INDERSCIENCE PUBLISHERS
Linking academia, business and industry through research

J. of Design Research

ISSN online: 1569-1551 - ISSN print: 1748-3050
https://www.inderscience.com/jdr

Where are the humans in human centred design? Intentionally representing people during idea generation deepens consideration of needs

Laura R. Murphy, Thanina Makhlouf, Shanna R. Daly, Colleen M. Seifert

DOI: 10.1504/JDR.2025.10070138

Article History:

Received:	17 November 2023
Last revised:	23 December 2024
Accepted:	24 December 2024
Published online:	29 April 2025

Where are the humans in human centred design? Intentionally representing people during idea generation deepens consideration of needs

Laura R. Murphy

Design Science,
University of Michigan,
1075 Beal Ave, Ann Arbor, MI, 48109, USA
Email: lrmurphy@umich.edu

Thanina Makhlouf

Systems Engineering + Design,
University of Michigan,
1075 Beal Ave, Ann Arbor, MI, 48109, USA
Email: ninamak@umich.edu

Shanna R. Daly*

Mechanical Engineering,
University of Michigan,
2350 Hayward St., Ann Abor, MI, 48109, USA
Email: srdaly@umich.edu
*Corresponding author

Colleen M. Seifert

Psychology,
University of Michigan,
530 Church St, Ann Arbor, MI, 48109, USA
Email: seifert@umich.edu

Abstract: Human centred design approaches aim to generate better solutions through understanding people's social, emotional, and physical needs. But how can designers 'centre humans' in their design thinking? We propose a method for centring people during early idea generation: When creating design ideas and sketches, explicitly representing people may help designers think more deeply about how their designs impact people. We tested this method in two empirical studies using a short, solo idea generation task. Using a think-aloud protocol, student designers generated ideas for a presented problem both without instructions and then with an instruction to depict people in sketches. When people were represented in sketches, student designers reflected more about how people were impacted by their designs. These findings were replicated in a between-subjects experiment with mechanical engineering students. Results showed that representing people within design ideas led to considering more physical interactions, emotions, contexts, and stakeholder roles.

Keywords: human-centred design; concept generation; conceptual sketching; idea generation; interdisciplinary design; mechanical engineering design; user needs; empathic design; user-centred design.

Reference to this paper should be made as follows: Murphy, L.R., Makhlouf, T., Daly, S.R. and Seifert, C.M. (2025) 'Where are the humans in human centred design? Intentionally representing people during idea generation deepens consideration of needs', *J. Design Research*, Vol. 22, No. 5, pp.1–26.

Biographical notes: Laura R. Murphy, PhD, is an expert on inclusive engineering design, supporting development of technology by centring disabled perspectives at every step in design processes. She has a BSE and MSE in Mechanical Engineering and a PhD in Design Science from the University of Michigan. She consults with teams in academia, non-profits, and industry to help engineers think more strategically about the people impacted by design decisions. She also teaches graduate courses on equity-centred engineering and project-based design at the University of Michigan, Ann Arbor.

Thanina Makhlouf is a Systems Engineer at The Boeing Company, specialising in Propulsion Integration for the 777X program. She holds a Master's degree in Systems Engineering + Design and a Bachelor's degree in Mechanical Engineering, both from the University of Michigan. Her academic research focused on human-centred design, with an emphasis on creating more inclusive design practices within educational and professional environments.

Shanna R. Daly, PhD, is an Arthur F. Thurnau Professor and Associate Professor in Mechanical Engineering at the University of Michigan, Ann Arbor. She has a BE in Chemical Engineering from the University of Dayton and a PhD in Engineering Education from Purdue University. Her research characterises front-end design practices across the student to practitioner continuum and studies impacts of developed tools and pedagogy for engineering success.

Colleen M. Seifert, PhD, is an Arthur F. Thurnau Professor and Professor of Psychology in the College of Literature, Science, and Art at the University of Michigan, Ann Arbor. She has a BA in Psychology from Gustavus Adolphus College and an MS, MPhil, and PhD in Psychology from Yale University. Her interests focus on understanding how content knowledge organisation in memory (what people think) influence mental processes (how people think) to change outcomes in learning, problem solving, and design.

This paper is a revised and expanded version of a paper entitled 'Considering people: an exploratory investigation of engineering student ideation' presented at *2020 ASEE Virtual Annual Conference and "Investigating Engineering Students' Consideration of People During Concept Generation"*; *2021 ASEE Virtual Annual Conference*. An additional paper with an analysis of a final participant survey, 'Who is this design for? Promoting consideration of people during concept generation', was presented at the *International Design Engineering Technical Conferences*, Boston MA, 20 August, 2023.

1 Introduction

Over several decades, designers have increasingly emphasised human-centred design processes to better meet people's complex needs. 'Centring' people during design involves exploring how people may be impacted by design decisions (Zoltowski et al., 2012) through design activities like problem definition and scoping; idea generation, selection, development and prototyping; and evaluation (Atman et al., 2007; Dym and Little, 2004). The people of interest include all who could impact or be impacted by designed solutions, often called 'stakeholders' (Freeman, 2010). Centring people in design includes the primary users as well as those impacted through its implementation, such as community members, manufacturers, policymakers, or government entities.

One opportunity to centre users occurs in the early stages of *conceptual design* (Hay et al., 2017; McNeill et al., 1998; Suwa et al., 1998) when designers explore alternative solution ideas (Cross, 2008; Daly et al., 2016; Khurana and Rosenthal, 1998). Design concepts have been defined as identifying primary functions and 'working principles' to be integrated into a principal solution (Cross, 2021; Pahl et al., 2007; Roozenburg and Eekels, 1995). Idea generation is a first step toward building a design concept through conceptualisation of a new design (Hay et al., 2017; Yang, 2009), with an outcome best described as a 'design idea' rather than "design concept".

