. Over the past five years (2015–2019), the team has attracted significant commercial interest, achieving a 300 per cent annual project growth and earning more than \$AUD4.5 million in industry-linked research income. The team’s fast-growing industry base could be characterised as ‘Small to Medium Enterprise’s (SMEs) with big ideas’ – the Australian business sector arguably most in need of professional design support. This diverse industry base includes, for example, suppliers of veterinary smart-device services, polycarbonate glazing systems, elite athlete injury recovery solutions, kitchenware, and Australia’s first fire-rated skylight. For this paper, one successful example of a project is shown in detail to illustrate the approach taken to conduct research within a university context to generate



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profitable commercial outcomes for the company. The impact case study within this paper explains the design process adopted by a product development research team within a university to develop a range of commercial track-mounted downlights, which utilised low-cost 3D printing as the commercial outcome.

The Australian SME sector often struggles to gain access to professional product design services, particularly a service that targets genuine innovation (IBISWorld Industry Report OD5443, 2018). The university product development research program has presented a clear economic advantage to this important group by providing a product design service that is comprehensive, targets innovation and is accessible. The design strategy challenges pre-existing design boundaries and draws broadly on the university's intra-faculty knowledge resources. In this regard, the team's design service targets product innovation — much needed in the Australian SME sector — rather than the incremental design upgrades often realised by conventional commercial design.

Roos and Kennedy (2014) in their book “Global perspectives on achieving success in high and low-cost operating environments”, show there is substantial evidence for design-led innovation as an enabler for the success of SMEs within high-growth environments. A chapter within their book by Bucolo and Wrigley (Chapter 9, 2014), show that businesses that may have been exposed to the concept of design previously at a product level are now seeking to better understand its value through implementation at a strategic level offering.

From an economic impact perspective, there is a general perception that design only delivers economic value for the design industry. However, there is proof that design has a high economic impact in non-design-led industries and how mistaken this assumption is (Micheli, 2014).

In a report from Micheli, 2014, he describes three key statistics showing estimated business growth for the UK when engaging with design as follows:

- Design increases turnover: For every £1 invested in design, businesses can expect over £20 in increased revenues
- Design is linked to profit: For every £1 invested in design, businesses can expect over £4 increase in net operating profit
- Design boosts exports: For every £1 invested in design, businesses can expect a return of over £5 in increased exports (Micheli, 2014)

2. Method

Developing commercial products through design practice has been around for centuries. Using design practice as a method to conduct design research and generate research funding to a university is however relatively new. Koskinen et al. (2011) note “design practice provides methods” (p. 23) and in particular when designing with specific cliental — as demonstrated in the case study described in this paper — research methods such as prototyping or general experiments with the material is a valuable way of gaining knowledge.

The 1990's and 2000's saw the growth of 'generative' research methods that put design practice at the core of the research process (Koskinen et al., 2011, p. 23). However, these methods did not always translate into a commercially viable product outcome. Dorst (2008) argues that design research should refocus its attention and enrich academic design research by working on a deep and systematic understanding of the 'design object', the 'designer' and the 'design context'. This statement is used in conjunction with the research aim to help legitimise the case study by promoting the designer, the design context and most importantly the physical manifestations of research-led practice in scholarly design research; with a direct focus on a new contribution to knowledge that is accessible to industry.

In the simplified version of the traditional supply chain, designers are the precursor to production. The roles and responsibilities between design and production are well established and clearly delineated. Irene (2013) states that in the 3D printing world (a primary focus of this paper), these roles have become blurred and the notion of who is a designer is called into question, as anyone with the ability to use CAD tools can create 'designed' products to be printed. This is true, however, not everyone can design products that have the extant commercial value that people will pay money for. There is a distinct difference between a 3D printed product and a 3D printed commercial product. As various 3D printers require expertise in file preparation, the CAD designer becomes an important part of the design process. The following research impact case study details the changed role of the designer; having to obtain the traditional skills of an industrial designer such as sketching and prototyping, while taking on modern skills in CAD/CAM that are constantly evolving with the rapid growth in additive manufacturing technologies. By necessity, the modern industrial designer needs to acquire both traditional skills for the initial imagination of a product, as well as modern technical skills to translate a clever/smart concept into a physical commercial outcome. The project took 11-months in total; from the initial project meeting through to the actual product launch. Initially, the team was divided into groups – one investigating the 3D printing technology and the design of the lights; and the other, investigating the engineering aspects of the 3D printing material and the development of a suitable heatsink. This was the fundamental research that led the design process described in detail within the following section.

3. Research Impact Case Study

The following case study describes research conducted within a university context that leads to a range of commercial products for the company. Significant research at the beginning of the project was required to frame a direction both the company and the research team agreed on. This is termed 'research-led design practice', where the research is used to direct the design process. It is noted that R&D departments within the industrial sector could also do this, however, in an Australian context, a large majority of companies are SME's where time, funding and capabilities are not always apparent to undergo the 'front-end' research required for successful product development. This is where a university with personnel skilled in both rigorous research and professional practice can assist to alleviate the pressures

of industry to work together on commercial product development.

At the beginning, it was as simple as a SME approaching the university wanting to improve their product range but did not know how to undertake the innovation process to accomplish this. The company concerned is classified as 'small' in relation to a SME, employing around 10 permanent staff and predominantly focused on commercial lighting based on imported componentry and localised assembly. The company had rarely engaged with design before and approached the university for assistance after visiting the university and being introduced to the research team. Initial conversations provided a reality check by highlighting the cost of introducing new products and the associated capital investment involved in the tooling set-up costs for injection moulded plastic parts. From a new product development perspective this is well understood by the research team as a large majority of products designed by this team require injection moulding. The company was shocked by the typical costs involved and reluctant to invest in tooling for a new product range – particularly one that didn't have a proven market. The discussions moved from injection moulding to the disruptive alternatives of additive manufacturing where product can be produced on demand and where there are many efficiency gains including eliminating the need to hold large inventories of components (Ghobadian et al., 2018). From this, the project was then framed around using 3D printing as the potential process for a new range of lighting. Consequently, the project brief was broad and unconstrained presenting more flexibility and the potential for infinite design outcomes within a given physical envelope. Nevertheless, this comes with a significant level of risk as in the early stages of the project the potential final outcomes were not realised. 3D printing is a fast, agile and cheaper method for testing new designs and can easily multiply the product range, however, there was very little precedence of low-cost 3D printers being used for large scale commercial outcomes.

Based in an industrial area of Melbourne, Australia, the company is a lighting manufacturer specialising in energy-efficient commercial lighting. Prior to 2015, the company focussed on simple geometry folded-metal and imported injection-moulded plastic luminaires – predominantly from China. The company CEO along with the research team workshopped and conceptualised a significant shift from this line: a LED track-lighting system featuring 3D-printed plastic housings and advanced electronics. While the conceptualised range presented a huge market advantage, two hurdles stood in its way: 3D printing as a commercial production mode was largely unproven, and the advanced electronics demanded particularly high levels of cooling. These two critical areas that needed development formed the design research criteria from the beginning of the project and are detailed in the design process below:

4. Design Process

4.1 Research

Research concentrated on 3D printers and plastic materials with an emphasis on the

capabilities and capacity of low-cost additive 3D printers. Comparative trials and full thermal analysis of the cooling requirements were undertaken in conjunction with the research and development of the heatsink. Figure 1 shows an example of research conducted on low-cost Fuse Deposition Modelling (FDM) 3D printers. A total of 19 low-cost FDM 3D printers were reviewed and trialled primarily to establish an understanding of the quality, reliability, cost and speed of printing. In addition, five reviews were also undertaken of low-cost Stereolithography Apparatus (SLA) 3D printers to determine the most suitable 3D print method for this project.

DESKTOP 3D PRINTERS COMPARISON (FDM)

IMAGE	MODEL	PRODUCTS SIZE (W D H)	BUILD VOLUME (W D H)	SUPPORTED MATERIALS	MAX RESOLUTION	APPROX COST
	MakerBot Replicator 2, G5	528 x 441 x 410 mm	252 x 199 x 150 mm Not heated	PLA	0.1 mm	\$5,450.00
	MakerBot Replicator z18	493 x 565 x 854 mm	305 x 305 x 457 mm Not heated	PLA	0.1 mm	\$11,500.00
	MakerBot Replicator 2X	490 x 320 x 531 mm	246 x 152 x 155 mm Heated	PLA & ABS	0.1 mm	\$4,568.00
	CreatBot DE Series	NOT GIVEN	400 x 300 x 300 mm Heated	PLA, ABS, PVA, HIPS, Nylon, Laywood, Laybrick	0.4 mm	\$7000.00
	UP BOX	485 x 520 x 495 mm	255 x 205 x 205 mm Heated	ABS & PLA	0.1 to 0.4 mm	\$3,000.00

Figure 1. An example of research conducted on low-cost FDM 3D printers.

For this project, access to a wide range of 3D printers supported by the university was invaluable for the front-end research to determine the most effective 3D printing methods for this application. This is another area worth highlighting where a university can play an important role in R&D by providing a large equipment capability that most SME’s would not usually have access to. From a design perspective, the project was one of the most unique projects the team have worked on. The idea of using low-cost 3D printers for commercial production appeared to be both implausible and challenging. Such challenges as understanding the limitations with 3D printing and the engineering characteristics of the printed outcome; comparing and identifying the best materials to meet the technical and thermal specifications of the LED source, and; the design of a heatsink that not only functions according to the LED specifications, but can also be utilised across all of the designs were the biggest challenges.

Minimising the printing time was crucial as this method of production is presently much

slower than other processes such as injection moulding. This is where the research into efficient production using low-cost 3D printing was vital for the commercial success of the project. Extensive research was carried out on currently available FDM machines while also anticipating new capabilities from established suppliers. A key focus was the printing process itself, with a detailed analysis of the fusing method as the polymer material is bonded together layer by layer on the build platform. Details such as overhangs cannot be printed in 'thin-air' and require support material made up of a lattice scaffolding to allow complex geometries to be printed. This, however, requires more material and slows down the print time for each part. Minimising the printed support material was a high priority so as not to jeopardise the final design by optimising the print quality and minimising the amount of post-print finishing required (removal of the lattice). This necessitated the careful configuration of the product on the print bed to reduce overhangs, minimise the lattice scaffold, and ultimately speed-up the print time.

Another key component of the 'front-end' research was reverse engineering existing track downlights to understand the componentry required in the new products. Reverse engineering is a method of disassembling existing products to better understand their construction and manufacture. There are a number of approaches to re-engineering (Chikofsky and Cross, 1990) (Eilam, 2005) (Kuys et al., 2009) but for the purpose of this project, the primary focus was an analytical process of observation and documentation used to ensure the newly developed products would function correctly and ensure the heat generated from the LED could dissipate throughout the heatsink.



Figure 2. Two of many photos showing the reverse engineering of existing track downlights used to better understand the internal componentry.

4.2 Concept Development and Refinement

The design process during the concept development stage was predicated on exploring organic forms and the development of shapes that could not be reproduced using conventional manufacturing techniques. All of the 'front-end' research for the project had to be adapted to the creative minds of the design team to come up with distinctive designs that both distinguished themselves in comparison to what was currently on the market and competing at a similar price point. A direct quote from a member of the design team

speaking of the design challenges is as follows:

“I ... had to think counteractively. We nearly always design parts which do not have undercuts (injection moulding), can be machined or extruded without even thinking about it. It's become such a part of our mental process that to break that mould within our own thinking was a struggle.”



Figure 3. *Early concept sketches trying to ‘break’ the mind-set of designing for injection moulding. Free-flowing organic shapes were promoted and prototypes were used to review with the company.*



Figure 4. *An example of one concept pushing the boundaries of organic 3D CAD modelling and exploiting the capabilities of 3D printing over injection moulding.*

After the design team pushed past their natural tendency to design componentry by complying to established constraints for injection moulding, they generated 10 concepts for presentation. The concepts were reviewed, scored and evaluated in terms of time of print, amount of material used, aesthetics, market potential and ease of assembly. The company committed to take five to production. Once these concepts were selected, this then presented another design challenge – refining the highly creative selected concepts to an appropriate level that would be optimised for printing on target FDM low-cost 3D printers, while keeping their original characteristics. The orientation of the product on the print bed not only affected the speed of print, but more importantly it affected the quality of print.

This is because FDM printing is done in layers and when a curvaceous surface is orientated incorrectly on the print bed it results in an unacceptably rough surface that is clearly visible (see Figure 5). Thin wall sections invariably failed on some prints and support material in some cavities was very difficult to remove. An extensive series of test prints was completed to better understand the limitations of the low-cost 3D printers. While this was replicated to some extent in the earlier stages of the research, it was now being done for a specific design and build context. This maturing understanding was vital in achieving the grade of the 3D printing to ensure a desirable quality of product.



Figure 5. An example of a poor-quality 3D print finish occurring from the layering process on curvaceous surfaces. This is avoided by reorienting the product on the print bed.

The team recognised the need to standardise the testing procedures and create sample 3D prints as a basis to ensure consistent and fair comparisons across all low-end 3D printers. CAD sample cubes and spheres were created with various features such as different wall thicknesses, extruded and embossed details and curvaceous surfaces to better determine some design constraints. These CAD shapes were then 3D printed and formed design guidelines during the refinement stage of all selected concepts. Rigor was required to ensure comparable and reproducible test results in similar environmental conditions. The tests proved to be a valuable exercise in identifying and setting the print orientation for final products to minimise support material, speed-up print times and maximise the surface quality of the prints (see Figures 6, 7, 8 and 9).

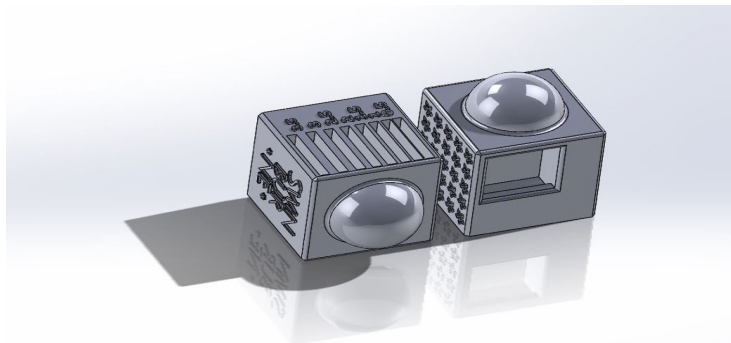


Figure 6 The CAD development of sample cubes used to better understand low-cost 3D printing capabilities.

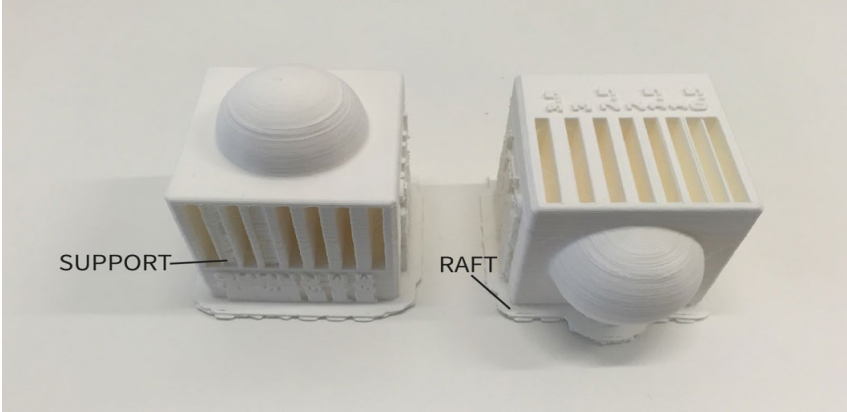


Figure 7. 3D printed sample cubes showing varying wall-thicknesses and intricate details.



Figure 8. The CAD development of sample spheres used to better understand low-cost 3D printing capabilities with a focus on curvaceous forms.



Figure 9. 3D printed sample spheres showing varying wall-thicknesses and intricate details.

While research was being conducted on 3D printing capabilities to help inform the design refinement, the engineering team were developing a unique heatsink specific to accommodate the LED light source and associated electronics. This is where product design engineers are a valuable asset to a product development research team by understanding

the design process supported by engineering rigor. This allows fluid discussion between the industrial designers and product design engineers to minimise the chances of the innovative features being 'engineered-out' of the final products. An example of this is seen within the development of the heatsink which consisted of curved fins at the end of each linear section. Here, the effective dispersal of the heat without affecting the surrounding polymer housing is critical. Figure 10 shows Finite Element Analysis (FEA) of a standard heatsink to understand the distribution of heat throughout the total surface area and to dissipate heat more effectively. Figure 11 shows CAD refinement that ensured design features were not eliminated. Figure 12 shows an example of the research and development to manufacture a proof-of-concept heatsink for testing, and Figure 13 shows the final heatsink prototype led by the industrial designers and refined by the product design engineers.

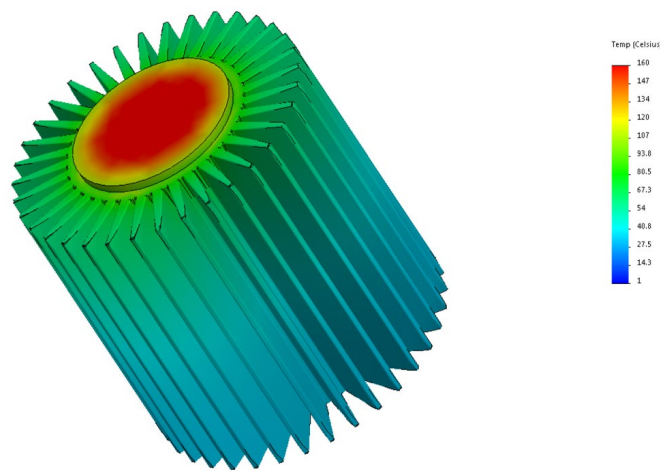


Figure 10. FEA conducted on a standard heatsink to understand the distribution of heat throughout the total surface area.