A design idea contributes toward a possible solution to a design problem through further iteration, synthesis and articulation. Because early ideas can significantly impact the ultimate success of a design process (Khurana and Rosenthal, 1998; National Research Council, 1991), idea generation is a critical moment for incorporating people within design. The co-design method, where designers invite people to jointly develop potential solutions to a problem, is a successful method for including people and their needs during idea generation (Sanders and Stappers, 2008). However, other methods are needed to help designers centre people's needs during idea generation.

In two studies, we explored how design students consider people during idea generation. Our research goals were to identify whether and how student designers choose to consider people during idea generation, and whether their design thinking changes when explicitly representing people within their design ideas. In a first study, undergraduate student designers in three disciplines followed a think-aloud protocol (c.f. Hay et al., 2017) as they generated design ideas for a problem on their own, and then repeated the task following explicit instruction to represent a person within each of their sketches. A second experimental study with engineering design students directly compared the impact of instructions to represent people in design ideas to a control group. Because sketches are important in visualising design ideas, the reminder to include people at this early stage may enhance designers' thinking about how their designs address people and their needs.

2 Background

2.1 Human-centred design

The need for human-centred design is emphasised across interdisciplinary design literature and industry standards. Several people-focused design approaches outline methods to place people at the centre of design development, such as Human-Centred

Design (IDEO, 2015, 2019; Norman, 2013), participatory design (DiSalvo et al., 2013), design thinking (Institute of Design at Stanford, n.d.), ergonomics (Singleton, 1971), user-centred design (Norman and Draper, 1986), and inclusive design (Inclusive Design Research Centre, n.d.; Shum et al., 2016). Work in human-computer interaction (HCI) emphasises an 'embodied embedded cognition' perspective to enhance attention to physical interaction (Van Dijk, 2009). These people-focused design approaches seek to close the gap between human needs and design outcomes and understand peoples' needs and their contexts holistically (Zhang and Dong, 2009; Zoltowski et al., 2012).

In HCI design (Carroll, 1997), Bødker (2015) described a first wave focused on human factors within a more rigid approach to studying humans' physical and cognitive abilities; a second wave investigated more practical and situated human actions; and a recent third wave delved deeper into people's everyday lives for a more holistic understanding of the interaction between people and technology. The International Organization for Standardization (ISO) has published guidance recommending that "the design is based upon an explicit understanding of users, tasks, and environments" (International Organization of Standardization, 2019). Centring people in a design process engages all stages of design to consider human needs as valuable throughout.

2.2 Idea generation within conceptual design

Within conceptual design, idea generation is defined as an initial stage for exploring potential ways to solve a problem (Atman et al., 2007; Centre for Socially Engaged Design, 2020; Cross, 2021; Institute of Design at Stanford, n.d.; Yock et al., 2015). Best practices in generating design ideas include coming up with as many ideas as possible in ordered to consider many different alternative solutions (Shah et al., 2000; Yilmaz and Daly, 2016). Idea generation is an early step in conceptual design, yet it plays a key role in guiding the development of successful outcomes (Yang, 2009).

Some methods have been identified across design fields to help designers centre people during idea generation with varying levels of success. Co-design or participatory design methods bring people such as potential users into the design process to partner with designers (Bannon and Ehn, 2013; Sanders and Stappers, 2008). These methods can also involve stakeholders such as community members who may be affected by a project, advancing justice, inclusion, and equity by directly incorporating the affected communities' perspectives (Costanza-Chock, 2020; Design Justice Network, 2018; Francis, 1983) Artificial intelligence (AI) prompts have been explored to mimic co-creation (Karimi et al., 2020). The ethical implications of leveraging AI in this way have not been studied, although it is well-documented that AI implementation can have complex ethical ramifications (Jobin et al., 2019). In many cases, adding people to the design team during idea generation adds logistical complexity to the early design process.

More typically, designers work on their own to centre people by identifying user needs to serve as requirements or specifications for ideas (Dieter and Schmidt, 2013; Dym and Little, 2004; Nuseibeh and Easterbrook, 2000). One commonly used method is persona development where aggregated user data is combined into a specific user profile to guide design (Miaskiewicz and Kozar, 2011). Using personas to capture users' perspectives may inadvertently amplify inaccurate or stereotypical assumptions about users (Costanza-Chock, 2020, p.81), leading to potential serious harm. Other methods help designers gain insight into people's needs through exercises where they engage in user experiences, such as empathy-building simulations (Bearman et al., 2015), role-

playing (Alzheimer's Association, 2018), and 'experience prototyping' (Buchenau and Suri, 2000). However, the use of experiential exercises by designers has been criticised as missing the benefits of direct engagement with users (Bennett and Rosner, 2019; Flower et al., 2007; Kafer, 2013; Siebers, 2008). These identified methods for considering people during idea generation also lack empirical support for their efficacy.

2.3 Visualising people within design ideas

Mental visualisation is another proposed method to advance idea generation (Athavankar, 1997; Macfie et al., 2023). Dahl et al. (2001) examined the use of mental visualisation for centring people in idea generation through several empirical studies. Engineering students working alone generated one solution for a presented design problem ("a car jack for seniors"). Students were given either no instructions or told to imagine visual images as they created their design. Some received guided visualisation training, and some were explicitly directed to imagine, "an elderly person interacting with the proposed design". After generating their idea, the students described the mental imagery they had formed during the process. Those given no instructions rarely reported a mental image including people; however, the group told to imagine people *interacting* with their design (as well as those given guided visualisation training) more often reported images including people. However, *how* people were included in designs was not directly observable in these studies.

More often, designers use visualisation in their free-hand sketches describing their design ideas (Ullman et al., 1990). While sketches are used for different purposes throughout design processes (Akin and Lin, 1995), the act of sketching is considered critical to generating ideas for concepts (Goel, 1995; Goldschmidt, 1994; Purcell and Gero, 1998; Suwa and Tversky, 1997). Sketching during idea generation creates an external representation in a concrete artefact (Buxton, 2007; Cross, 2008; Daly et al., 2016), Sketches can offer a concise representation of the design problem, constraints, ideas, and objects with related information grouped spatially (Shah et al., 2001), facilitating the processing of information (Larkin and Simon, 1987). Through their sketches, designers may see unanticipated relationships suggesting how to build on their ideas (Goldschmidt, 1994; Suwa and Tversky, 1997), providing access for designers' reflection (Schön, 1983; Valkenburg and Dorst, 1998), communication with co-designers (Stompff et al., 2016), and iteration (Goldschmidt, 1992) towards a complete design concept. While evidence is limited, designers allowed to sketch during the design process produced higher quality solutions (Schütze et al., 2003).

Individual designers may benefit to different degrees from the use of sketches in idea generation. Effective representations useful in design (Larkin and Simon, 1987) may arise through practice and experience with sketching (Suwa and Tversky, 1997) as well as individual preferences. However, sketching is promising as a method to deepen designers' consideration of people during idea generation. Sketching deepens examination of potential design ideas (Suwa and Tversky, 1997), and sketches that include people interacting with a design may allow reflection on the effects and unintended impacts of design ideas. This suggests sketches with people explicitly included may assist designers in more deeply considering people during idea generation, potentially improving design ideas to better meet people's needs.

3 Study 1: Does design thinking change when people are represented in design ideas?

Our research investigated the potential for visualising people within design idea sketches as a means of promoting centring people in designs. The following research questions guided the studies:

- Do student designers represent people within design ideas on their own, and does that representation influence their idea generation?
- How are students' design ideas and thinking impacted when they are specifically asked to include people within their sketches?

Following the procedure from Dahl et al. (2001), we observed student designers working alone in a single, brief session as they generated design ideas for a provided design problem. In practice, designers often generate initial design ideas on their own before joining collaborative brainstorming sessions (Osborn, 1963; Wilson, 2006) to enhance idea generation. Empirical studies of idea generation often use brief, solo design exercises in order to limit confounds (such as differences in project scope, complexity, teamwork, and timeline) while identifying factors affecting outcomes (number and differences in ideas generated) (e.g., Daly et al., 2016; Hay et al., 2017; Murphy et al., 2022; Shah et al., 2003; Yilmaz and Daly, 2016). In addition, studies of idea generation have often collected 'think aloud' protocols to capture subjective verbal reports during a design task (Ericsson and Simon, 1993; Gero and Tang, 2001; van Someren et al., 1994) along with associated sketches and movements (Suwa et al., 1998).

3.1 Method

In this first study, we followed a think-aloud protocol (Cross, 2001; Hay et al., 2017) during idea generation sessions with design students before and after instruction to represent people. We used a within-subjects, single-case AB design where each participant generated design ideas first before and again after an instruction to include people in the sketches. We examined qualitative changes in design thinking through identification of patterns across design ideas guided by inductive qualitative analysis (Creswell, 2013).

3.1.1 Participants

Participants included 15 fourth-year undergraduate students in 3 design disciplines: mechanical engineering (Participants 2, 10, 11, 12, 14), art and design (Participants 4, 5, 7, 8, and 9), and user experience design (Participants 1, 3, 6, 13, and 15). Nine reported their gender as female, five as male, and one did not indicate. Students identified their race and/or ethnicity as Indian American (1), Asian American (2), white (3), Hispanic (1), Latina (1), Latine (1), Indian (1), and Asian (3), and multi-racial (2). Students were recruited through program email lists and received $25 as compensation for their time.

3.1.2 Procedure

Each participant engaged individually in a single 1-h session including two idea generation sessions. The study followed a 'think aloud' protocol where participants were asked to speak aloud any thoughts coming to mind as they generated design ideas, as described in Atman and Bursic (1998). Verbalising thoughts may affect design processes; however, evidence shows speaking thoughts that come to mind (rather than explaining thoughts) does not influence cognitive task outcomes (Ericsson and Simon, 1980, 1993). Following the prescribed protocol, participants first practiced thinking aloud using a simple word problem. During the study, participants who stopped talking were prompted by the facilitator to, "please keep talking".

For Session 1, we instructed participants to generate as many design ideas as possible to solve the provided design problem, as shown in Figure 1. We developed a problem intended to be accessible and appropriate for undergraduates with design training in mechanical engineering design, user experience design, or art and design. We intentionally described the problem without specific solution requirements so that a wide range of approaches (e.g., digital, physical, informational, computational, service-based, organisational) across design disciplines were applicable.

Following Shah et al.'s (2000) idea generation metrics, a 'design idea' in this study was defined as a completed sketch and written description. A design idea could represent any idea (whole or partial) that contributes toward a possible version of a solution to the provided problem. Participants recorded each design idea on separate worksheets with instruction to include any information they wished in enough detail to allow comprehension by others.

Figure 1 Design problem provided to students for both idea generation sessions

Design Problem: Helping people move

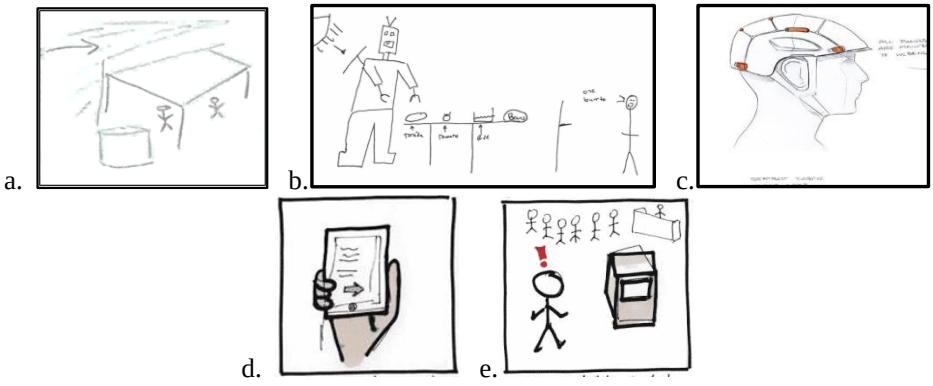
Moving is considered one of the top stressors in life. When people move, they experience multiple challenges. For example:

- lifting heavy furniture
- navigating through small spaces (door frames, corners, narrow hallways, stairs)
- keeping belongings organized
- finding other people to help them move
- continuing living (and even working) while belongings are in transit
- moving in extreme weather (snow, heat, rain)
- and many others…

Imagine you are asked to design for this problem. Considering one or more challenges on moving day, design a way to help people move households. Make sure to consider the physical setting in your solution.