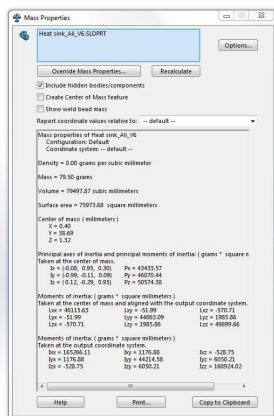


Figure 11. CAD refinement of the heatsink showing the advanced design details.

HEAT SINK PROTOTYPES



CNC MACHINING

Using Swinburne University's state of the art DMG MORI 5 axis CNC machine centre, we were to prototype multiple heat sink's for the purpose of testing.



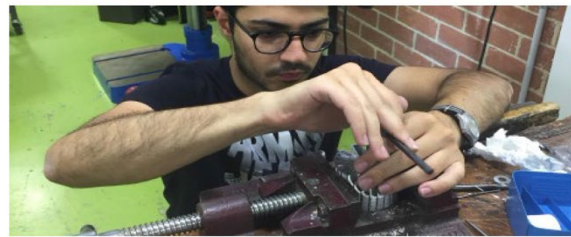
HEAT SINK POST CNC MACHINING

Cutting the machined heat sink off the billet post machining, using a BROBO cold saw.



HEAT SINK POST CNC MACHINING

Separated heat sink.



ALTERNATIVE HEAT SINK DESIGN PROTOTYPE

Although the main hole required to join the two halves of the heat sink together were machined and tapped using the CNC machine centre, some holes required manual tapping.

Figure 12. Production of the aluminium heatsink before committing to a full extrusion system.

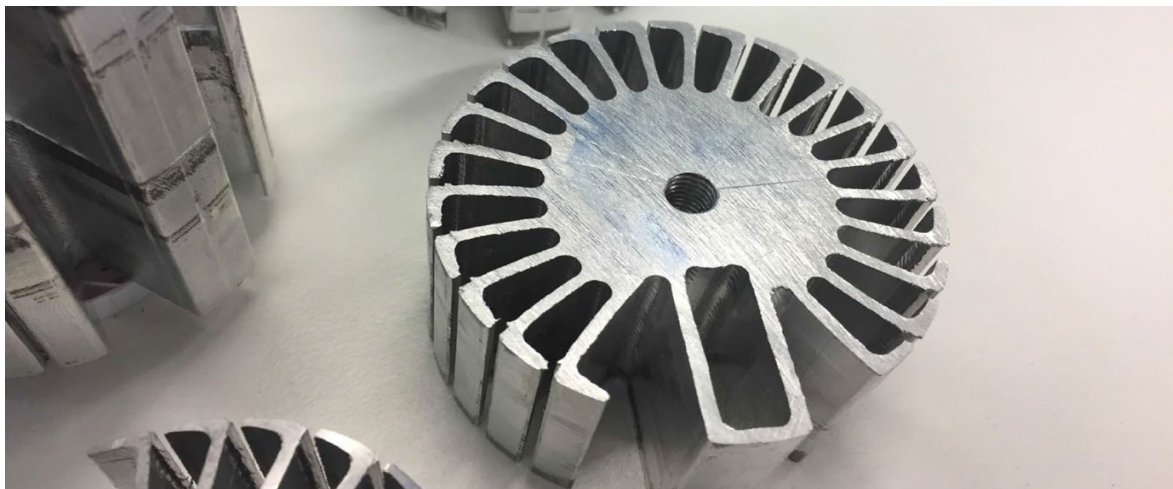


Figure 13. The first aluminium machined heatsink used as a proof-of-concept for validating the 3D printed lights.

While the engineering team were refining the heat-sink, the industrial design team were advancing the visual concepts. The ability to create photo-realistic imagery was important for the company to better understand what the final products would look like. These concepts were then printed and evaluated between the product development team and the company on a weekly basis.

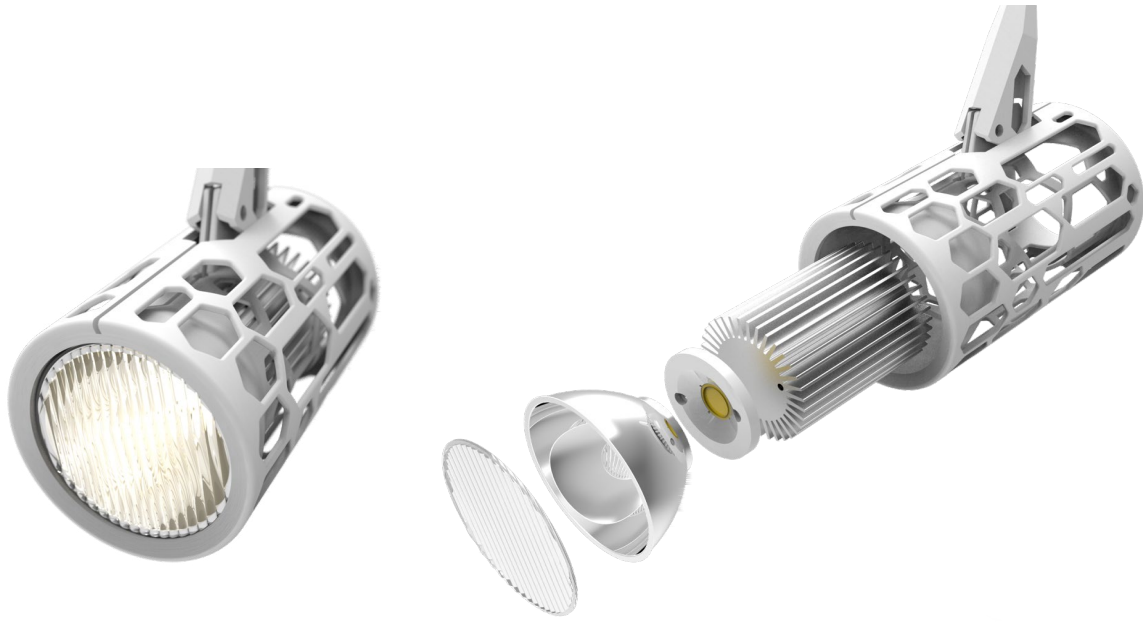


Figure 14. 3D rendering showing the final product along with the assembly process.



Figure 15. A 3D printed example showing the complex geometries possible with a low-cost 3D printer.

The development also benefitted from regular engagement with the company throughout the project. The company could readily assess and evaluate progress by engaging directly with the tangible realities through all the critical stages of the development, which led to a design outcome that was not a surprise to the company.

4.3 Design Outcome



The end result was an entire new range of high-end, production ready, light features designed by the university-based research team that benefitted from regular involvement

and feedback from the company. The company’s track-lighting range, comprising five unique designs shows how research can inform decisions concerning the design process; and by default, informing practice of ‘research-led industrial design practice’. This example shows how design teams can think more strategically about identifying opportunities for companies that are forced to diversify/innovate their product portfolio due to rapidly changing economic environments. This is typical for SME’s who do not have much experience in innovation processes and engaging with designers. Many SME’s have limited resources which means any innovation collaboration needs to build on existing organisational capabilities. A direct quote from the company helps validate the impact this research has had for his company:

“Without the [university] team this range simply wouldn’t have occurred. We are very excited about the product range, its 3D printing production advantages and its great export potential.”

In summary the final five 3D printed track downlights are made from ABS, a plastic common for 3D printing and costs on average \$AUD70 per spool of material (800 grams of material). Depending on the design, the research team were able to print between 4–10 lights per spool of material as shown in Table 1.

Table 1. Manufacturing comparison of material usage, print time and amount of prints per spool for the 5 lights chosen to go into production.

Light Design					
Amount of material used	76 grams	137 grams	104 grams	185 grams	182 grams
Print time	11:20 hours	23 hours	15 hours	20 hours	29 hours
Light housings per spool	10	5	7	4	4

While clearly more expensive than the raw cost of an injection moulded part, it is the capital investment required at the front end of the manufacturing process that is avoided in this situation. Comparable costs for injection moulded parts could be 10–20 cents per part in raw material, however, the tooling set-up for each light would be around \$AUD30,000–50,000 up-front investment. While this investment would be amortised across the production run, there is no guarantee the final product will be successful. Crucially, it would avoid a large

investment in tooling for mass-production with a risk of an unpopular design languishing on the shelf – with 3D printing it is ‘print to order’. And that is exactly what the company is doing. When an order is received, printing can occur immediately, but moreover the key benefit is having 3D printers running overnight. As shown in Table 1, the longest print time for one light is 29-hours. By utilising the 3D printers overnight, a large proportion of the print time occurs when the company is closed – once again maximising efficiencies and helping SMEs stay responsive to global markets.

Another benefit of directly using 3D printing for commercial outcomes is the ability to create unique designs that are impossible to produce by any other manufacturing process. 3D printing allows complex geometries to be created and unlike injection moulding, undercuts within the products are not a problem. The layering process of 3D printing allows for multiple walls and intricate details on alternating planes, whereas with injection moulding all designs must conform to a two (or multiple)-part mould in order for the injection moulded part to be released. While injection moulding can have dual cores and sliders to allow more complex geometries, it adds significantly to the tool costs creating even higher risks that if the product is not successful, the return on investment will rapidly diminish especially where low volumes of production are concerned. Even with these advancements in tooling for injection moulded parts, the geometries created for the 3D printer’s equivalents are so complex, they are physically impossible to produce with injection moulding, or any other manufacturing process available. This presents a truly unique offering by using clever design and expert CAD modelling, with an advanced understanding of 3D printing to create products that are exclusive to the company and cannot be replicated by any other means. This strategy reduces risk and the anxiety associated with being committed to a limited range of injection moulded products that involves considerable upfront investment and the subsequent costly storage of multiple component parts (Clarke & Mia, 2004). While the complex geometries can be potentially copied to replicate the designs, there is no real advantage to whoever is copying the design. This is because minimal labour is involved and the cost of 3D printing and materials is similar no matter where you are in the world.

Further flexibility and competitive advantage can be gained through the use of colour. The colours available in the current range of Zortrax 3D printers (preferred printer for this project) currently consists of blue, sky-blue, android green, green, orange, cool-grey, pure white, pure black, red, warm grey and yellow. However, the company has worked with the material supplier to have batches of unique colours made to their own specification on mass so, hypothetically, they can print the lights in any colour they want or to suit the bespoke needs of customers. This range of products has the ‘smarts’ within the designs and not the manufacturing. The five initial designs created for this project are used to introduce the product range; however, the research team created another five follow-up designs ready to expand the range when required. This highlights the value of design in creating a family of products that can be readily introduced into the market by the company when they identify or recognise an opportunity. This advantage means the company can be first in the marketplace with new and unique product ahead of any conventional competitors.

This underlines the potential of this responsive agile approach that can provide Australian manufacturers with significant competitive advantages. This is all achieved while expensive capital investments in tooling is eliminated and production inventories are kept to a minimum.



Figure 16. The final products developed for the Australian SME – 3D printed track downlights.

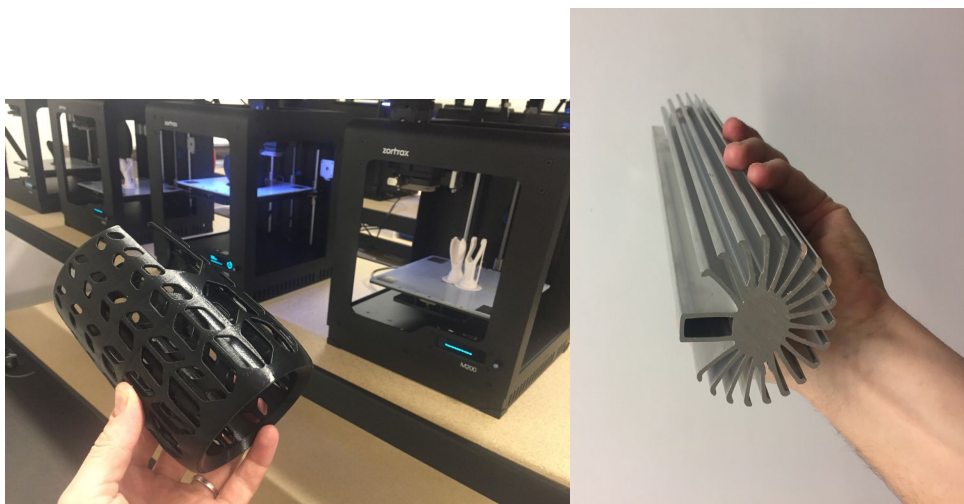


Figure 17. Left: The final aluminium extruded heatsink. Designed to be consistent across all designs and docked to length as required.
Right: The final 3D printed light at the production facility – showing an impressive surface finish for a low-cost 3D printed part due to the significant research done on 3D printing.



Figure 18. A detail photograph of the final 3D printed product with an anodised heatsink.



Figure 19. The final product installed and operating.

5. Discussion

Published literature on 3D printing is often dedicated to the specifics of 3D printing technologies such as speed, quality of print, materials and improvements in the scaffolding (support material) (Bak, 2003). In particular, it is dominated by literature that focuses on 3D printing in the medical industry with applications such as bone tissue engineering and bone substitute implants, however, these are mainly focused on high-end titanium metal 3D

printers (Bogue, 2013). There is minimal research on how low-cost (AUD\$3,000–\$6,000) 3D printers can be used to advance company innovation by using this low-cost manufacturing for commercial outcomes. In some cases, the published literature actually discounts this. In a statement from Wohlers Associates in an article by Bak (2003), Wohlers states, “Rapid manufacturing is the direct production of finished goods from a rapid prototyping device.” This definition suggests that true rapid manufacturing systems are those that employ additive processes to deliver finished goods directly from digital data, eliminating all tooling. Such systems, Wohlers says, do not currently exist, although he acknowledges that conventional rapid prototyping systems are being successfully applied to produce low-volume end-use parts. The challenge, he notes, is to merge rapid prototyping capabilities with the high-volume throughput traditionally associated with manufacturing applications. This impact case study acknowledges the issue of high-volume production but, by contrast, illustrates how rapid prototyping can be used in a different way to create commercially viable products. Rather than use rapid prototyping for mass-produced parts, it is used for complex parts that cannot be replicated by any other manufacturing process. It also illustrates how a small company can avoid the high start-up costs of production and help ‘test’ the market before committing to large scale injection moulding production.

The article from Bak (2003) is dated and in a field that has significantly advanced in the past 16 years, it shows the importance of this paper by providing a real-world commercial industry project using low-cost 3D printing to advance company innovation. More importantly it shows the results of a profitable outcome using sophisticated design and a thorough understanding of 3D printing to ensure commercial viability. An advantage of 3D printing is the rapid advancement in technology. The costs of 3D printers are continually going down while at the same time the quality and speed are both going up. An example of this is the HP Jet Fusion 3D printer (introduced in 2017), which utilises a new powder printing technology. While currently expensive (AUD\$400,000), this is arguably the biggest innovation in 3D printing in the past 10-years advancing beyond SLA, Selective Laser Sintering (SLS) and FDM, due to significantly faster print times, quality, and material options.

In the dated article from Bak (2003), Wohlers Associates states: “For Rapid Prototyping to better penetrate new markets, a number of changes must occur. Machines must become less expensive to buy and easier to use and maintain. System prices and the overall cost of ownership must drop further and materials must improve. Furthermore, new machines and applications must develop to support the production of finished manufactured parts, versus models and prototypes.” It can be argued that with this project, a great deal of the concerns mentioned in 2003 have been addressed. 3D printing machines are much more affordable than 10-years ago. The quality has improved significantly and the cost of material is cheaper, however, it is the application of this technology for projects of commercial merit that is still lacking. 3D printers are only as good as the CAD operator and the design team who understand how to design end-products specifically for 3D printing.

Projects such as this are beneficial to both the university with an ever-growing expectation for industry income, as well as the company to help expand their product range with minimal

investment. In the context of Australian manufacturing, which is suffering from the decline of the automotive sector, innovation needs to focus on products with maximum profit and minimal investment. While not possible for all products, in the lighting industry this is ideal. Rarely do we look directly at lights when installed. They are either too high, mounted in the ceiling or when they are on they are too bright to look directly at. This is what sparked the idea to develop low-cost 3D printing methods for the commercial finish of the exterior housing of track-lighting – a product that is high-value in the lighting industry; a product that requires significant design resolution to stand out from the competitive products; and a product that doesn't necessarily require a perfect 'injection-moulded' exterior finish. This helps businesses be agile and responsive. By working closely with a university, the company have access to state-of-the art equipment which in this case was a wide-range of 3D printers, as well as in-depth research capabilities. There was significant research and development undertaken for this project which this paper cannot do justice, however the aim of this paper is to promote a research-led industrial design project done within the framework of a university. It aims to inform other research-intensive organisations to adapt to new forms of research output (non-traditional research output or NTRO) and promote the impact the research can produce.