After 15 min, the first idea generation session ended. We then introduced verbal and written instructions to represent "people, a person, or part of a person" within each design idea sketch in a second session. This specific language encouraged drawing people as appropriate for the design idea (e.g., a hand operating a phone app or group moving a couch). We provided five example sketches with people (shown in Figure 2) to suggest that rough sketches such as stick figures are adequate. In this second session, participants again generated as many design ideas as possible for the same design problem. The entire study lasted about 60 min.

Figure 2 Five example sketches including representations of people provided to participants with the instructions. Images (a), (b), and (e) include depictions of one or more people, while images (c) and (d) depict a portion of a person (see online version for colours)



Source: Image C by courtesy of Laut design (2023); images D and E with permission from Trucchia (2020)

3.2 Results

Fifteen participants produced a total of 106 design ideas over two generation sessions. Each design idea sketch, written description, and related protocol transcript portion was scored for the presence of a depiction of a person or body part (see Figure 3). Sketch quality was quite basic, with 'stick' figures often used to indicate a person.

3.2.1 Representations of people in sketches

In the first session, 30% (n = 17) of design ideas depicted at least one person, while 90% (n = 46) of design ideas in Session 2 did so (see Table 1). This result indicates participants successfully followed instructions in the second session to include representations of people within their design idea sketches.

Table 1 Number of design ideas generated by session and number depicting people

Generated design ideas	*All design ideas*			*Design ideas with people*		
	Session 1	*Session 2*	*Total*	*Session 1*	*Session 2*	*Total*
Total	56	50	106	17	46	63
Mean	3.7	3.3	7.1	1.1	3.1	4.2
SD	1.8	1.5	3.1	1.4	1.8	2.6
Percentage	53%	47%	100%	30%	92%	59%

Then, following practices of thematic analysis (Creswell, 2013), two authors identified qualities of the sketches through an iterative process. Five independent themes (shown in Table 2) described representing people through emotion, communication, physical interaction, a full body, or multiple people. Two authors scored for each theme in each

design idea and discussed discrepancies to consensus following Landis and Koch (1977). Table 3 shows satisfactory rater agreement and reliability for each category (Cohen, 1960).

Figure 3 Examples of design ideas from two participants, including sketch, written description, and think-aloud transcript during idea generation tasks

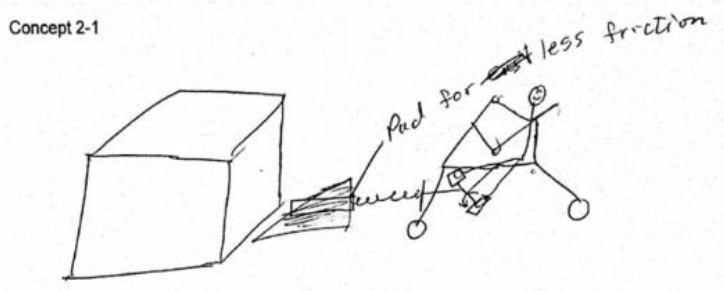
<table>
<tr><td colspan="2">  </td></tr>
<tr><td>Written Design Idea Description:
1. App/online organize resources and requires
2. Robot/Machine</td><td>Think-Aloud Transcription: “The user requirement can be finding other people to help them to move. So I think first, maybe an app to clearly... No, to organize resources, such as moving companies, and the users who want some people to help them to move. An app, or some simply online website, or tools, that help people to move.”</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td>Written Design Idea Description:
Bike style pedals to push slider under heavy objects and move objects around</td><td>Think-Aloud Transcription: So the first one I would say, I still want to focus on is lifting heavy furniture or lifting heavy boxes. So I might say... Bicycle. You would get...Let's say you have a heavy box and... You need something to lift it up. So you just have like a wedge. Oh, this is not really well drawn. Oh well. A wedge. And there's a crank or a screw of some sort, and it's powered by this chair that has a bicycle. And there is a person, his feet on that bicycle. And as they peddle, it pushes the wedge under the box and... or it pushes the pad under the box. Pad for easy pushing or for less friction. So the pad gets pushed under the box, and then once the pad is under the box, they can just move... or the stop will hit the box and then they can essentially just bicycle their way over... that's how you draw a bicycle. So, it's actually this pad goes under the box. So, bike-style pedals to push slider under heavy objects and move objects around. It works. Somehow the steering gets figured out and let that happened.</td></tr>
</table>

Table 2 Thematic codes capturing representations of people in participants' sketches