The impact of this form of research-led design engagement highlights how SMEs can be helped with the development of new products. It can generate greater reward for those organisations that want to innovate but do not have a specific product direction. In this case, the research-led industrial design team within the university understood the difficulties faced by an SME to invest in new designs, leading them to consider low-cost 3D printing to propose some new products. In 3D printing the design team could foresee a fast, agile and cheaper method for testing new designs and multiplying the range. Indeed, such research-led design and the adoption of such additive manufacturing technologies could be considered the zenith of the JIT 'Just-in-time' management philosophy. A situation where a company's competitiveness is substantially strengthened by minimising waste, improving product quality and maximising production efficiency (Ghobadian et al., 2018).

6. Conclusion

The research and development team involved in this project was led by a professor of design with advanced knowledge in industry-university engagement and new product development. For this project, he was supported by members of his research team consisting of three industrial designers and two product design engineers. Like most product development it's rarely done in isolation and is most successful when done in teams. This can be said for industry engaged research where the research lead is taken by the research active academic, while having a supporting network of commercial designers to ensure the research translates into an outcome that satisfies the company. Using the research to influence the design team has created a unique value proposition within the university because the company is exposed to thorough academic research, has the use of university equipment and receives an outcome with true commercial potential.

The comprehensive nature of these services, particularly the on-campus prototyping and testing, has proven hugely attractive to industry. Most importantly, the research team has been able to realise the fast timelines and responsiveness demanded within a commercial consulting environment. This is something that university teams and the systems within a university need to adapt to. Examples such as procurement of equipment, purchasing of goods and ethics reviews where applicable all need to work faster. Before forming this research group, certain processes within the university took longer to execute than many of the projects themselves. The fast-nature of such commercial ventures require industry-university engagements to be agile and adaptive, and not be inhibited by cumbersome university systems that do not work in the company's favour.

For the project presented in this paper it is not suggested that 3D printing will replace injection moulding especially where high-volume production is concerned. This paper presents a case for developing and introducing new products for a SME that has not previously engaged with design or research services. The approach taken has minimal up-front investment and directly results in reducing risk. The biggest issue for new product development for most companies (especially SMEs) is the risk associated with upfront investment and exposure to an unpredictable market. Usually new products incur large up-front expense when taking a conceptual idea through to a manufactured product. The research program reduced this risk by producing a comprehensive collection of both traditional and non-traditional research output to inform the commercial design outcome. Traditional peer-reviewed academic publications have focussed on the analysis of the working practices and processes. In this domain, scholarly design theory is tested, and the very nature, limitations and potential of research-led industrial design is explored. The program's non-traditional research output manifests in the form of each project's final product or service; an artefact that embodies new design knowledge developed over the course of the research-led design process.

The company these products were designed for now employs a full-time member of staff dedicated to the 3D printing aspects of the business and they currently have over 30 low-cost 3D printers – with a business model to support at least 100 3D printers as the first product range matures. The printers are now running 24 hours a day which is the beauty of 3D printing. When an order comes in the 3D printer starts printing – it runs overnight and the next morning the light housing is removed from the FDM print bed, support material cleaned off, the product assembled, packaged and ready to send to the company. The following quote from the company CEO highlights the importance of this project to their business:

“We expect the number of lights being printed to build up to a couple of thousand a month at least.”

The relationship between the product development team within the university and the lighting company continues and a second project using low-cost 3D printing for a commercial range of pendant lights has just been completed. This shows confidence in the company's willingness to further engage with the university and build from the knowledge created in

the first project to further advance the product offerings – Australian designed and Australian made products competing in the global marketplace.

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A pilot study used to better construct a research direction to understand where industrial design fits within the 4th industrial revolution (Industry 4.0)

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Abstract: The industrial design profession is engaging with a new manufacturing revolution — Industry 4.0 (I4.0). This new paradigm presents new opportunities and challenges for industrial designers. However, it is still unclear what knowledge industrial designers can contribute to manufacturers in an emerging I4.0 context. This pilot study serves to determine the current state of practice of industrial design, and to discover areas of improvement as well as strengths to build on. Most importantly, this study functions as the first step to better qualify questions for a subsequent online questionnaire survey, in conjunction with findings from literature. A focus group was conducted with an even ratio of males to females (n=6) of industrial design professionals, and identified current and future problems and opportunities for industrial design practice and its preparedness for I4.0. This study was intentionally kept concise to ensure all participants in the focus group contributed to the discussion and to minimise echolalia. This was important to give everyone a ‘voice’ to develop an appropriate framework to help substantiate a series of questions for a much larger study. The findings suggest poor communication between industrial design and industry, as well as confusion around what I4.0 entails and how industrial design can contribute to this new manufacturing revolution.

Keywords: industrial design; industry 4.0; design practice; qualitative

1. Introduction

Industrial design is the profession of design concerned with the design of mass-manufactured consumer products (Britannica-Academic, 2018). Its origins lay in the beginning of the 1800’s during the First Industrial Revolution. With the shift from workshop to factory (Hauffe, 1998) the design profession became removed from the physical labour (craft) and thus a mental labour through the advent of mechanisation and mass production (Walker, 1989). Industrial design was therefore an integral and logical consequence of the developments in science, technology and large-scale mechanisation in production during that time (Conway, 1995).



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The shift from handmade to machine made thus opened new niches for occupations that industrial design utilised. Although the profession of the industrial designer was not officially coined until the 1960's (Moody, 1980), it was practiced long before that. Humans engaged in design activities since the advent of humanity (Barnwell, 2011). One crucial thing that sets humans apart from animals is the use and creation of technology (Toth and Schick, 2015), and now — more than ever — the technology we created is changing us.

Over two centuries later, industrial design is living through the 4th Industrial Revolution (Industry 4.0), which is a relatively new term coined to describe the concept of the smart factory or smart manufacturing (Petrelli, 2017). Even though industrial design is its own profession and is closely linked to manufacturing, both areas depend on each other. Hence, changes in each field influence the other. The advances and changes in science and technology created the industrial design profession in the beginning, and now, industrial design needs to adjust to these changes this new manufacturing paradigm (I4.0) presents. In brief: manufacturing is changing which is driving industrial design to change and adapt too.

Due to these rapid changes happening in the manufacturing sector, it is still unclear what is required for industrial design to evolve to stay relevant in I4.0. This led to the two research questions deduced from the literature:

1. What are concrete requisites of industrial design and Design for Manufacture (DFM), which ensure they are appropriate and relevant in adding value to manufacturing?
2. How does the industrial design profession have to change and adapt to stay relevant in the future manufacturing environment (I4.0)?

Both industrial designers and manufacturing industries depend on each other, and the collaboration of both parties is vital for the success of businesses and start-ups. Equally important is the consideration of new manufacturing technologies into design practice. Including new technologies, such as additive manufacture, Artificial Intelligence (AI), Virtual Reality (VR) etc., this enables industrial designers to be a proactive part in the creation of innovative products and systems/services. To conclude: in the words of Heskett (2001, P.25-26), "Should designers fail to adapt, new competencies will emerge to fill the gap left behind. The evidence of history is that design, as a basic human ability, is constantly required to adapt and redefine itself to meet the needs of its time. We should expect no less for our age." García Ferrari (2017, P.2631) elaborates that the design discipline — not unlike in the 20th century when confronted with crisis, such as I4.0 — "has the possibility of embracing a process of change and mutate again". Therefore, industrial design is in a state of continuous flux and its evolution inevitable.

2. Study Aim

The aim of this study is to determine the current state of practice of industrial designers and to explore areas for improvement and strengths to build on. I4.0 is predicted to change

the way we manufacture and design products and collaborate. This pilot study serves as an immediate instrument to determine the current state of industrial design. The focus group is thus the initial step in designing a subsequent questionnaire, targeting a higher quantity of industrial designers worldwide to gain a better understanding where the profession is lacking competencies and to iterate on opportunities emerging from the data. Moreover, this pilot study serves as an exemplar to educate other researchers in the design-specific fields on the use of the focus group method to develop questions for subsequent large-scale questionnaire survey (van Teijlingen and Hundley, 2001).

3. Method

3.1 A Focus Group as a Pilot Study

The focus group was conducted at a prominent design school in Melbourne, Australia by all authors involved and included 3 female industrial designers and 3 male industrial designers, all with at least 2 years of experience.

A structured approach was important since the topic is relatively unexplored (Hesse-Biber, 2017) and the results of the pilot study thus helped to design the following quantitative questionnaire survey (van Teijlingen and Hundley, 2001, Puchta and Potter, 2004). This focus group study is a non-self-contained pilot study, serving in the initial exploration phase (Puchta and Potter, 2004) to answer the research questions generated from an extensive literature review on this topic. This method was mainly used to identify issues within the industrial design practice when working with manufacturers and industry. The extensive online questionnaire survey will help to further clarify these issues identified and find areas of improvement for the industrial design profession.

Conducting a focus group as the first methodological approach for this research, instead of in-depth interviews or other relevant methods, presented itself as an appropriate tool for this pilot study, since it offers a richer and deeper range of data through group dynamics taking place in a social environment (Breen, 2006, Rabiee, 2007). Further advantages include the time-efficiency in collection of big quantities of qualitative data with few participants (Breen, 2006, Hesse-Biber, 2017). Furthermore, focus groups are especially useful as part of a mixed method study (Hesse-Biber, 2017).

Further reasons for using a pilot study before conducting an extensive survey is assessing the feasibility of a full-scale study/survey, as well as the collection of preliminary data (van Teijlingen and Hundley, 2001, P.2). Concluding, according to van Teijlingen and Hundley (2001, P.3): “pilot study procedures can serve to improve the internal validity of questionnaires”. This was achieved by asking participants for feedback to find difficult and vague questions, as well as omitting unnecessary questions in regard to the research questions (van Teijlingen and Hundley, 2001).

3.2 Coding and Analysis

The qualitative data analysis software (QDAS) NVIVO was used to identify reoccurring and popular themes. Thematic Analysis (TA) was used to “systematically identifying, organising and offering insight into patterns of meaning (themes) across a data set” (Braun and Clarke, 2012, P.57). Since qualitative methods are after meaning (Hesse-Biber, 2017), TA allows making sense of “collective or shared meanings and experiences” across a data set (Braun and Clarke, 2012, P.57). Multiple patterns of meaning and experiences were identified and showed relations in the data set (Braun and Clarke, 2012). These patterns and relations were identified and mapped out to show the connections between themes visually. This was important to make sense of commonalities. The data set consists of an audio recording (1h 30min) which was later transcribed, as well as photos of the participant-organised Post-It-Notes. The data was imported into NVIVO which served as the QDAS.

The TA was conducted in 6 steps according to Braun and Clarke (2006, P.87):

1. Data familiarising
2. Initial code generation
3. Theme identification
4. Theme review
5. Theme defining/naming
6. Report findings

3.3 Structure and Approach

The focus group was structured to ask initial questions followed by a brief explanation of the methods and an introduction to I4.0. These initial questions were all formulated from an extensive literature review conducted as part of a larger study but was subsequently used to inform this research. The following questions were discussed and individually written on Post-It-Notes and later pinned up and organised by each participant (Figure 1).

1. Q: What does design mean to you?
2. Q: What is industrial design and what does it mean to you?
3. Q: What are the strengths of industrial design?
4. Q: What are weaknesses of industrial design?
5. Q: What do you think the future of industrial design looks like?
6. Information and background: Research
7. Discussion and Post-It-Note pin-ups
 - a. What are issues or challenges you encounter during everyday working life in regard to manufacturers and manufacturing?
 - b. What are demands from manufacturers you cannot fulfil?
 - c. What are your demands for manufacturers they cannot fulfil?
 - d. Are there any things you want to know or understand better about manufacturing and your place in new product development?
 - e. What information gathered from industrial designers would help you being

A pilot study used to better construct a research direction to understand where industrial...

- better prepared for the future in your profession?
- f. What information gathered from manufacturers would help you being better prepared for the future in your profession?
8. Organisation of the topics and themes (Post-It-Notes)
9. Thoughts and feedback?

4. Results

The thematic analysis identified 5 main themes – Communication, Society Ethics & Norms, Capabilities (manufacturing limitations), Change and Industry 4.0. These themes are explained in detail below:

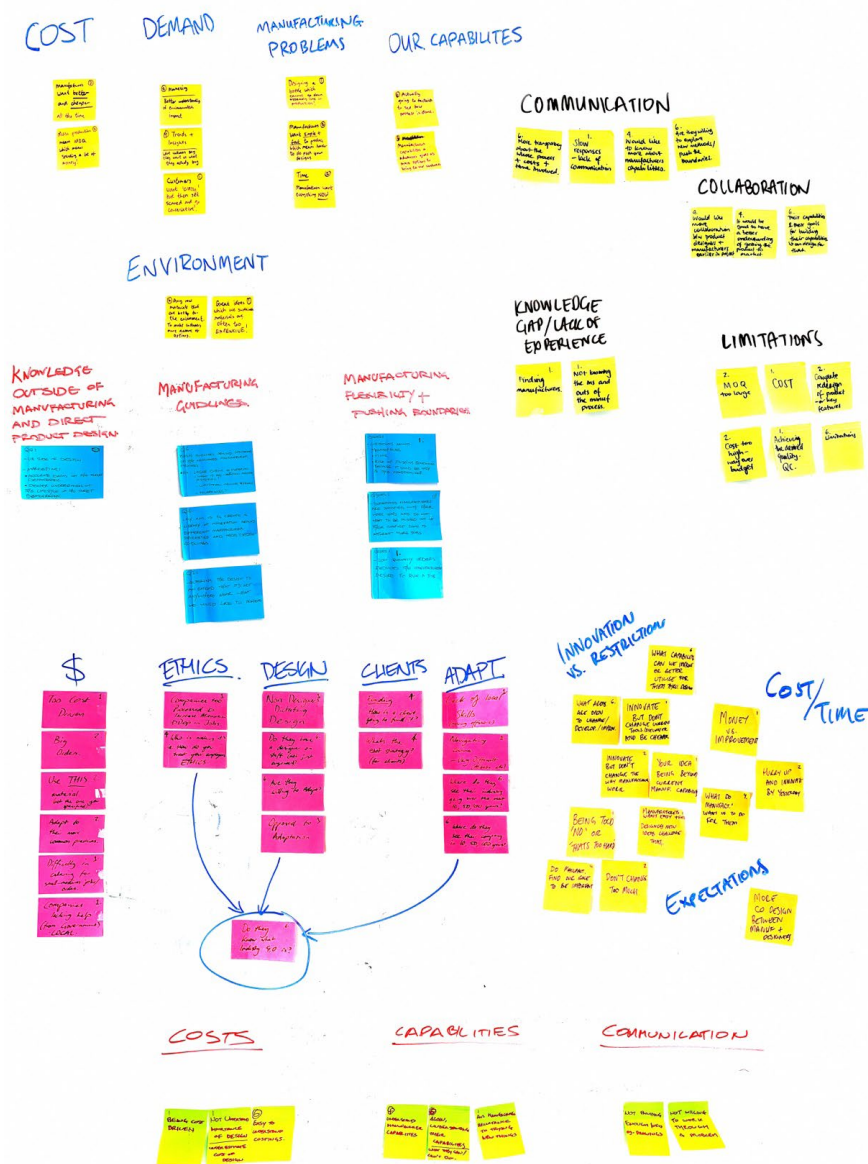


Figure 1 Focus group Post-It-Notes organised by participants after the focus group discussion

4.1 Communication

The thematic analysis showed the constant occurrence of miscommunication between industrial designers and manufacturers. For this study it was found that industrial designers do not fully understand the current practices manufacturers employ and it suggests, that the manufacturing industry does not fully understand industrial design. This may be caused by the lack of transparency of certain manufacturing processes and stubbornness to collaborate on projects. In addition, the capabilities of manufacturers are largely miscommunicated — if even at all discussed. The industrial designers reported the constant issue of miscommunication in regard to the machines and processes involved in the manufacture of a given product. Industrial designers felt that their production capabilities were some sort of ‘black box’, where industrial designers are not aware what is happening inside.

The data suggests a conflict of interest through different understandings of meaning, as well as language barriers, especially with foreign industry partners (e.g. through aggregators such as Alibaba). Another interesting aspect is, that industrial design as a profession, and its capabilities are largely misunderstood by manufacturers with the resulting demands are often too high. A further cause of conflict is the expectation of manufacturers to constantly innovate, but without the will to adapt and make change towards their practice and capabilities. This could be largely attributed to risk-versus-reward, however with a lack of design intervention, certain manufacturers could cease to exist. The industrial designers within this focus group felt a general opposition from industry about trying new methods of production keeping their demands towards designers high. Other issues arose through having distinct priorities; whereas industrial designers are concerned with the end product and how the market and its users perceive it — manufacturers interest lie mainly in efficiency, cost and time savings during production. Most of the time, that means that industrial designers have to adapt to the manufacturer’s common practices and have to work within the dictated boundaries.

4.2 Society Ethics & Norms

The second main theme identified where the social and ethical implications were associated with design and manufacture. This includes female representation and communication between people within an office. Industrial designers have a social responsibility to create products which are empathic and mirror different social and cultural values for different clients. Furthermore, the participants emphasised the importance of the worker’s wellbeing in manufacturing-dominant countries such as China and India, as well as the responsibility of manufacturing processes which links to the sustainability of materials, the actual design of product and product life cycles. Industrial designers described the feeling of being indirectly responsible for the exploitation of labourers and their working conditions in foreign countries. The missing transparency of manufacturers — especially overseas — makes it hard to determine ethical manufacturing of products.

Yet the societal demand for production and consumption continue to drive new product

development so there will always be a compromise between sustainability/socially responsible design versus profit and consumer demands.

Another concern expressed by the industrial designers within the focus group was sustainability in product design and the inability to control the use of materials, as well as manufacturing processes. Industrial designers felt disappointment about their profession through missing environmental regulations and the disregard of industry to see the sustainable aspects of the manufactured products. Industrial designers — although removed from manufacture — feel responsible for their designs and are often powerless against the choices of their clients and partners. Sometimes, they feel either misunderstood or not even heard. It can be suggested that industrial designers want to have a greater influence over manufacturing and its processes to have a stronger influence around the ethicality of what is being produced.

4.3 Capabilities (Manufacturing Limitations)

Participants felt manufacturers were far too cost driven and thus hindering innovation on a product design level. One participant stated: “money versus improvement” still plays a huge role for industry today. Therefore, the resilience of industry to adapt and integrate changes into their practice is also an enormous limiting factor in the collaboration of both fields. Additionally — according to the participants — manufacturers do not fully seem to understand the importance of new product development. Participants felt frustrated by the expectations set by manufacturers since there is a discrepancy between the priorities of both professions. Whereas manufacturers favour efficiency and cost savings, industrial designers focus is with the design of products appropriate for customers and the market. Interestingly, industry expects industrial designers to “innovate by yesterday”, but at the same time anticipate to only utilise current manufacturing processes and technologies. Achieving innovation as well as saving costs, the resilience to adapt to changes and incorporating new processes stand in direct conflict with the manufacturer’s priorities. Manufacturers seem to be open to innovation, however, feel intimidated by design proposals brought forward from industrial designers.

4.4 Change

There seems to be a big resilience from manufacturers towards change, which includes the adaptation of new technologies and innovative processes. Industrial designers are willing to push the boundaries whereas manufacturers want to keep traditions and current systems in place since the perceived risk is too high. This, in turn, influences the responsiveness and quality of collaboration in between manufacturing and industrial design. The expectations of industrial designers are therefore high, and it is assumed they have to work around these limitations. However, the authors of this paper tend to disagree with these findings as there are many examples within manufacturing where true innovation occurs, and where an industrial designer’s ability is prioritised. It is, however, a small sample and fulfils the purpose of this study by substantiating questions that lead to a much greater study. If the

opinions of a small sample of industrial designers suggest there is a disconnect between industrial design and manufacturing, then this needs to be questioned. The main finding of this section suggests a poor or even missing communication between manufacturers and industrial designers, which will also be explored in the subsequent online questionnaire survey. The participants felt that the manufacturers often show resilience towards trying out new ideas which conflicted with their own demand to industrial designers to innovate in the product design process. This incoherence leads to misunderstandings or even conflict during collaboration and often resulted in suboptimal product outcomes.

4.5 Industry 4.0

The most important finding of this focus group was that industrial designers are largely unaware or divided about what I4.0 means. This presents a huge opportunity for further research, as “design is the first step in manufacturing” (Boothroyd, 1994, P.505). Understanding I4.0 is vital for industrial designers to become a valuable and integral part of this new manufacturing revolution. Participants described I4.0 as a “buzzword” with its creation occurring somewhat “not organically” and felt a bit “forced” upon them. Consensus from participants was that new technologies in the industry drive new innovations and developments and open up opportunities in the design field. They noted the importance of being aware of I4.0, but failed to understand exactly where industrial design fits. This is the core aim of an extended study to better understand the role of industrial design in I4.0.

To summarise this section, discussion topics were generated based on the research questions asked during the focus group. The given answers, and identified themes gained through the conduction of this focus group serve as a base to design the subsequent online questionnaire survey. The research thus follows a structured approach in conducting and designing a rigorous mixed methods study.

5. Discussion

The findings of this study will help better prepare industrial designers for the future manufacturing environment — I4.0. It has been found that design professionals still feel largely misunderstood by manufacturing and the effort and cost involved in new product development is constantly underestimated. This may be due to the lack of knowledge and miscommunications between industrial design and manufacturing during collaboration. Therefore, both manufacturers and industrial designers need to communicate their priorities and capabilities better to enable mutually beneficial collaboration. Another important aspect of this study is that the industrial design participants suggested they felt socially responsible and would like a larger influence over the choice of materials and manufacturing processes. The authors of this paper see these areas as key attributes of a good industrial designer. While there is a clear disconnect between manufacturing and industrial design in terms of communication and awareness of each other’s profession, they are both fundamentally inherent with each other. It is the responsibility of the industrial designer to understand

materials and their manufacturing processes and 'push' manufacturers to accomplish the desired outcome without jeopardising the design intent. This is not always possible due to costs, capabilities and expertise available; however, a good industrial designer must design products that are feasible to manufacture without being fixated on 'known' manufacturing processes. They must stay abreast with modern manufacturing processes – This is particularly important in the context of I4.0, where new manufacturing techniques will evolve that will directly benefit industrial design.

Another finding of this study was the lack of understanding of the term Industry 4.0. They felt that the word and its meaning need to be further clarified and multiple sources such as Schwab (2016) described Industry 4.0 in very different ways. This presents an opportunity for future research and how to educate design professionals about the changes happening in the manufacturing sector. It is vital that future research focuses on the exploration of how well industrial design professionals are prepared for the changes I4.0 brings. These include the integration of novel technologies and systems into industrial design-routine.

As discussed within this paper, the pilot study focus group was conducted to substantiate the questions for the subsequent online questionnaire survey. These are questions where relevant literature couldn't answer (either outdated or none existent) and are used to better understand where industrial design fits within a I4.0 manufacturing context. The questions derived from this research are as follows:

1. Do you feel like the profession of industrial designer is misunderstood or confused by the public or non-designers?
2. Rank your top 6 strengths of industrial designers.
3. Who benefits most from your abilities as an industrial designer?
4. Do you feel yourself rather included or excluded in the manufacturing process?
5. Give one example how you achieve innovation and creativity in product design when working with manufacturers or industry.
6. How prepared do you feel for the changes happening in the manufacturing sector?
7. How prepared do you feel your company is for the changes happening in the manufacturing sector?
8. What changes would you wish to see being implemented in the industrial design practice in the future?
9. Do you see a role for industrial designers in the future of manufacturing?
10. Do you know what Industry 4.0 is? If yes: Please explain in your own words.

The first question (Q1) is based on the constant occurring miscommunication between industrial designers and manufacturing/non-designers. The results will give clarity if the perception of industrial design differs in different countries and regions. Q2 expands the first question by clarifying the self-perceived strengths of industrial designers, which will assist manufacturers and industry in understanding the services they provide, as well as their capabilities in product development. Knowing this is important due to the persistent

confusion of the industrial design profession seen within literature and within the focus group when linked to manufacturing. Q3 adds to Q2 and aims to find answers of who industrial designers prioritise in their practice. Q4's purpose is to validate if industrial designers worldwide share the same view towards manufacturers like the Australian focus group participants did. Q5 builds on the strengths of industrial designers and how manufacturers can benefit from innovation created through design. Since it is still unclear what is required for industrial design professionals to be a valuable part of I4.0; Q6/Q7 will elucidate this question without mentioning I4.0 directly. Q8 elaborates on the perspective of industrial designers and their view on self-implemented interventions in the future of their profession. Since there are large changes taking place in the manufacturing sector — with the concept and implementation of I4.0 — industrial designer's input is largely ignored. Thus, the question (Q9) participants raised in the focus group around whether or not manufacturers and industry value industrial designers as an integral part of their industry will be asked. Finally, considering the divisive nature of the term — I4.0 and the changes this paradigm will present to industrial designers — Q10's objective is to gain insight into how many industrial designers worldwide are un/aware of I4.0 and how understandings or definitions differ from designer to designer (or company to company). Targeting these questions to a bigger audience will validate and/or disprove the findings of this focus group study, and therefore give a solid base to find answers to the two research questions. Because the survey questions are both quantitative and qualitative in nature, they will provide a variety of useful information about the current state of industrial design and what changes have to be fulfilled to continue be a valuable asset for manufacturers and industry in the future.

6. Conclusion

The focus group that was conducted as part of our study served as the first step of a mixed methods study to determine the current state of the industrial design practice, as well as finding areas for improvement — especially in collaboration and communication with manufacturers. The main finding of this study was the poor, or even missing communication, between the manufacturing industry and industrial designers. However — most importantly — finding out about the confusion surrounding I4.0 in relation to industrial design presents an opportunity for further research, which aims to empower the importance — and adaptation — of industrial design in the next industrial revolution. Since new questions arose from this pilot study, it helped to design the subsequent online questionnaire survey which aims to further elaborate on new findings relevant to the research questions. The focus group method, as a pilot study, thus served to bridge the gap between the literature and the major questionnaire survey to continually advance the industrial design professional — keeping it relevant and on par with the advancements of manufacturing.

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Sharpening Critical Thinking in Problem Identification in Design and Technology Education

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Abstract: The current study aimed to identify and clarify students' critical thinking processes when understanding the design problem towards formulating design specifications within the problem identification stage when engaging in a design project at upper secondary level. Using design journals done by students in a Singapore secondary school, the study broke down students' critical thinking processes based on various elements of reasoning to assess the quality of reasoning. From this study, a set of general guidelines can be proposed for students to achieve good reasoning standards in order to understand the problem and to determine appropriate design specifications. To achieve good reasoning standards when breaking down the design problem, research in three basic related areas such as environment, users and products are necessary to form important background knowledge.

Keywords: pedsig; critical thinking; design education; design and technology

1. Introduction

In responding to the effects of globalization and the knowledge-based economy, a major curriculum review was undertaken in 1997 by the Ministry of Education, Singapore (MOE) to rethink its goal and direction for the future (Poon, Lam, Chan, Chng, Kwek & Tan, 2017). The knowledge-based economy has shifted the efficiency driven education into an ability driven education, where ability for life-long learning by its people is key to the sustainability and economic growth of Singapore (Goh & Gopinathan, 2008). The major curriculum review in 1997 led to the inception *Thinking School Learning Nation* (TSLN) in the same year (Poon et al., 2017). TSLN was considered as the pivotal policy shift toward 21 Century Competencies (21CC) education and the defining moment that aimed to systematically educate 21CC by concentrating resources on teachers, infrastructure and technology with the aim to prepare Singapore's students with the necessary knowledge and skills for the future (Poon et al., 2017).

The importance of critical thinking as part of the 21CC required of a student can be



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articulated with the policies and initiatives that came after the TSLN. To enhance the pedagogical change that set out in TSLN, the *Teach Less, Learn More* (TLLM) initiative was introduced in 2004 and subsequently launch in 2005. The TLLM set out to enhance the quality of education through reduction in syllabus content to encourage active learning and independent learning; and also, to enhance critical thinking and inquiry-based learning among students (Tan, Koh, Chan, Pamela & Hung, 2017; Koh, 2013). The revision in the *Desired Outcomes of Education* in 2009 further emphasized the importance of critically thinking in the four desired outcomes of the student (Tan et al., 2017).

Supporting the revised *Desired Outcomes of Education* in 2009 was the formalization of the *Framework for 21CC and Student Outcomes* in 2010 that represented one of the most significant developments in Singapore's efforts for 21CC education (Tan, 2013; Poon et al., 2017). Critical thinking and inventive thinking are part of the three broad areas of emerging 21CC, where they are recognised as vital to helping Singapore's young people strive in the 21st century. Since its formalization in 2010, 21CC framework has been infused into the academic curriculum (Tan et al., 2017). However, currently, few studies had been done to understand how critical thinking and creativity is being developed systematically through the implementation of pedagogy and practices in Design and Technology (D&T) in schools (Chia & Tan, 2007; Lim, Lim-Ratnam & Atencio, 2013; Loh, Kwek & Lee, 2015, 2017; Tan, 1996).

The current study is part of a research to enhance critical thinking of students studying D&T by first identifying and clarifying students' critical thinking processes in D&T projects using the Singapore context. In this study, the main focus is to identify and clarify students' critical thinking processes in understanding a chosen design problem that lead to the determination of design specifications within problem identification stage. The findings will contribute to the understanding of how critical thinking may be systematically developed through D&T and also contribute to the international practices in D&T education.

2. Critical Thinking

2.1 What is Critical Thinking?

Conceptualizing critical thinking may be divided by the generalist (domain-general) or the subject-specific (domain-specific) approach (Butler, 2017; Moore, 2004; Davis, 2006). The generalist approach conceptualises critical thinking as a set of skills that may be applied across subjects and disciplines (Moore, 2004), whereas, the subject-specific approach believes that critical thinking is closely tied to the subject or domain which it is applied. This is because, the set of critical thinking skills varies among the different domains or situations in which it is applied to (Moore, 2004).

While the definitions of critical thinking remain varied, they tend to have similarities with considerable overlaps (Halpern, 2014; Butler, 2017). Based on a study of literature review on critical thinking by Fischer & Spiker (2000), most definitions of critical thinking include reasoning/logic, judgement, metacognition, reflection, questioning and mental process.

Butler (2017) mentioned that most definitions of critical thinking involved the attempt to achieve a desired outcome by thinking rationally in a goal-oriented fashion. Other studies also seemed to have obtained a consensus among policy makers, employers and educators who agreed that critical thinking involves constructing a situation and supporting the reasonings that form a conclusion (Jones, Dougherty, Fantaske, & Hoffman, 1995; Jones et al.,1995). In a way, this “common consensus” on critical thinking definitions tend to tie critical thinking with reasoning.

One of the mainstream concepts of critical thinking was developed by Ennis (1991, 1993, 2018), where “critical thinking means reasonable reflective thinking that is focused on deciding what to believe or do” (Ennis, 1991, p.8). Taking the generalist approach in defining critical thinking, Ennis (1991) considered critical thinking as an important part of problem solving. To provide more clarity on the nature of critical thinking, Ennis (1991) explained the conceptualization of the critical thinking definition through the decision-making process. Decisions about belief or action that generally occur in problem solving should have some basis. This basis may consist of observations, information and/or some previously accepted propositions. A decision is made through the inferences of this basis. Thus, when making and checking decisions independently, an ideal critical thinker should exercise a group of critical thinking dispositions where any decision made should be justifiable and able to be articulated to others (Ennis, 1991, 2015). According to Ennis (2018), other well-known definitions such as the one by Scriven and Paul (1987), as well as definitions by Seigel (1988), Facione (1990), Fisher and Scriven (1997) and Kuhn (2015) are not significantly different from his or from each other.

Scriven and Paul (1987) described critical thinking as a disciplined process that actively and skilfully conceptualize, apply, analyse, synthesize, and/or evaluate information gathered from/or generated by observation, experience, reflection, reasoning or communication, to guide one’s belief and action. In other words, critical thinking is a self-directed, self-disciplined, self-monitored and self-correcting thinking process that involves analysing and evaluating thought processes with the intention of improving them (Paul & Elder, 2002, 2019). The conceptualization of the definition of critical thinking by Scriven and Paul (1987) and Paul and Elder (2002, 2019), rest on the basis that thinking can be analysed and evaluated by first taking thinking apart and then applying standards to those parts. Paul and Elder (2002) explained that whenever thinking occurs, reasoning occurs. This is based on the concept that thinking always occurs for a purpose within a point of view based on assumptions that lead to implications and consequences (Paul & Elder, 2002, 2019). Concepts, idea and theories are used to interpret data, facts and experiences in order to answer questions, solve problems and resolve issues (Paul & Elder, 2002, 2019). As such, all thinking processes involve generating purposes, raising questions, using information, utilizing concepts, making inferences, making assumptions, generating implications and embodying a point of view (Paul & Elder, 2002, 2019). These eight areas form the eight basic structures of thinking, which Paul and Elder (2002, 2019) also called the elements of reasoning that are present in reasoning across subjects and cultures. By deconstructing thinking into the

elements of reasoning, each element of reasoning may then be assessed.

2.2 Exercising and Assessing Critical Thinking

To further clarify critical thinking, this section reviewed the type of skills and abilities a person may display when critical thinking is exercised. Ennis (1991, 2018) conceptualized a set of general critical thinking dispositions and abilities of an ideal critical thinker. Expanded from the list published in 1991, the latest list included 12 dispositions and 18 abilities (Ennis, 1991, 2018). Mainly using examples from his experience as a juror, Ennis (1991) exemplified and elaborated on each of the dispositions and abilities to explain his conception of an ideal critical thinker. Similarly, Halpern (2014) provided a list of 15 generic skills that a critical thinker will possess. In addition to acquiring skills, it is necessary to develop the attitude or disposition of a critical thinker. Thus, Halpern (2014) included 8 attitudes or dispositions that a critical thinker should exhibit, and just to name a few, willingness to plan, flexibility, and persistence. Among the skills and dispositions suggested by Ennis (2018) and Halpern (2014), some of the overlapping skills and dispositions are the use of existing knowledge, metacognition, understanding and using math, graphs and diagrams for communication, judging credibility of information, making justifiable decisions, open-mindedness, taking a position when there is sufficient evidence and an ability to employ critical thinking skills and dispositions.