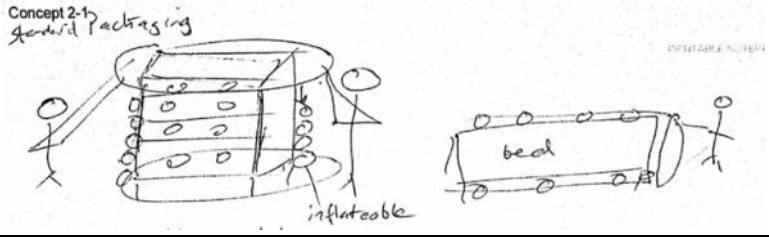
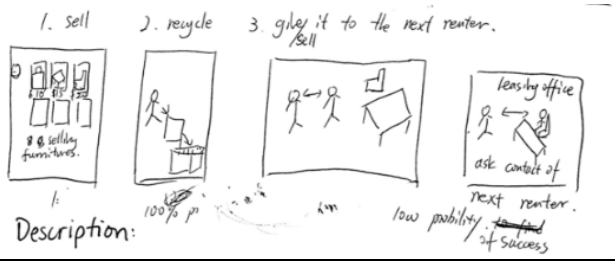
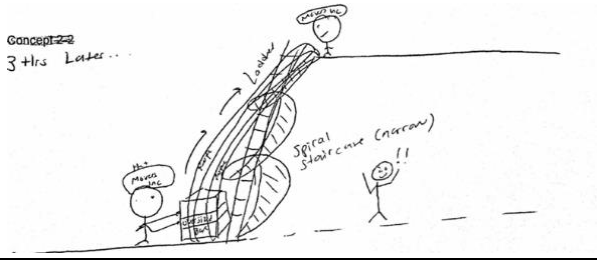
	Depicts emotion
Example: Smiling at message	
	Shows physical interaction with design
Example: People stacking materials	
	Depicts a person's full body
Example: Alternative removal steps	
	Depicts multiple people
Example: Second floor moves	
	Displays communication
Example: Posting on webpage	

Table 3 Rater agreement and reliability for coded themes in depictions of people

Theme	*Emotion*	*Physical interaction*	*Full body*	*Multiple people*	*Communication*
Percent agreement	100%	88%	94%	88%	88%
Cohen's kappa	1.000 – perfect	0.534 – moderate	0.765 – substantial	0.768 – substantial	0.602 – moderate

Of 106 design idea sketches, 59% included depictions of people, and 90% included people after the instruction to draw people. Figure 4 shows the proportion of sketches in five identified themes: emotion, physical interaction, full body depiction, multiple people, and communication between people by session. The number of sketches depicting people increased following the instruction, with physical interaction, full body depictions, and multiple people increasing significantly following the instruction (see Table 4). Too few instances of emotion and communication occurred for analysis.

Figure 4 Distribution of sketches from session 1 (n = 56) and session 2 (with the instruction to draw people) (n = 50) observed for five identified themes: physical interaction, full body depiction, multiple people, communication, and emotion

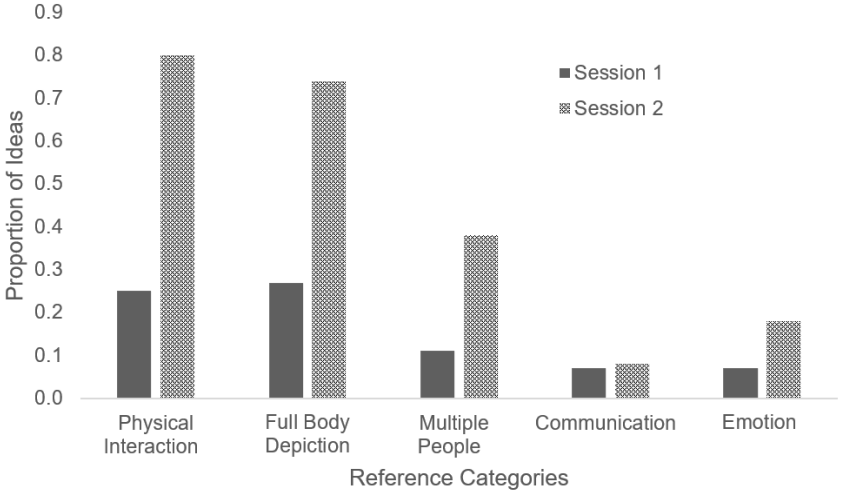


Table 4 Proportion of sketches by session observed for five identified themes: physical interaction, full body depiction, multiple people, communication, and emotion

	Proportion		*Count*		*Chi square*	*Significance*
	Session 1	*Session 2*	*Session 1*	*Session 2*		
Physical interaction	0.25	0.80	14	40	31.9	$p < 0.001$
Full body	0.27	0.74	15	37	23.6	$p < 0.001$
Multiple people	0.11	0.38	6	19	10.9	$p < 0.001$
Communication	0.07	0.08	4	4	undefined	
Emotion	0.07	0.18	4	9	undefined	
Total	0.53	0.47	56	50		

3.2.2 Generality of references to people in think-aloud protocols

The references to people in the think-aloud protocols were evaluated for their generality. Two researchers independently coded the protocol segments by design idea for the presence of any reference in four categories: general level ("everyone"), type of person, specific individual, and the designer ("me" or "I"). Table 5 shows two raters' percent agreement and Cohen's *kappa* for each category, with satisfactory agreement for each and differences discussed to consensus.

Table 5 Results of coding for generality of references to people in think aloud protocols

References	*Definition*	*Example*	*Percent agreement*	*Reliability (Cohen's kappa)*
General	No specific person: 'everyone,' generic "you"	"The *user* requirement can be finding *other people* to help *them* to move"	100%	1 – perfect
Types of people	Groups with qualifications or contexts: "tall people"	"I will draw a muscular person with little bulges on the arms to show that *he's a mover*"	92%	0.821 – almost perfect
Specific individual	Particular individuals: "this friend of mine"	"So I've a *younger sister*, but she's a lot stronger than I am"	97%	Too few occurrences
Self	Self as person (not as designer): "When I did this"	"*I* wouldn't want my boxes getting stuck in the rain or anything especially while *I was moving*".	92%	0.719 – substantial

Think-aloud protocols revealed explicit references to people in almost all design idea transcript segments. Only one design idea -- generated before the instruction to draw people -- had no direct reference to people. References to specific individuals were rare, while most references to people across both idea generation tasks were generic (e.g., 'people,' 'they,' "everyone"). The small differences observed in the generality of references to people by session indicate little change after the instruction to draw people (see Table 6).