In order to exercise critical thinking, possessing the skills may not necessarily mean that critical thinking has been achieved. For example, the ability to analyse evidence and make justified decisions does not mean that a good decision is made based on the quality analysis of the information at hand. In determining if a person has exercised critical thinking, Bailin (1999) emphasized that it is the quality of thinking, not the process of thinking, that differentiate critical thinking from 'uncritical thinking'. As such, not all thinking activities that aimed at decision making can be considered as critical thinking and the quality of thinking has to fulfil a certain level of acceptable standard (Bailin, 1999). In assessing critical thinking skills, many such assessments come in the form of a critical thinking test.

According to Ennis (1993), no subject-specific tests were found but a list of general-oriented-based tests could be consolidated during a study on critical thinking assessment. Almost all the tests were multiple choice test which were good for efficiency and cost, but not comprehensive enough in effective testing for many significant aspects of critical thinking such as being open-mindedness and drawing warranted conclusions cautiously (Ennis, 1993). Ennis (1993) further suggested that open-ended critical thinking tests were necessary for comprehensive assessment, unless appropriate multiple-choice tests were developed. In a recent study, Butler (2017) provided a brief review on the reliability and validity of critical thinking assessments that measure critical thinking skills and those that measure critical thinking dispositions. These tests are used mainly to assess student learning outcomes so as to provide formative feedback to improve instructional methods. In fact, much of these tests may also be seen as an advocate for teaching of critical thinking explicitly rather than implicitly.

While critical thinking skills and dispositions can be assessed using test-based assessment, Paul and Elder (2002, 2019) provided an alternative model for assessing the quality of critical thinking. Paul and Elder (2002, 2019) suggested that a well-cultivated critical thinker should exhibit the following characteristics:

- Raises vital questions and problems, formulating them clearly and precisely
- Gathers and assesses relevant information and effectively interprets it
- Comes to well-reasoned conclusions and solutions, testing them against relevant criteria and standards,
- Thinks open-mindedly within alternative systems of thought, recognizing and assessing as need be, their assumptions, implications, and practical consequences
- Communicates effectively with others in figuring out solutions to complex problems

The formation of these characteristics is based on a conceptual framework where the basic structures of thinking, also called elements of reasoning, can be assessed using a set of standards (also called intellectual standards). Intellectual standards can be conceptualized as standards necessary for making sound judgements and rational understanding (Elder & Paul, 2013b; Paul & Elder, 2008). The intellectual standards are formed based on the argument that all modern natural languages (such as English, German, Japanese, etc.) provide their users with a wide variety of words that, when used appropriately, serve as plausible guides in the assessment of reasoning (Elder & Paul, 2013a; Paul & Elder, 2008, 2014). Words such as clarity, accuracy, relevant, significant, logical and so forth are identified as intellectual standard words (Paul & Elder, 2008, 2013, 2014). Though the focus on determining intellectual standard words are based on the availability in English language, it is hypothesized that similar web of intellectual standard words exist in every natural language, though perhaps with differing nuances (Elder & Paul, 2013a; Paul & Elder, 2008, 2014). Paul and Elder (2002, 2019) suggested that there are at least 9 intellectual standards (also called intellectual standard words), recently expanded to 10. The intellectual standards are *clarity, accuracy, precision, relevance, depth, breadth, logicalness, significance* and *sufficiency* (Paul & Elder, 2002, 2019). Using questions to deconstruct reasoning, a framework of how intellectual standards can be applied to these questions to assess quality of critical thinking has been further explained by Paul & Elder (2002, 2008, 2019).

2.3 Adopting a working definition and a mode of assessing quality critical thinking

The different ways of defining critical thinking seems to be just different ways of cutting the same pie. The main concept of critical thinking process revolved around the process of reasoning. With this assumption, Paul and Elder provided a clear structure to unpack reasoning into parts. Without the need for a standardized critical thinking assessment test, Paul and Elder had also created a model to allow the quality of reasoning to be assessed using the intellectual standards, through questioning techniques. Furthermore, this model is flexible in application across different subject areas and provides a great potential for the

application in this study. With above considerations, the current study adopts the definitions of critical thinking conceptualized by Paul and Elder (2002, 2008, 2019) and at the same time, attempts to apply the concept of elements of reasoning and intellectual standards to achieve the objectives of this study.

3. Research Question and Methodology

3.1 Research Question

This study sought to answer the following main question.

- After choosing a problem to solve, how do students exercise critical thinking to clarify the problem and determine the necessary design specifications?

3.2 Research Approach and Method

The current study employed a qualitative research methodology to gain insights on students' application of critical thinking to clarify the problem and determine necessary design specifications. The method used for the current study was the collective case study, as described by Goddard (2010). The current study will be conducted within a single site, which is a government secondary school in Singapore. The considerations for choosing the site are shown in Table 1. Singa Secondary School (the school name used is a pseudonym), was identified as a potential site for the study. The selection of Singa Secondary School was based on the following reasons in Table 2.

Table 1 Criteria for choosing a study site.

Criteria for Selection of Study Site
1. School should be recognised to implement a progressive D&T programme
2. D&T teachers are active in professional sharing in the Singapore D&T fraternity.
3. Profile of students studying D&T consists of a mix of academic abilities

Table 2 Reason for choosing the current study site.

Reasons to select Singa Secondary School as Study Site
1. As a pilot school for implementing Framework for 21CC in 2010, the school will have more experience with the review and implementation of pedagogy and practices to develop critical thinking.
2. Widely recognised by the D&T fraternity in Singapore, for the last 15-17 years, for innovation in pedagogy and teaching practices, and the ability to achieve excellent student outcomes. D&T teachers from different parts of Singapore often seek opportunities to visit the school to learn from the teachers.

3.3 Objects of Study

The objects, or cases, for this study are the design journals done by upper secondary students in Design Project A for a D&T Express course. Design Project A is a major design project that all upper secondary school students in the Express course (between the age of 15 and 16) have to go through in Singa Secondary School. The main purpose of Design

Project A is to allow students to exercise their knowledge and skills learned in D&T up till the point of Design Project A to engage in a full design process that starts with a given theme and ends with a proposed working prototype. In this project, students take main control of the design process as teachers supervise. The given theme for Design Project A differs yearly, but the tasks required, and assessment criteria are consistent.

In Design Project A, students are required to record any forms of explorations, research, ideation, experimentation and evaluation processes related to problem identification, ideation, idea development and prototyping into the design journals. Thus, the used of design journals as objects of study is based on the assumptions that design journals are a detailed collection of students' thinking and decision-making processes during the design process. In the selection of design journals for study, the following considerations were made. (Refer to Table 3)

Table 3 Considerations for design journals selections as study cases.

Considerations for Selecting Design Journals as Cases	
1.	The design journals should be done by students who were conscientious in completing their work. This is to ensure that any deficiency in their performance in the design journals are due to their abilities rather than the lack of effort.
2.	The design journals should be done by students who had gone through similar D&T curriculum before attempting Design Project A. This is to reduce the disparity of student performance due to the difference in terms of content knowledge and skills.
3.	The design journals should be representative samples that reflect the quality of work done by majority of the D&T students in Design Project A. The design journals selected for study should not be the outliers in terms of performance.

In a pilot school for 21CC, the D&T department had reviewed the curriculum for the lower and upper secondary D&T Express course. Started in 2012, critical thinking is taught more explicitly in lower secondary D&T. Thus, upper secondary students engaging in the Design Project A from 2014 onward would have gone through a similar D&T programme starting from lower to upper secondary. Using available archives, 15 design journals completed between 2014 and 2016, and supervised by two teachers were selected as study samples. (Refer to Table 4)

Table 4 The number of journals used for study between 2014 and 2016.

Year:	No. of Archived Journals Used	Supervised by:
2014	8	Teacher A
2015	1	Teacher A
2016	6	Teacher B

Based on class deployment, the academic profile of students supervised by the two teachers were similar. Throughout the year, it is a practice in the school that all D&T teachers will often share and discuss about teaching and learning, and students' progress for all

levels (secondary 1 to 4) of D&T learning. These forms of meeting provide professional development for all D&T teachers and also reach consensus on what to expect for student outcomes for each level. Though the selected design journals for this study were supervised by two D&T teachers, the disparity in the quality of supervision, teaching and student academic abilities related to this study were considered to be minimum.

3.4 Research Design

The primary set of data was collected via students' documentations in the design journals. The scope of data collection covers students' documentation during the process of problem clarification, problem re-define and determining design specifications. Students' documentation will include written and printed text, sketches and photos. The general processes undertaken by students during the processes in focus can be described as follow. After deciding on a problem to solve, students would conduct research to clarify the problem with the aim of having a thorough understanding of the problem. Sometimes, students might be required to re-define the problem after they gained deeper understanding of problem. During the research process, students will identify potential design considerations for the solution. Based on the design considerations surfaced, students would then determine the design specifications necessary for the design solution.

To design a method to interpret the students' documentation, firstly, the author consulted the teachers and collected the expectations for students to achieve in the processes within the scope of study (refer to Table 5 and 6). These expectations were in line with the assessment rubrics for Design Project A. Though the critical thinking model by Paul and Elder (2008) can be applied to all reasonings across different fields, the importance of some intellectual standards may be different in different fields. Thus, it is necessary to contextualize the intellectual standards within the field and then to articulate the intellectual standards that are most important for reasoning (Paul & Elder, 2008). Table 5 and 6 provided the context for the author to contextualize the intellectual standards relevant to the current study.

Based on Table 5 and 6, questions were used to deconstruct reasoning for clarifying the problem, re-defining problem and determining the design specifications and then after, intellectual standards were applied to answer these questions (Paul & Elder, 2008). By answering the questions, the intellectual standards essential to good reasoning related to the processes in the current study can be articulated (refer to Table 7 and 8). Using Table 7, and 8, the author was able to observe students' critical thinking processes by interpreting the documentations in the design journals. To increase validity of the interpretations, any queries related to the documentations were clarified with teachers before further interpretations. In addition, all observations were provided to the D&T teachers for clarification so that any misinterpretations could be corrected.

3.5 Research Implementation

During the implementation of the study, to gain a holistic view, the documentations in each design journal were first studied to understand the processes embarked by students for problem clarification, problem re-define (if any) and determining design specifications. Then after, using Table 7 and 8 to interpret the documentations, observations of each student's good reasonings and weak reasonings with respect to each of the elements of reasoning were recorded. After all the 15 design journals, were interpreted and observations recorded, common and different patterns in students' reasoning for each element of reasoning could be identified and clarified.

Table 5 *Teachers' expectations for students during the phase of understanding the problem and re-defining the problem.*

Teachers' expectations of student in understanding the chosen problem and re-defining problem when necessary
Student needs to come up with a research plan on what they need to find out in order to understand the chosen problem.
Student needs to clarify the problem through research in related areas such as environment, user, product and others when any additional information is required.
Student needs to explain the objectives for each research to show the relevance or importance to understanding the issues in the problem.
Student needs to conduct at least one relevant site visit to observe the issues in the problem. If the sites are not accessible, student needs to conduct research on the sites and issues based on internet, books, newspaper, etc.
Student needs to observe user(s)-environment and/or user(s)-product interaction and behaviour, take photo, note down details and draw connections of how and why problem arise.
Student may interact with relevant products as a form of immersion in order to obtain insights on possible problems.
Student needs to take photos of the problem issue on the site or to find reliable photos on the internet, books, newspapers to justify the existence of the problem.
Student needs to conduct questionnaire surveys and/or interviews with users or relevant stakeholders to understand the users and problem better.
Student needs to prepare the questions for the questionnaire surveys and interviews with rationale stated for each question.
Student needs to analyse results from the questionnaire surveys and/or interviews to identify trends or varied responses, justified by logical and valid reasons.
If the relevant users are not accessible, student needs to research about the users and issues based on the internet, forums, books, newspaper, etc.
Student needs to research existing products, any form of make-shift/homemade solutions that can solve the problem or possibly solve the problem.
Student needs to analyse the existing products, any form of make-shift/homemade solutions to find out the parts required to make the product and the purpose of each part. This will help them understand what they need to consider for their solutions.
Student needs to draw relevant insights from the analysis of the research with respect to the chosen problem and the users involved.
Student needs to research on relevant information to achieve a deeper understand of related concept(s).
Student needs to draw relevant conclusions based on the findings in their research.
If student's research findings showed that the problem that they have stated initially is not accurate, they have to re-define the problem and brief.
If student realised after/during the research that the scope of the problem is too wide, they can narrow the scope of the problem and re-define the problem and brief.
After re-defining the problem and brief, the student needs to assess the relevance of the initial research and determine if they need to do new research to understand the problem better.
Student needs to find out new information that they need with objectives of research stated and provide conclusions at the end of the research.

Table 6 *Teachers' expectations for students during the phase in determining design specifications.*

Teachers' expectations of student in determining design specifications
Student needs to identify important and relevant design specifications with respect to the chosen problem based on the research done.
Student needs to write the design specifications clearly and logically.
Student needs to provide relevant, justified and logical reasons for the design specifications that they have stated.

Table 7 Deconstructing reasoning and articulating intellectual standards for understanding the chosen problem and re-defining the problem.

Elements of Reasoning during Understanding the Chosen Problem and Re-defining Problem	Questions to deconstruct reasoning	Intellectual Standards for good reasoning in Understanding the Chosen Problem and Re-defining Problem
Purpose	<ul style="list-style-type: none"> ▪ Is the student clear about the purpose of research to understand the chosen problem? 	<ul style="list-style-type: none"> ▪ The objectives and significance of each research conducted are justified and clearly articulated. ▪ Display clarity and consistency in purpose by identifying and conducting relevant research in areas that provide better understanding to the problem. ▪ The objectives and significance of the questions used in the questionnaire survey are justified and clearly articulated. ▪ The need for re-defining the problem is justified and clearly articulated.
Questions	<ul style="list-style-type: none"> ▪ Is the student able to use relevant questions when planning research? ▪ Is the student able to use relevant questions to clarify the problem? ▪ Is the student able to breakdown the main question into useful sub-questions to clarify the problem? 	<ul style="list-style-type: none"> ▪ Formulate relevant and clear questions and apply in planning of research. ▪ Formulate relevant and clear questions and apply in the analysis of existing products related to the problem. ▪ Formulate relevant and clear questions and apply in understanding the problems that users faced through questionnaire surveys and interviews. ▪ Ability to breakdown the main question into sub-questions to achieve a more precise clarification of the main question. ▪ Sub-questions are used to break down the problem to achieve clarity and precision in understanding the problem.
Point of View	<ul style="list-style-type: none"> ▪ From what point of view did student look at the problem? 	<ul style="list-style-type: none"> ▪ Understanding of the problem based on other points of view to achieve fairness and clarity.
Information	<ul style="list-style-type: none"> ▪ To what extend is student's reasoning about the problem supported by clear, relevant, accurate and adequate information? ▪ Did the student manage to present or state the evidence clearly and fairly in the research? 	<ul style="list-style-type: none"> ▪ Source of information in understanding the problem is reliable and accurate. ▪ Multiple sources of information are fairly gathered to achieve an accurate claim. ▪ Research conclusions are supported with reliable, adequate and accurate evidence. ▪ Findings from research are clearly and fairly reported without distortion.
Concepts and Ideas	<ul style="list-style-type: none"> ▪ Are the key ideas and concepts that guide students' reasoning clear, accurate or deep? 	<ul style="list-style-type: none"> ▪ The concepts and keys ideas used by student to clarify the problem are clearly articulated and displayed depth of thinking.
Assumptions	<ul style="list-style-type: none"> ▪ Are the student's assumptions justifiable and reasonable based on evidence or past experience? ▪ Is the student clear about the assumptions that he/she is making? 	<ul style="list-style-type: none"> ▪ Research conclusions are based on the student's assumptions which are justified and clear.
Implications and Consequences	<ul style="list-style-type: none"> ▪ What implications and consequences follow student's reasoning? ▪ Is the student able to clearly and precisely articulate the possible implications and consequences? 	<ul style="list-style-type: none"> ▪ Inferences on research findings based on the evidence clearly and precisely articulated the possible implications and consequences. ▪ Able to articulate clear and logical implications on the need to re-define the problem when necessary.
Inference and Interpretations	<ul style="list-style-type: none"> ▪ Is the student able to make inferences and interpretations that are justified, reasonable, clear and logical? 	<ul style="list-style-type: none"> ▪ Inferences and interpretations of the problem are consistent with evidence from the research findings. The inferences and interpretations are logically, reasonably and clearly articulated. ▪ Decisions on the necessity of possible considerations for design solutions (design considerations) are logically, reasonably and clearly explained.

Table 8 Deconstructing reasoning and articulating intellectual standards for determining design specifications.

Elements of Reasoning during Design Specifications	Questions to deconstruct reasoning	Intellectual Standards for good reasoning in Design Specifications
Purpose	<ul style="list-style-type: none"> Is the student able to distinguish significant and relevant design specifications that are necessary for the design solution to solve the problem? 	<ul style="list-style-type: none"> Design considerations identified in research are examined and selected as design specifications based on the significance and relevance to solving the problem.
Point of View	<ul style="list-style-type: none"> Did student seek different points of view when determining the design specifications? 	<ul style="list-style-type: none"> Design specifications that are adopted are justified and fair (unbiased) based on points of view from related target users.
Concepts and Ideas	<ul style="list-style-type: none"> What are the main concepts and ideas used in articulating the design specifications? 	<ul style="list-style-type: none"> Relevant concepts and ideas used to determine the design specifications are clearly articulated.
Implications and Consequences	<ul style="list-style-type: none"> What implications and consequences follow student's reasoning? Is the student able to clearly and precisely articulate the possible implications and consequences? 	<ul style="list-style-type: none"> Significant potential implications and consequences of adopting the design specifications are clearly articulated based on earlier research.
Inference and Interpretations	<ul style="list-style-type: none"> Is the student able to make inferences that are justified, reasonable, clear and logical? 	<ul style="list-style-type: none"> The decision for adopting each design specification is clearly and logically articulated and justified based on the earlier research.

4. Findings: Critical Thinking in Understanding the Chosen Design Problem

In the process to understand the chosen problem, students conducted research to clarify the problem. To clearly understand the problem, students engaged into different areas of research which can be categorised into, 1) environment related, 2) users related, 3) product related, and/or 4) any other additional information. In each research, after achieving a conclusion from the findings, students would identify a number of possible design considerations and constraints for the design solutions.

Within an area of research, the common modes of inquiry can be presented as follow. For 11 students who conducted environment related research, the main mode of inquiry was making observations about the environment. For 13 students who conducted users related research, the modes of inquiry were 1) questionnaire survey [conducted by 6 students], 2) interviews [conducted by 2 students], 3) observations on user behaviour at the site [conducted by 9 students], 4) internet search [conducted by 5 students] and 5) immersion into actual situation [conducted by 2 students]. All students conducted products related research and product analysis was mainly done.

Based on the 15 design journals, the critical thinking process exercised by students to clarify the problem through research can be broken down by elements of reasoning. By applying the intellectual standards articulated in Table 7, the quality of students' critical thinking could be assessed through the documentations. In this section, Table 9 consolidates the observations of common and different patterns of good reasoning exercised by students. When necessary, the observations may be accompanied by an example presented via a figure indicated at the end of the respective observations.

Table 9 Observations of good reasoning during research to clarify the chosen problem

Elements of Reasoning during Understanding the Chosen Problem	<p style="text-align: center;">Observations of Good Reasoning in Understanding the Chosen Problem^{1,2}</p> <p>¹The number in the bracket [] represents number of design journals with similar observation ² When necessary to present the observation clearer, a picture of the journal may also be provided as a fig.</p>
Purpose	<ul style="list-style-type: none"> ▪ All students started the process by making a research plan to identify relevant research areas clarify the problem. In most cases, the methods for investigation were also stated and were clearly and logically articulated. [15] (Refer to Figure 1) ▪ When conducting their research, students stated the research objectives with clarity and relevance to the problem. [15] (Refer to Figure 2) ▪ Students stated the rationales to the questions used in questionnaire surveys and interviews clearly, logically, and with relevance to understand the chosen problem. [8] (Refer to Figure :) ▪ During the process of research, some students surfaced evidence which suggested some inaccuracy in the initial hypothesis of the problems, such as the related users, the leading caus of the problem, scope of the problem, etc. Students stated clearly the purpose of their problem to be re-defined and justified by their research findings. [5] (Refer to Figure 4)
Questions	<ul style="list-style-type: none"> ▪ Most students used relevant questions as a guide to identify relevant research areas and formulate a research plan. [11] (Refer to Figure 1) ▪ Only a handful of students used relevant sub-questions to breakdown the main questions in th research plan to clarify the problem with depth and precision. [3] (Refer to Figure 1) ▪ Students who conducted questionnaire surveys used relevant questions to gain clear and accurate understandings of the problem faced by users or related stakeholders. [6] (Refer to Figure 3) ▪ A few students conducted interviews and used relevant questions to have a clear and deeper understanding on the problem faced by target users or related stakeholders. [2] ▪ One student used relevant questions as a guide to analyse more clearly and precisely on existing products or “make-shift” solutions used by target users that may solve the problem. [1]
Point of View	<ul style="list-style-type: none"> ▪ A handful of students sought teacher’s opinions to obtain different relevant viewpoints when finalising the research plans. [2] (Figure 1) ▪ A handful of students sought teacher’s opinions to obtain broader viewpoints when formulating questions for questionnaire surveys. Students were also able to clearly articulate viewpoints from teachers. [2] ▪ Almost half of the students used questionnaire surveys to sought other points of views in order obtain a clear and fair understanding of the problem faced by users and/or relevant stakeholders. [7] ▪ A handful of students sought other points of views through interviews to obtain a clear, fair and deeper understanding of the problem faced by users and/or relevant stakeholders. [2] ▪ A handful of students seek broad viewpoints from teachers and/or stakeholders when making decisions in re-defining the problems. [2]
Information	<ul style="list-style-type: none"> ▪ About half of the students went to at least one relevant site to collected relevant information in order to clarify the problem. While two of these students collected information from two or more relevant sites to ensure fair and adequate information collected. (7) (Refer to Figure 5) ▪ Most students took relevant photos of the sites related to the problem and/or users’ behaviour with respect to the problem as evidence for analysis. For students who made observations related to uses, they may only focus on users’ behaviour without considering the environmental influence on the users. [11] (Refer to Figure 2) ▪ Most students noted clearly the observations of how users and related stakeholders interact with the environment and the products related to the problem. [11] (Refer to Figure 2) ▪ Students sourced for relevant pictures, videos and articles from the internet to understand the users and environment better, especially for students who are not able to visit the site and talk the target users. [9] ▪ Students conducted questionnaires surveys with more than one relevant user and/or related stakeholders to ensure adequate and fair information collected. [7] (Refer to Figure 6) ▪ A handful of students conducted interviews with more than one relevant user and/or related stakeholders to ensure adequate and fair information collected. [2] (Refer to Figure 2) ▪ One student went to experience the problems faced by users by using the products related (seeking relevance) to the problem to surface potential issues. [1] (Refer to Figure 7) ▪ Student played the role of a stakeholder to obtain accurate insights on possible problems. [1] (Refer to Figure 8) ▪ Students identified relevant products for product analysis. [15] (Refer to Figure 9) ▪ A few students collected information from relevant product based on product descriptions to analyse accurately. [3] (Refer to Figure 9) ▪ A few students collected information on relevant existing “make-shift” solutions that users use to solve the problem. [3] (Refer to Figure 10) ▪ Quite a number of students collected relevant information from the internet and research journals to gain in depth understanding of the concepts related to the problem. [6] ▪ All students generally presented the research information fairly (without distortion), clearly and logically. [15] (Refer to Figure 2) ▪ To obtain clarity and accuracy on different aspects of the problem, most students conducted more than two different areas of research such as environment related, user related, product related, or any others to ensure fair and adequate information collected. [14]

Concepts and Ideas	<ul style="list-style-type: none"> Several students were able to use concepts and key ideas to explain the issues inherent in the problem clearly and accurately. [6] (Refer to Figure 11) One student thought deeply about the concepts on hygiene as she was able to explain clearly the concepts in relationship to the hygiene issues that signalled the need to re-define the problem. [1] (Refer to Figure 4)
Assumptions	<ul style="list-style-type: none"> Students generally made reasonable assumptions in analysis of information collected as they can explain clearly and logically on the implications presented by the information. [15] (Refer to Figure 10) Students generally made reasonable assumptions about the problem as they can present clear and logical claims about the problem based on the research. [14] (Refer to Figure 4)
Implications and Consequences	<ul style="list-style-type: none"> Several students articulated clearly on the implications of the questions formulated for the questionnaire surveys and interviews, and how these questions may enhance understanding on the related users. [6] (Refer to Figure 3) Most students articulated the implications and consequences clearly and logically when concluding certain parts of their research based on the interpretations from research findings. [11] (Refer to Figure 11) After achieving a clear, accurate and deep understanding of the problem based on research, students articulated clear and logical implications that lead them to re-define the problem. [5] (Refer to Figure 4)
Inferences	<ul style="list-style-type: none"> Students articulated justified inferences clearly and accurately based on information collected from site visits. [7] (Refer to Figure 2) Students interpreted the data from the survey and interview results logically and reasonably. [8] (Refer to Figure 6) Inferring from questionnaire survey findings, students identified relevant design considerations and articulated the reasons clearly and logically. [6] (Refer to Figure 6) Most students made inferences from the photos and information collected related to users logically and reasonably. [12] Inferring from observation surveys and interviews related to users and stakeholders, students identified the design considerations and articulated the reasons clearly and logically. [8] Students articulated their inferences of relevant products clearly, logically and reasonably based on relevant pictures and information. [15] (Refer to Figure 9) From the product analysis, students identified relevant design considerations and articulated the reasons clearly and logically. [9] (Refer to Figure 9) Most students made inferences from information gained from the different areas of research to triangulate accurate, clear and justifiable understanding of problem and derived relevant design considerations. [14] Student made justified inference based on evidence from the research that resulted in the need to re-define the problem. [5] (Refer to Figure 4)

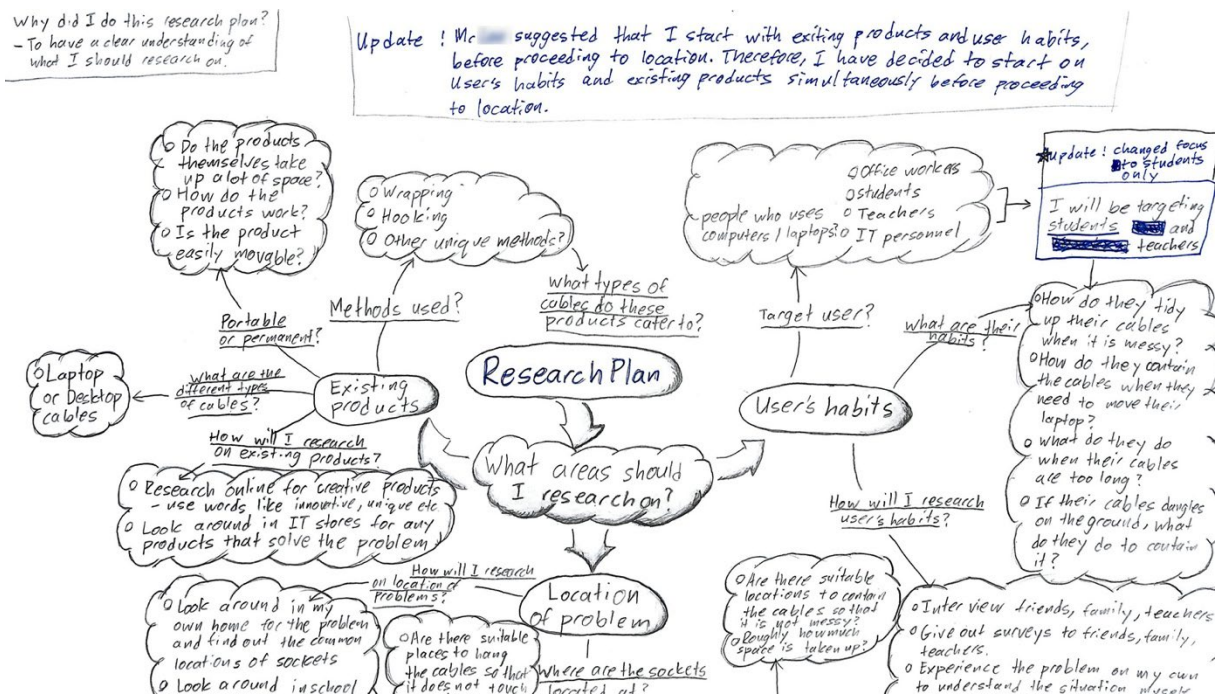


Figure 1 Example of a research plan.

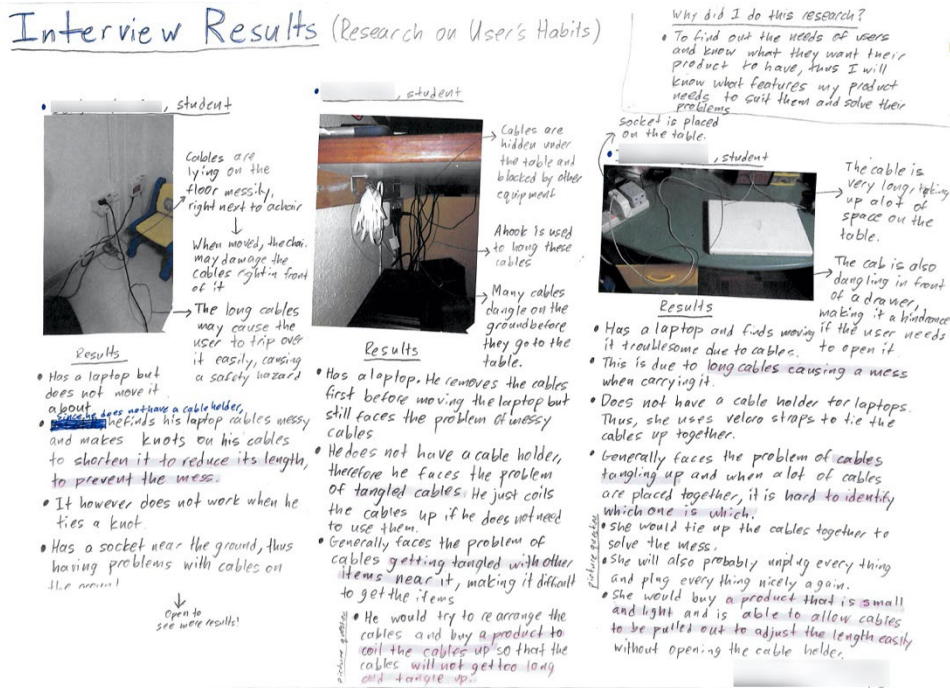


Figure 2 An example of student who showed a clear purpose for the research conducted.

Change of focus...

After doing some research on the growth of bacteria and how it lands on the toothbrush. I realised that in order to prevent bacteria from doing so, it would have to be fully enclosed or it would need sterilisation. This would impose further problems if the tooth brush had to be fully enclosed as it prevents it from being able to dry out well and may cause water clogging in the toothbrush holder itself. Thus this can also lead to the growth of mould.

I then decided to shift my focus mainly on how to keep the toothbrush dry at all times and at the same time to ensure that the toothbrush is able to dry out well when it is kept in the toothbrush holder after use so as to prevent the growth of mould that would cause the toothbrush to be very unhygienic to use.

New Chosen Problem Situation

After using their toothbrush, users would store them in a toothbrush holder or in their mugs for it to air-dry. However, some toothbrush holders, especially those with lids would prevent the moisture from the toothbrush to dry out easily due to the lack of ventilation. This would result in the collection of bacteria and thus increases the chances of mould growth. Therefore making the toothbrush very unhygienic for users to use.

NPKs Design Brief

Figure 3 An example of student providing the rationale for each question used for surveys.

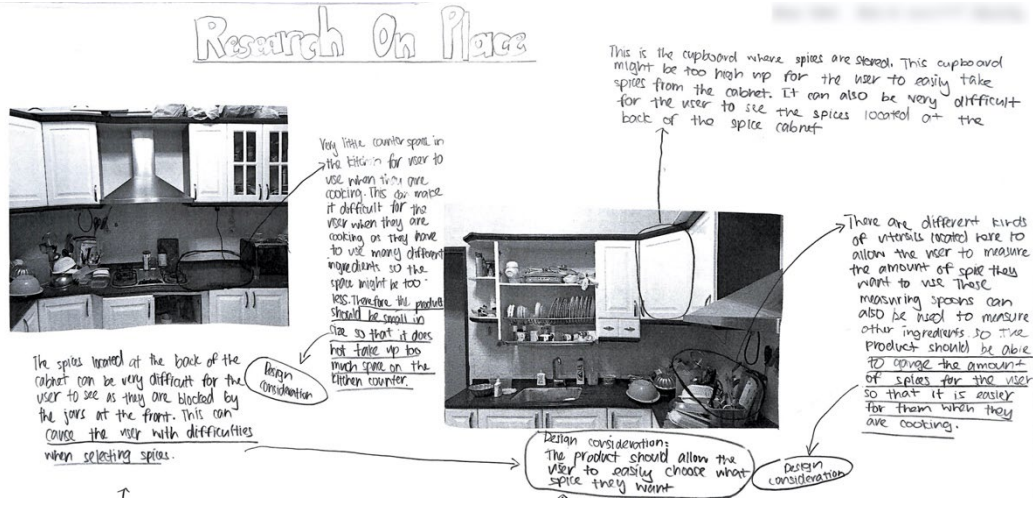


Figure 4 An example student who re-defined the design problem and re-stated the design brief.

Design and Technology Coursework Survey

Hi! My name is _____ and I'm here to conduct a survey on cutlery hygiene. *11/21*

1(i). Do you wash your hands before taking cutlery from a cutlery holder?
 Yes / No

(ii). Why do you/do you not wash your hands?
 Because I value hygiene alot.

2. When taking cutlery from a cutlery holder, do you accidentally touch the other cutlery that you don't need?
 Yes / No

3. Do you think it is hygienic for others to be touching your cutlery? Why?
 Yes / No
 I have no idea whether they have washed their hands beforehand.

4. If faced with this problem, which of these do you think is the best way to overcome it?
 (Tick)
 Clean your cutlery with tissue paper.

ANALYSIS

WHAT we can infer

1(i) Only half the interviewed wash their hands before taking cutlery.
 → Therefore, other half do not wash their hands before taking cutlery and these half might touch other's cutlery accidentally with their hands which might contain germs.
 → Out of these half, some might be sick and become EVEN lazier to wash their hands before taking their cutlery. This can cause diseases to be spread.