Table 6 Proportions of reference categories observed in think-aloud protocol design ideas (n = 106) by sessions (before and after instruction) show little differences before and after the instruction

Reference categories	*Examples*	*Session 1* (*n*)	*Session 2* (*n*)	*Difference* (*n*)
General	"people", "they"	0.66 (53)	0.61 (49)	0.05 (4)
Type of person	"tall people"	0.18 (14)	0.21 (17)	0.03 (3)
Specific individuals	"my brother"	0.04 (3)	0.04 (3)	0.00 (0)
Self	"me", "I"	0.12 (10)	0.14 (11)	0.02 (1)
Total		1.00 (80)	1.00 (80)	
Total design ideas		56	50	

3.2.3 Changes in consideration of people before and after instruction

Changes in how participants talked about people in think-aloud protocols were compared in the first and second sessions. Two authors independently compared think-aloud protocols using memoing (Charmaz, 2006) to record differentiating characteristics. Six patterns were identified by consensus in the 15 participant's protocols, with three patterns occurring in multiple protocols.

Participants often shifted consideration of context and stakeholders in several ways following the instruction, as shown in Table 7. While we did not detect consistent differences across disciplinary training, we included reference to participants' training for added context: User Experience Design (UX), Art and Design (AD), and Mechanical Engineering (ME).

Table 7 Description of prominent qualitative changes in considering people following the instruction for each of 15 participants (training: UX = user experience design; AD = art and design; ME = mechanical engineering)

Prominent change in Session 2	*Participants* (*n = 15*)	*Description of change with instruction*
Centre people	P10 (ME), P12 (ME)	Places users at the centre of designs
Add emotions	P3 (UX), P5 (AD)	Considers user's emotional needs
Physical interactions	P2 (ME), P6 (UX)	Considers physical contexts of users
Add community context	P7 (AD)	Considers a community impacted by idea
Others' experiences	P13 (UX)	Considers others' life experiences
Build on experiences	P14 (ME)	Reflects on past life experiences
Centring as a practice	P4 (AD), P11 (ME)	No change: centred people before *and* after
No detected change	P1 (UX), P8 (AD), P9 (AD), P15 (UX)	No change evident across sessions

Centre people. One observed change spurred by the instruction for two participants was adding people at the centre of design ideas they created. For example, Participant 12 (ME) made only generic references to people in Session 1 ("Light containers can be moved by *a person*"); but in Session 2, they included people throughout their description: "If [I] give [furniture] to the next renter, I only have to talk with them and I can keep all my furniture in the house so I don't have to move them... So I have to talk with the guy, with the leasing office to ask [for the] contact of [the] next renter if they have one".

Add emotions. Another observed change in two participants' protocols was moving from no discussion of emotion in Session 1 to discussing emotional context of potential users in Session 2. For example, Participant 3 (UX) addressed only physical context of use before the instruction to draw people, but after the instruction, they introduced emotional stress from moving and incorporated it in design decisions: "They're helping her take the boxes into the new house to ease heavy lifting and maybe emotional stress to have her friends there with her".

Consider physical interactions. Two other participants shifted from considering user emotions to a focus on specific physical contexts after the instruction. Participant 2 (ME) discussed "the emotional stresses... not being in control of the situation" first, but after the instruction, focused on physical engagement with their design: "The user will

assemble this mechanism on the armchair…they put the handle here and then they take their other hand and they put the backing inside…then they can use this magnet handle to change the way that they're holding the different items without damaging the items".

Add community context: One participant moved from focusing on a single person to understanding how a community of people interact with a design. Participant 7 (AD) first identified what a 'generic' user needs: "These materials have to be lightweight because you don't want heavy boxes…" After the instruction, they discussed different people with differing motivations engaging with a design idea: "This is the person who wants to move…Needs help, physical help…that would be these people. But these people need incentive to help. Let's draw, these are drawing household items. And then their incentive, receive unwanted household items. And they also are giving away items in moving".

Consider others' experiences: Another participant was moved by the instruction to focus on other people's experiences rather than solely their own. Participant 13's (UX) Session 1 design ideas were related to their experiences in college dorms: "One problem that stands out to me from moving around dorms to apartments… would be the idea of having to pack up everything in such a short time while still living in the space and wanting to continue living there before you move into your new space". In the second session, Participant 13 spoke about a situation they had not personally experienced: "So he goes into the store, and maybe it's a moving store that also does this, I don't know. Part of the store is that they help you move your things, so you go into the store and you chat with this guy and he says, 'Okay, I'll handle it for you.'"

Build on past experiences: Participant 14 (ME) moved from discussing people in general terms to adding specific personal experiences. They spoke generically about people before the instruction: "The user requirement can be finding other people to help them to move". After the instruction to draw people, they pulled inspiration from real experience: "When I first moved to [City], I spent a couple of days going to buy furnitures (sic), and take them back to my home. It's painful to move the Ikea furniture, even though they are broken to pieces, I still have to carry it from the first floor to the third".

Centring is already a practice. Participants 4 (AD) and 11 (ME) included people in all sketches in both sessions with equally detailed, involved, and user-engaged designs. These participants appeared to already incorporate explicit representations of people in their thinking and sketches. This suggests that employing explicit representations of people in design ideas and sketches occurs across design disciplines.

No detected change. Four participants (27%) showed little change following the instruction to include people in sketches. For example, Participant 9 (AD) discussed people minimally before and after instruction to draw people, expressing discomfort with sketching people: "For lifting heavy weights, for people like me, who are freaking weak, we are going to make an arm. First, we're going to draw a person and that's believable (*sarcastic*)". Difficulties with sketching people may distract from the aim of design. Inexpert sketches of physical objects appeared to be more tolerated.

Multiple changes between the sessions indicate greater consideration of community by participants. One participant explicitly incorporated community context into their designs, and several others explicitly centred a variety of people in ideas. Explicitly

exploring and centring a variety of people in design ideas are building blocks for designing for communities impacted by designs.