(ii) Product made must NOT BE
 → Troublesome to use
 → Inconvenient for users
 → Difficult to use

DESIGN CONSIDERATION: Product made must be easy to use for all ranges of user groups.


(2) Through the results, I can find out that a huge majority of people touch the cutlery that they don't need.
 → This confirms that the problem is real and majority of people do cause these problems.
 DESIGN CONSIDERATION: Product made should only allow users to touch their own cutlery.


(3) This shows that all of the interviewed do NOT find others touching their cutlery hygienic. Thus, everyone does not want others to touch their cutlery, and shows that the problem situation is real and faced by many.
 ∴ I can infer and find out that users are concerned about their


Figure 5 An example of student who did site visits to collect information.

Role Playing as a student (Research on user's habits)
 o What problems do I face whilst moving my laptop at home?

Why did I do this research?
 - To personally find out what problems my target user faces when moving their laptop.
 - Thus I know what features my product will require to tackle these problems.

1) Turning on of laptop

 - No problems yet

2) Placing mouse onto the keyboard

 - The mouse cable may get very messy here if the cable is not tied up.
 - Even if the cable may be tied up, the part of the cable which is not tied may get tangled, probably causing a mess.

3) Taking out charging cable

 - The charging cable is tangled up with other cables. It is very troublesome to untangle the cables as the cable head and center of the cable is big in size.


4) Rearranged cable


Figure 6 An example of a student who conducted questionnaire survey, followed by interpreting data and listing possible design considerations.



Figure 7 An example of a student playing the role of a target user.

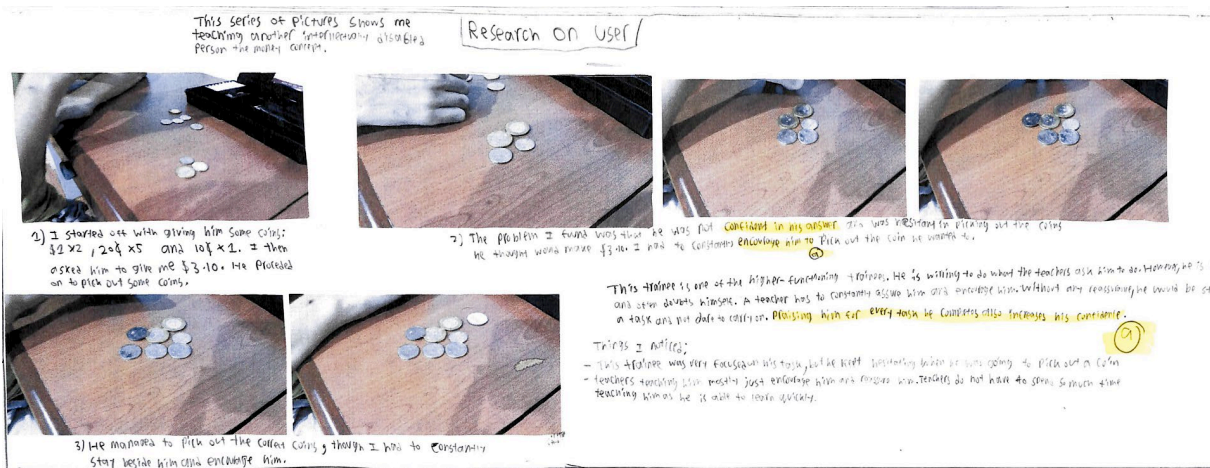


Figure 8 An example of a student who immersed into experiencing teaching a student with special needs to find out the problems faced by teachers.

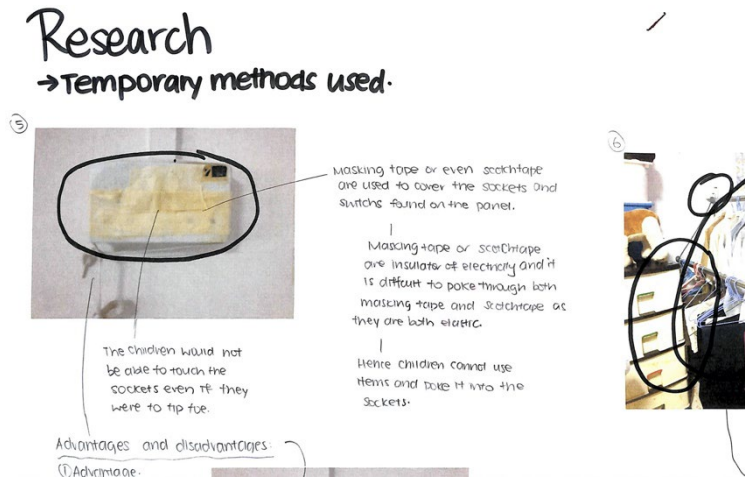


Figure 9 An example of a student's research on existing product.

What materials are porous?

Porous means the material contains pores (small or tiny holes) while non-porous means the material does not contain pores. If the material will pass liquid or gas, it is porous.

Examples of porous materials include: dry wall, wood, concrete, gunite, rubber, some plastic.

Examples of nonporous materials include: hard fired brick, some ceramic tiles, some types of marble, granite, smooth concrete that has been sealed, some types of masonry finishes, such as epoxy coatings, glass, granite, slate, polyethylene, Athermic windshields.

The handle of a toothbrush is usually made of rubber so as to provide comfort and better grip for the user.

However, rubber is a porous material hence it is able to absorb and contain water in it. These damp conditions would thus cause mold to grow on it.



Figure 10 An example of a student collecting information on relevant "make-shift" solutions.

Conclusion

Mold is able to grow at room temperatures, provided there is moisture. The material that the mold grows on also affects the growth of the mold. The more porous the material is, it is more likely for mold to grow on it.

As the handle of the toothbrush and the back of the bristles are usually layered with rubber, mold would more likely grow there.

Figure 11 Example of a student who used the concept of the growth of mold with respect to material.

Presenting as Case Example A, it may be useful to present in more detail how Student K conducted different modes of inquiry on related stakeholders and target users. Student K wanted to design a product to encourage intellectual disabled students to learn independently. He conducted a simple questionnaire survey with 13 teachers in a special needs school to find out if students can complete learning tasks on their own and the

motivation strategies teachers used in class. He also conducted an interview survey with 9 students with special needs to find out if they were able to complete their learning tasks in daily learning and if not, what were the reasons. Student K then had the opportunity to teach 3 students with special needs using the strategies that he gathered from the questionnaire and interview surveys. Based on the teaching experience, Student K was able to verify the strategies used by teachers and understand the issues presented by the 3 students (refer to Figure 8). Finally, Student K also conducted literature reviews of relevant journal articles on intellectual disabilities to gain more understanding based on expert views. In this example, the combination of different modes of inquiry provided Student K with accuracy and breadth to gain clarity and a fair understanding of his users to derive the possible design considerations.

Using Table 7, areas of weak reasonings displayed by students can also be observed based on the documentations in the design journals and can be presented in Table 10. In general, most design journals did contain a couple of weak reasonings among the good reasonings observed while clarifying the problem. Thus, the number of design journals associate with weak reasoning are not indicated in Table 10. But instead, the examples of weak reasoning in Table 10 are elaborated in detail to provide a deeper insight into some of the reasoning issues. More importantly, the observations of weak reasoning will serve as important insights to inform teachers that even though students may be able to exercise good reasoning skills in general, there may be instances where their reasoning are not up to the standards. As such, it will be useful for teachers to be aware of such instances and provide interventions to redirect students to achieve quality critical thinking.

Table 10 Observations of weak reasoning during research to clarify the chosen problem.

Elements of Reasoning during Understanding the Chosen Problem	Observations of Weak Reasoning in Understanding the Chosen Problem
Purpose	<ul style="list-style-type: none"> ▪ There were some instances where students reasoned without a clear purpose and forming conclusion based on inaccurate and insufficient data and information. For example, Student O wanted to solve problems related to retrieving disposable utensils from their original packages during parties and BBQ. He conducted an observation survey of users during the BBQ session but noted observations unrelated to retrieving disposable utensils. He seemed to have lost focus on the original purpose of research.
Questions	<ul style="list-style-type: none"> ▪ Some students were not able to craft sub-questions in the questionnaire surveys to gain clearer and more precise understanding of the main questions. For example, Student M hypothesized that the problem of cutleries being touched by different people when trying to retrieve from the cutlery holder in the restaurant is unhygienic and may spread diseases. Using the questionnaire survey, Student M asked very general questions and seems to lack the specifics to find out details like, "how the intended users may come in contact with other cutleries when retrieving cutleries in the cutlery holder?", "under what circumstances where the intended users' cutleries are touched by other?" etc.
Point of View	<ul style="list-style-type: none"> ▪ In some instances, information gathered from questionnaires surveys merely to support students' point of view instead of gaining a broader perspective. ▪ In some instances, questionnaire surveys conducted did not include relevant stakeholders.
Information	<ul style="list-style-type: none"> ▪ There were two students who chose one or all the sites that were not relevant to the problem. Students chose a site that the issues may seem similar, but the context was different. For example, Student A decided to solve a design problem to help people organise electrical cables in a home context. He conducted a field research in school facilities rather than home environment which resulted in inaccurate findings. ▪ When conducting research on a single area, for example understanding the target users, although students may conduct multiple modes of inquiry to understand target users, unsound reasonings with respect to the data may still lead students to a skewed understanding of the design problem and eventually led to conceptualising unsound design considerations. ▪ During research related to products, some students took pictures of products that are available in their homes and conducted the analysis. Some of them did not state the source of information. But nonetheless, the pictures are generally unambiguous that may not affect accurate analysis. ▪ A handful of students sourced and studied information that may have little relevant to their design problem. For example, Student O wanted to tackle the design problem on the difficulties and hygiene issues of taking disposal utensils out of the original packaging during BBQ and parties. However, the information studied was about how kitchen utensils at home are organized and kept clean. The relevance of the information reviewed is questionable as the context is different from the problem.
Assumptions	<ul style="list-style-type: none"> ▪ Some students interpreted information collected from internet based on their assumptions without verifications. For example, Student H collected pictures and made observations of how people collected water in Africa. She did not quote the source of information and was not able to conduct any site observations to make clarifications. Hence, parts of her analysis may be based on assumptions without verifications. ▪ During research related to products, some students analysed the images retrieved from search engines rather than visiting the actual sites where more information may be presented. Hence, the analysis was generally based on their own assumptions that eventually influence their inference. Although there may be some accuracy and logicalness in their analysis, some parts may lack precision or accuracy.
Inferences	<ul style="list-style-type: none"> ▪ At times, some students made unjustified inferences based on visual observations related to the environments with/without target users or stakeholders without further verifications with the users/ stakeholders involved. ▪ There was a single case where student did not clarify the research data and led to his inference of the problem that did not follow the evidence presented. Student L hypothesized that when the straw dispenser lever was pressed, more than one straw was dispensed will be a problem for users. He conducted observation survey and noticed that more than one straw was dispensed only when users pressed the lever several times rather than one time. Furthermore, from his questionnaire survey, 40% of the respondents wanted the dispenser to dispense more than one straw when the lever was pressed. His findings somehow contradicted his hypothesis. But he did not clarify further as his inference about the problem did not follow the evidence presented.

5. Findings: Critical Thinking in Stating Design Specifications

After clarifying the problem through research, students created a list of Design Specifications mainly based on the design considerations identified during research. Design Specifications is list of requirements that the design solutions should fulfil and will be used to evaluate

the final design prototype. Based on Table 8, the quality of students' reasoning can be observed (refer to Table 11). At this stage, students generally displayed good reasoning skills. The degree of accuracy of each design specification is highly dependent on the quality of research. Thus, any weak reasonings in conceptualising the design specifications would be related to the previous section of this paper.

Table 11 Observations of good reasoning when determining the list of design specifications.

Elements of Reasoning during Design Specifications	Observations of Good Reasoning in Design Specifications ^{1,2}
	¹ The number in the bracket [] represents number of design journals with similar observation ² When necessary to present the observation clearer, a picture of the journal may also be provided as a figure
Purpose	<ul style="list-style-type: none"> Only one student noted the objectives of crafting a list of design specifications clearly and logically. [1] (Refer Figure 12) All students generally determined the list of design specifications based on relevance and significance to solving the problem. The relevance and significance on the selection of the design specifications were clearly and logically explained. [15] (Refer to Figure 13)
Point of View	<ul style="list-style-type: none"> About half of the students articulated the design specifications clearly based on relevant and fairly gathered points of view from target users or related stakeholders during research. [8] (Refer to Figure 12)
Concepts and Ideas	<ul style="list-style-type: none"> Slightly less than half of the students used relevant concepts and ideas to articulate the adopted design specifications clearly. In addition, depth of thinking on the concepts and ideas were also displayed. [6] (Refer to Figure 13)
Implications and Consequences	<ul style="list-style-type: none"> All students articulated the need for the adopted design specifications clearly based on the significant potential implications and consequences surfaced during their research. [15] (Refer to Figure 13)
Inference and Interpretations	<ul style="list-style-type: none"> All students were able to articulate the design specifications clearly and logically with justifications based on their research. (15) (Refer to Figure 13) Only one student justified the selection of design specifications based on accurate data by tabulating the frequency of occurrence of each design considerations that were surfaced at the end of each research area.

★ Because I have yet to choose between the ironing/steaming problem, so my design specs might be a little vague

↓

I want to open up myself to more solutions + more interesting if I can solve both problems with the same product.

Design Specifications #2

Design Specifications.	Explanation.
My product should be able to function (along with both irons and steamers) that it can be used by a larger amount of people.	Being able to solve the problems in both ironing and steaming clothes, my product will appeal more and also attract more consumers as both iron and steamer users will be able to use my product. My product will also help users save money, not spending money on buying two products. (one for ironing & one for steaming)
My steam product should not interfere with the ironing or steaming process so as to not slow down the process.	This reduces the time needed for users to iron or steam their clothes thus saving and giving time to the users to do other things. Also, by doing so, users will not find ironing or steaming a chore as they do not have to spend as long time to finish the process (compared to the usual time). Most importantly, the product would not make the process more complicated, making it harder for inexperienced teenagers to finish the process.
My product should be user-friendly, such that it does not add danger	Because my users are very inexperienced in ironing and steaming, they become very vulnerable to the dangers. Making my product user-friendly will help to limit the dangers of the process.

Figure 12 Example of a student who provided clear objectives of crafting design specifications.

Design Specifications (FINAL)

Design Specification	Reason	Design Specification	Reason
The product should prevent the clogging of water.	After use, the toothbrush bristles would still remain wet, however users would usually immediately store their toothbrush back into the toothbrush holder before allowing it to dry. If the product clogs water, water from the bristles would not be drained out thus may provide a good environment for bacteria and mold to grow.	The product should not occupy more space than an existing typical toothbrush holder.	Since there is not really much space on the sink counter-top in the bathroom, the product should not occupy too large of a space so that the users have more ease when using the sink and also have ample space to put other items on the counter-top.
The product should allow the toothbrush to dry up easily.	Without ventilation, the moisture from the toothbrush would not dry up and the water in the bristles may end up contributing to the clogging of water. The moisture would provide a good environment and thus causing the growth of mold and bacteria.	The product should be simple and convenient for users to use.	As brushing teeth is the first thing people normally do when they wake up, they would feel very groggy and lethargic thus they would not have an alert state of mind to do things. Therefore, the product should not be too complicated to operate and use so that users can use it with ease.
The product should not	Toothbrush holders are often neglected in the	The product should have good stability.	For toothbrush holders that is made to be attached to the wall: It is to ensure that the toothbrush holder is able to

Figure 13 Example of a student who crafted the list of design specifications with good reasonings.

6. Discussion

The current study presented an approach to dissect students' critical thinking into the various elements of reasoning and then assessing these elements of reasoning using the intellectual standards that are contextualised for the current study. Although current study is based on Singapore context, the findings may provide the following implications for critical thinking development in D&T design projects with respect to understanding the problem and determining design specifications.

Firstly, the observations of good reasonings in this study will provide D&T teachers with useful insights of what the students are capable of achieving when applying quality critical thinking in clarifying the problem to determine appropriate design specifications. Conversely, observations on common weak reasoning exercised by students may provide D&T teachers with more awareness and develop strategies that may be used to guide students to have a deeper understanding of the problem. More importantly, weak reasonings in an element of reasoning often have chain effects on other elements of reasoning. As such, the current study proposed that teachers may use the intellectual standards drafted in Table 7 and 8 as general guidelines when coaching students to clarify design problems and determining design specifications. Furthermore, the author believes that the questions to deconstruct reasoning and intellectual standards in Table 7 and 8 can still be further developed, contextualised and articulated to suit the required student outcomes of other design projects.

Secondly, research is an important process to enable students to triangulate the causes and effects of the problem. In addition, research will generate important background knowledge relevant to the design problem that is important for students to understand the problem holistically so that appropriate design specifications may be crafted. As supported by Bailin (1999), background knowledge will form important intellectual resource that can be accessed by students to achieve good reasoning skills in the critical thinking process. But based on the weak reasonings observed in findings, it can be suggested that different research areas should be done in order to achieve the holistic understanding of the problem. For example, some students in this study conducted visual observations on the environment related to the problem but without including target users or stakeholders into the research to further justify the causes and effects of the problem perceived. Other examples include some students who collected information from the internet rather than conducting site visits when situation allowed.