The simple instruction to include people in design idea sketches introduced new foci (emotional, physical), potential users (community, self), and user needs to consider in designs. The changes observed following the instruction identified different designers' approaches to centring people, suggesting the same instruction allowed customised application to each designers' idea generation process.

3.3 Discussion

In this first study, we found the prompt to represent people explicitly in sketches led to changes in students' design thinking about people. Students rarely included representations of people in their sketches on their own, but all students represented people in sketches and showed improvements in considering people following the instruction to draw people. Applying the instruction in the second session may incur some cost: Students generated slightly fewer design ideas (10%) in the second session, though this may be due to creative exhaustion (Gray et al., 2019).

After the instruction to draw people, more design ideas considered how people would physically interact with a design. Considering physical integration is critical for designs requiring direct interactions with users' bodies; for example, one study found positive impacts of practicing somaesthetic reflection during ideation, a practice where the designer mindfully brings attention to interactions between their body and the designed object (Wonjun et al., 2014). Design ideas after the instruction also included a full person's body more often. Depicting people in design idea sketches enhanced awareness of physical interactions with the human body.

The instruction also spurred an expansion of considering multiple people beyond the primary user. More attention went to multiple stakeholders, such as movers, landlords, and neighbours. Students' expanded attention shows awareness of social roles and reflects a more accurate understanding of the interdependence upon which many communities are built (e.g., Piepzna-Samarasinha, 2018). Further, the exploration of varied roles shows greater awareness of the context of use, a practice essential in implementing human-centred designs (Burleson et al., 2020; Holtzblatt et al., 2004). Inclusion of people's emotions in design ideas may be expected to aid empathy development (Kouprie and Visser, 2009), and depicting communications between people may suggest thinking more deeply about complex social contexts (Zoltowski et al., 2012).

Qualitative analyses revealed multi-faceted effects of the instruction for individual designers. The changes after instruction included moving to integral descriptions of people in designs and highlighting physical or emotional context with individuals moving in both directions. It is reported that emotions can impact the success of designs (Artacho et al., 2010; McDonagh et al., 2009). Further work is needed to understand how the instruction to draw people is adapted by individual designers, and how disciplinary training may support specific directions.

Designers often design for themselves (Duquenoy and Thimbleby, 1999) and use generic language to extend their own experiences onto others as a way of meaning-making (Orvell et al., 2017). However, human-centred design approaches emphasise the importance of understanding the variety of potential users beyond oneself (Costanza-Chock, 2020; Molenbroek and de Bruin, 2005; Shum et al., 2016). The instruction to

depict people in designs requires more specific descriptions of people, moving away from generic or self-inspired designs. Design ideas in the second session were often inspired by more complex scenarios grounded in richer descriptions of experiences. The instruction to represent people in design sketches helped students across disciplines think differently about people impacted by their designs.

4 Study 2: does instruction to draw people in sketches change design ideas?

In a second study, we tested whether the observed within-subject differences occur in an experimental design with a larger sample, focusing on the changes to design idea sketches.

4.1 Method

4.1.1 Participants

Participants included 42 undergraduate university students studying mechanical engineering in their second to fourth years of study. All previously completed at least one project-based engineering design course. Students self-identified their gender, with 27 men, 14 women, and 1 non-binary person, and their race/ethnicity as Asian (21), white (11), multi-racial (9), and Hispanic/Latinx (1). Students were recruited through email lists in a mechanical engineering department. Each student received $30 as compensation for their time in completing the study.

4.1.2 Materials

To make direct comparisons between the first and second studies, we employed the same design problem, ‘help people move households,’ described in Figure 1. We provided participants with design idea worksheets to record as many design idea sketches and written descriptions as possible within a single 30-min session.

4.1.3 Procedure

The stand-alone design sessions were conducted with small groups of participants in the same room. Participants performed the individual design task from Study 1 working only on paper without any think-aloud protocol. Participants were assigned at random to receive the instructions to draw people (n = 20) or were given no instructions as a control group (n = 22). In both contexts, students worked alone on the same design problem to generate design ideas. The facilitator instructed participants to include any information they wished in their design idea sketches and to add written details for each design idea to allow someone else to understand it. The experimental group received the additional instructions and example sketches from the first study (shown in Figure 2): “Represent people, a person, or parts of a person” in their design idea sketches.

4.1.4 Data analysis

For each design idea, we analysed all participants' design idea sketches using themes from Study 1 to compare the sketches on emotion, communication, physical integration, multiple people, and full body depiction (see Table 2). Given the previously established high inter-rater reliability, a single trained researcher completed all coding for this study while blind to condition (experimental or control).

4.2 Results

Participants generated between 2 and 9 design ideas, with the control group (n = 22) generating 106 design ideas with an average of 4.8 (SD = 1.7) and the experimental group (n = 20) generating 89 design ideas with an average of 4.5 design ideas (SD = 1.6) (see Table 8). Of the 195 total design idea sketches, 107 (54.9%) included depictions of people, with most (80, or 75%) generated by the experimental group. Figure 5 shows the proportion of sketches identified by themes, with all revealing significant differences by group (see Table 9).