Design problem generally revolves around environment, users and products and it occurs when there is a need. The need generally occurs when the users are interacting with the environment and/or the product to do something. In a way, conducting research in areas related to environment, users and products will form a good basis of background knowledge that may lead to the holistic understanding of the design problems. At a minimal level, students should conduct research related to environment, users and products, refer to Figure 14. Depending on the nature and context of the design problem, research on *environment-*

users interaction, product-users interaction, environment-product interaction, and/or environment-users-product interaction may be required.

Thirdly, when conducting research, the following points should be noted. When conducting research related to the environment, it is important for students to conduct field visits as much as possible to understand the actual environment where the problem occurs. Thus, it is important for students to engage problems that are accessible. As much as possible, students should find opportunities to interview users and related stakeholders to understand the problem with clarity, accuracy and depth; as it may not be possible by just doing questionnaire survey or visual observations. In forming questions for questionnaire survey for users and related stakeholders, it seems that some students faced difficulties in breaking down their main questions into sub-questions to obtain a clearer and more precise understanding of the users and the problem. To enhance students' abilities of drafting good questions and sub-questions for questionnaire survey, it may be useful for students to first conduct a couple of user interviews to have a good background knowledge of the design problem before seeking to obtain more quantitative inputs. With this background knowledge, students will have a clearer purpose on what they hope to know through the questionnaire survey and are clear and precise about the questions they are going to ask.

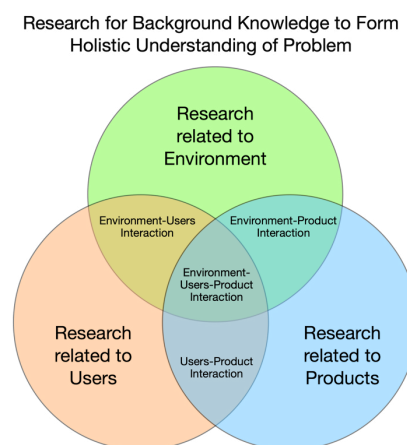


Figure 14 Areas of research to gain a holistic understanding of the problem.

7. Limitations

As limitation to this study, observations in the findings can only be based on what are documented in the design journals. However, what goes into the discussions between student-teacher and student-target users-stakeholder, that may influence students' analysis and conclusion of their research may not be fully clarified. This can be quite apparent where only one observation can be surfaced on how student decided on the design specifications by using statistical method. But how other students decided on their list of design specifications in the first place was not known.

In addition, some of the students' assumptions that were not justified in the documentations could not be verified if they were being informed by teachers or other sources that are not visible in the documentations.

8. Conclusion

The current study aimed to identify and clarify students' critical thinking processes to understand the design problem towards determining appropriate design specifications, using Singapore D&T as a context. Breaking down students' critical thinking into elements of reasoning, the quality of reasoning can be assessed using intellectual standards. From the study, the follow main points may be summarised. Firstly, the intellectual standards contextualised for understand the problem and determining design specifications may provide D&T teachers with useful guidelines for supervising students during the design projects. Secondly, for students to achieve good reasoning standards, background knowledge generated by research in a minimal of three areas such as environment, users and products, with respect to the design problem, is necessary. Finally, to enhance research authenticity and accuracy for the benefit of learning, it is important for students to engage in a problem where field visits and interview with target users and/or stakeholders can be conducted.

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AHMADPOUR, Naseem	1262	CHEN, Chin-Wei	1132
AHORLU, Collins	1336	CHEN, Shu-Yi	358, 1132, 2203
AKMAL, Haider Ali	2377, 2442	CHEUNG, Vien	572
AKTAS, Bilge Merve	1659	CHEW, JiaYing	1847
AKTAŞ, Bilge Merve	2326	CHIVUKULA, Shruthi Sai	1707
ALEXANDER, Sasha	1916	CHONG LU MING, Rubez	310
ALHONSUO, Mira	975	CHOY, Sonny Yip Hong	824
ALVARADO, Maya	423	CLARK, Sheila	554
ALVES DA MOTTA FILHO, Mauricy	2460	CLARKE, Rachel E	23
ALWAZZAN, Aysha	479	CONNORY, Jane	494
ANANDAN, Shivanthi	1297	COOPER, Rachel	1458, 2392
ANDERSON, Paul	1458	CORNET, Henriette	1185
ARNOLD MAGES, Michael	1727	COSCO, Giulia	1828
ASADA, Sion	1082	COULTON, Paul	73, 88, 2377, 2392, 2442
ASTELL, Arlene	615	COUPE, Gemma	992
ATHERTON, Jack	1278	DARBY, Andy	1336
AUERNHAMMER, Jan	1315, 1563	DAVID, Perez	992
AURICCHIO, Valentina	667	DEFI, Irma Ruslina	1408
AUSTIN, Judith	1246	DESAI, Shital	615
BAHA, Ehsan	139, 1898	DESERTI, Alessandro	1993
BAKER, Sarah Elsie	275	DESMET, Pieter	1229
BARNES, Carolyn	686, 838	DEWBERRY, Emma	710
BEATSON, Amanda	1201	DE SOUZA, Dziejdom	1336
BEH, Jeanie	1426	DE VERE, Ian	423
BEN, Pearson	992	DIGRANES, Ingvild	1867
BERGER, Estelle	2344	DONG, Hua	329, 1597
BERNABEL, Rina	111	DONG, Yumei	423
BERRY, James Henry	1916	DORST, Kees	1964
BLACKLER, Alethea	615	DROSSAERT, Constance	1246
BOAKYE, Daniel	1336	DUBOSE, Jennifer R.	1392
BODEN, Marie	947	DUQUE, Melisa	1354
BOESS, Stella	1, 445, 803, 926, 1508, 1962	EGGINK, Wouter	713
BOHEMIA, Erik	822	ELY, Philip	447
BOLING, Elizabeth	1870	EMANS, Denielle Janine	1009
BOON, Boudewijn	139	ERIKSSON, Pernilla	1492
BOS-DE VOS, Marina	39	ESCOBAR-TELLO, Carolina	1366
BOUDHRAË, Sana	1743	EVANS, Mark	1597
BRANDEWIE, Brooke	1512	FAVILLA, Stu	1426
BROOK, Lynda	169	FEAST, Luke	1883
BROUGH, Dean	1803	FELS, Deborah	615
BRUINEBERG, Jelle	1691	FENG, Jeff	1644
BÖREKÇI, Naz A G Z	1867	FERRARELLO, Laura Filippa	1458
BÖREKÇI, Naz Ayşe Güzide Zehra	2284	FILIPPI, Allyson	1168
CAIN, Rebecca	1, 445, 926, 1229, 1366, 1508, 1962	FINGER, Melanie	1803
CAMPANA, Kathleen	1168	FISCHER, Daniel	479
CAMPIGLIA, Gabrielle Conrad	1392	FISHER, Tom	652
CAMPINOTI, Matteo	2427	FRENKLER, Fritz	1185
CANIGLIA, Joanne	1168	FUNK, Mathias	1474
CAREY, Hillary	299	GARAJ, Vanja	1828
CASH, Philip	1977	GARCIA FERRARI, Tomas	751
CASSIM, Julia	423	GATTO, Gionata	1677
CHAMORRO-KOC, Marianella	1201	GAULE, Scott	169
CHAN, Yvonne	152	GEENEN, Anouk	389
CHANG, Chien-Hsiang	638	GERA, Kritiy	259

GERMANY, Jason O'Neill	1611	KUYS, Blair	822, 824, 866, 887, 1116
GERO, John	2234	LAAMANEN, Tarja-Kaarina	2326
GIUSTI GESTRI, Lisa	838	LALLEMAND, Carine	1474
GONG, Yubei	1788	LANDA-AVILA, Irma Cecilia	1366
GRADINAR, Adrian	88	LASCHKE, Matthias	1229
GRAY, Colin M.	1707, 1870	LAURSEN, Linda Nhu	2010
GREGORY, Marston	1201	LAWRENCE, Abbie	2023
GROTH, Camilla	1659	LEE, Boyeun	2392
GULLIKSEN, Jan	1492	LEE, Jung-Joo	1847
HAASE, Louise Møller	2010	LEE, Kyungho	240
HALL, Ashley	1458	LEHTONEN, Miikka J.	1677, 1847
HANDS, David	2392	LEIFER, Larry	1563
HANGKAWIDJAJA, Aan Darmawan	1408	LEITÃO, Renata M.	257
HARDGROVE, Robert	929	LENZEN, Max	1563
HARLAND, Robert George	586	LEON, Cruickshank	992
HARLE, Josh	54	LI, Chih-Yun	358
HARROW, Dale	554	LI, Hong	2083
HASDELL, Peter	259	LI, Yi-Jie	358
HASHIMOTO, Kyoko	54	LIBERATI, Nicola	713
HASSENZAHL, Marc	1229	LIM, Ming	169
HAY, Naomi	1767	LIM, Youn-kyung	1232
HEINER, Scott	929	LIN, Fu-Yu	1531
HEPBURN, Leigh-Anne	963	LIN, Janice	1727
HESSELD AHL, Katrine	554	LIN, Yang-Cheng	638, 1408
HESSELGREN, Mia	787	LINDLEY, Joseph	88
HIDAYAT, Tania Ananta	463	LINDLEY, Joseph Galen	2442
HOCKING, Darryl	2116	LISA, Stafford	1201
HOGHOOGHI, Shahab	1946	LIU, Yi-Fan	638
HONG, Shih-Min	1132	LIU, Ying	853
HOOKWAY, Samantha	975	LOH, Wei Leong	899
HSIAO, Shih Wen	2267	LONSDALE, Maria dos Santos	572
HSIEH, Eric Chen-F.	1531	LOTZ, Nicole	1867
HUANG, Chung-Ching	2098	LOU, Yongqi	1788
HUANG, Jiawei	1216	LUH, Ding-Bang	2245
HUMMELS, Caroline	1691	LUH, Ding Bang	1216
HUNTING, Amabel	601	LUND, Justin	1611
HWANG, Eujeen	1232	LÉVY, Pierre	1691
HÄKKILÄ, Jonna	2083	MA, Min-yuan	1531
JARUSRIBOONCHAI, Pradthana	2083	MACDONALD, Lorna	2166
JIN, Xiaoneng	1597	MALGWI, Grace	1168
JOHNSON, Nicholas Samuel	2023	MANN, Neha	1512
JOHNSON, Samuel	554	MARKUSSEN, Thomas	186
JONES, Derek	1867	MARTENS, Marianne	1168
JUN, Gyuchan Thomas	1366	MARTINI, Nataly	1551
KAMIYAMA, Tsukuru	1168	MATOS-CASTAÑO, Julieta	389
KELLY, Meghan	288	MATTHEWS, Ben	929, 2166
KETTLEY, Sarah	2373	MATTHEWS, Sarah	929, 947
KEULEMANS, Guy	54	MAUDET, Nolwenn	1082
KHAN, Awais Hameed	929, 947, 2023	MEJÍA, G. Mauricio	479
KLEINSMANN, Maaïke	654	MENHEERE, Daphne	1474
KNUTZ, Eva	186	MESA, David	1116
KOCH, Christoph	887	METH, Deanna	1803
KOCH, Maartje	1898	MICHAEL, Yvonne	1297
KOLFF, Louise Moana	535	MICKLETHWAITE, Paul	423
KORKUT, Fatma	2284	MIETTINEN, Satu	4, 975
KUNNEMAN, Youetta	2460	MONTIEL, Miguel	2116

MORADI, Parisa	601	RINNERT, Gretchen Caldwell	1168
MORTATI, Marzia	667	RIZZO, Francesca	1993
MORTENSEN STEAGALL, Marcos	1150	ROBERTS, Sarah	1628
MOTUS, Maarja	975	ROGER, Whitham	992
MOUGENOT, Céline	2048	ROSS, Chris	1458
MUGAVIN, Liam	54	ROUDAUSKI, Stanislav	731
MUPINGA, Davison	1168	ROZENDAAL, Marco C.	139
MURDOCH-KITT, Kelly	1062	SAAD, Qassim	447
MURPHY, Andrew	1426	SAHOO, Shalini	2133
MÄKELÄ, Maarit	2326	SARANTOU, Melanie	4, 975
NAQSHBANDI, Khushnood Z.	1262	SARTIKA, Erwani Merry	1408
NG, Sandy	376	SARTORI DO AMARAL, Carla	1201
NGUYEN, Mimi	2048	SCHMIDT, Ruth	1443
NICHOLAS, Diana S.	1297	SCHMIDT, Stefan W.	2133
NICKPOUR, Farnaz	169, 332	SCHMITTINGER, Felicitas	1993
NIEDDERER, Kristina	1440	SHIH, Pei-Ling	2203
NIELSON, Liv Meret	1867	SHORT, Carolina	751
NILBRINK, Fredrik	1492	SIJNJA, Nicole	2065
NIMKULRAT, Nithikul	2323	SILVESTER, Sacha	803
NOEL, Lesley-Ann	257, 1867	SINGH, Abhigyan	139
NORMOYLE, Catherine	1025	SJÖMAN, Martin	787
O'SULLIVAN, Cara	332	SLEESWIJK-VISSER, Froukje	803
OKAWA, Keiko	463	SMITH, Dianne	447
OVERHILL, Heidi	2151	SMITH, Kennon M.	1870
OZKARAMANLI, Deger	713, 1229	SMITH, Maarten	1691
PAGE, Rowan	1628	SNELDERS, Dirk	1898
PAYETTE, Jean	1916	SNOW, Stephen	929
PAYNE, Alice	768	SOSA, Ricardo	601, 1551, 1583, 2116
PEDELL, Sonja	1426	STADLER, Sebastian	1185
PENG, Po Hsiang	2267	STAPPERS, Pieter Jan	139
PENNINGTON, Miles	1082	STEAD, Michael	88
PEROLINI, Petra	1767	STOIMENOVA, Niya	654
PETERMANS, Ann	1229	STOLTERMAN, Erik	2098
PETRELLA, Viola	23	STORER, Ian	2023
PETROVICH, Tanya	1426	STRACHAN, Mark	866
PICKUP, Roger	1336	STURKENBOOM, Nick	1898
PILLAI, Ajit	1262	SUHENDRA, Fanny	686
PILLING, Franziska Louise	73, 2442	SUMARTOJO, Shanti	1354
PINK, Sarah	1354	SWANN, Levi	1946
POHLMAYER, Anna E.	1229	SÄRMÄKARI, Natalia	2410
POLDMA, Tiuu	1229	TABOADA, Manuela	768
POPOVIC, Vesna	1946	TAN, Ed	186
POWER, Jacqueline	111	TAN, Linus	1045
PRESSER, Mirko	2427	TANG, Hsien-Hui	358, 1132, 2203
PRICE, Rebecca	1898	TAVARES, Tatiana	1150
PRIEMUS, Jessica Lynne	2358	TAYLOR, Silas	1262
PUA, Talia	152	TECE BAYRAK, Aslihan	2184
PUNEKAR, Ravi Mokashi	2303	TEGTMEYER, Rebecca	1025
PÄÄKKÖNEN, Tarja	4	TEO, Chua-Tee	1817
QUINLAN, Daniel	554	THOMPSON, James Robert	1933
RACHEV, Rumen	152	THONG, Christine	1116
RANSCOMBE, Charles	1116	TIAN, Tian	572
REBOLA, Claudia	1512	TIMPANY, Claire	513
RENDA, Gianni	824, 887	TIMPANY, Claire Louise	223
REYNOLDS-CUÉLLAR, Pedro	310	TOBIASSON, Helena	1492
RICHARDSON, Mark	1628	TONETTO, Leandro	1229

TONETTO, Leandro Miletto	1392
TORRENS, George Edward	2023
TSAI, Shin-Chih	1132
TSEKLEVES, Emmanuel	1334, 1336
TUZOVIC, Sven	1201
VANDERSCHANTZ, Nicholas	513, 2065
VAN DER SPEK, Erik	1474
VAN DER VOORT, Mascha	389
VAN DER ZWAN, Sander	1691
VAN DIJK, Jelle	1246
VAUGHAN, Laurene	1354
VERMA, Shiv Kumar	2303
VERSWIJVELEN, Miranda	1551
VIAL, Stéphane	1743
VILLA ALVAREZ, Diana Pamela	667
VILLER, Stephen	947, 2166
VISCH, Valentijn	186
VOS, Steven	1474
VÄNSKÄ, Annamari	2410
WABEKE, Elise	803
WALLACE, Niki	204
WANG, Danyang	1132
WATSON, Rodger	1964
WEGENER, Frithjof E.	139, 1977
WEN, Qi	376
WEN, Yifeng	2245
WIANTO, Elizabeth	1408
WRAGG, Nicole	686
WRIGHT, Kristy	513
WU, Chi-Hua	2245
WU, Chi Hua	1216
WU, Jiayu	554
WU, Meng-Ting	638
WU, Ting-Yi	638
WU, Yiyi	125
WU, You-Hsun	638
XIE, Yumeng	479
XIUCHUAN, He	1097
XU, Anni	1727
YADAV, Prithi	406
YANG, Chih-Chun	638
YANG, Sam	2184
YANG, Yi-Sin	358
YEE, Joyce	23
YEO, Jesvin Puay-Hwa	1817
YEVENES, Karen Tamara	1916
YOU, Yen-Ya	1132
YU, Chia-yin	2221
YU, Jing-Ting	358
YU, Rongrong	2234
ZAGA, Cristina	713