Table 8 Number of design ideas generated by session and number depicting people

	Control group (n = *22*)		*Experimental Group* (n = *20*)	
Generated design ideas	*All design ideas*	*Design ideas with people*	*All design ideas*	*Design ideas with people*
Total	106	23	89	80
Mean	4.8	1.2	4.5	4.0
SD	1.7	1.1	1.6	2.0
Percentage	54%	12%	46%	41%

Figure 5 Proportion of sketches from the control (n = 107) vs. experimental group (n = 89) identified in five themes: depicting physical interaction, a full body, multiple people, communication between people, and emotion

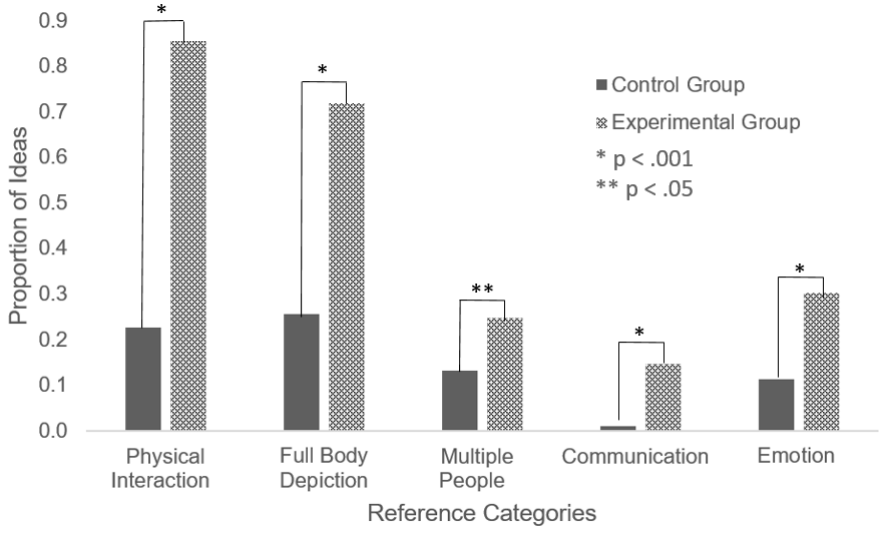


Table 9 Proportion of sketches by session observed for five identified themes: physical interaction, full body depiction, multiple people, communication, and emotion

	Proportion		*Count*			
	Control	*Instructed*	*Control*	*Instructed*	*Chi-Square*	*Significance*
Physical interaction	0.23	0.85	24	76	76.2	$p < 0.001$
Full body	0.26	0.72	27	64	41.9	$p < 0.001$
Multiple people	0.13	0.25	14	22	4.3	$p < 0.05$
Communication	0.01	0.14	1	13	13.5	$p < 0.001$
Emotion	0.11	0.30	12	27	10.9	$p < 0.001$
Total	0.55	0.45	107	89		

The proportion of all theme categories was significantly higher in the experimental group than in the control group, with design ideas depicting physical interaction and a people's full bodies occurring most often. The greatest change after the instruction occurred with the physical interaction category, indicating that the instruction particularly supported participants in increasing their consideration of how stakeholders interact with the designed solution. Almost no ideas in the control group considered communication between stakeholders, indicating that the instruction to draw people was an important tool in eliciting that consideration for more of the ideas in the experimental group.

4.3 Discussion

In this second study, we found the instruction for mechanical engineering students to represent people explicitly in sketches generated important differences in design idea sketches. Students in the experimental group showed significantly more representations of people across all five categories of interest: stakeholder physical interaction, showing full bodies, drawing multiple people, representing communication between stakeholders, and showing stakeholder emotion. Students generated slightly fewer design ideas in the experimental group than the control group, indicating that the instruction may take students more time to implement than their natural, unaided idea generation process.

5 General discussion

Overall, the instruction to represent people in sketches during idea generation led to many improvements in students' considerations of interactions of people within their design ideas. The findings from the first study were supported across a greater number of students in the second study. By analysing the sketches from both studies using the same categorisation scheme, we found the effects identified in Study 1 were replicated in Study 2. Additionally, in the second study, we found the instruction to draw people prompted a significant increase in students' consideration of communication between people within their design ideas. The two studies differed: the first study examined 15 design students across mechanical engineering, user experience, and art and design programs; the second study examined 42 mechanical engineering students. The variation in training may lead to different effects by the instruction. Alternatively, the difference could indicate a trend that simply was not evident in the smaller sample in Study 1.

We aimed to determine whether a simple instruction to represent people in sketches may help student designers to centre people during idea generation. This instruction on its own may not produce nuanced empathy comparable to co-design research methods, but it appears to be a method promoting incorporation of nuanced and complex information about people during idea generation. Educators and designers can combine this instruction to represent people in idea sketches with other strategies to deepen consideration of people.

The findings from the present studies support many of the same conclusions about mental visualisations by Dahl et al. (2001). Working without instructions, student designers rarely showed evidence of visualisations of user interactions within their design idea sketches. With a simple instruction to depict people in sketches, resulting designs showed varied ways for people to interact with proposed designs. Our findings are consistent with those of Dahl et al. (2001) in showing that imagining people within design ideas increased consideration of users. In Dahl et al.'s (2001) experiments, they prescribed a specific type of customer to visualise (a senior citizen). In our studies, we allowed students to define the qualities of people they wanted to represent. This approach not only allowed for more flexibility in designed solutions, but also provided insight in the qualities students naturally considered when attempting to centre people in design.

An advantage of the simple 'represent people' instruction in the present studies is that it avoids specifying how the process of mental visualisation is to take place; instead, the instruction only specifies the presence of people in the design sketch. This approach may produce more variation among individuals about how they generated their design ideas and the representations of people within them; however, Dahl and colleagues (2001) also noted a lack of consistency in applying their instructions across students. While our instruction about depicting people is much simpler, it is effective in producing design outcomes with desirable features of deeper consideration of centring people. In further analyses of students' reflections on their design ideas from this dataset, we examined more closely what types of people students selected to describe as their end user (Makhlouf et al., 2023). We found that with the instruction to draw people, students focused more on people's social and physical context of use as well as their personal preferences and values. We also found that depicting people decreased students' claims that their designs worked for 'everyone,' suggesting a more nuanced understanding of the ways design decisions impact different people differently.

Our findings go beyond earlier studies by demonstrating that sketches and descriptions of design ideas during the design task capture differences in how people are considered depending on adding an instruction to include people in the design idea sketches. The present research establishes a method for assessing what designers consider about people and how their design thinking changes with a prompt to represent people in their design idea sketches.

Expanding focus beyond a singular user and exploring communication between stakeholders demonstrate increased attention to people in a community. Bradshaw (2008) described community in part as built on social relations – namely, community structure and interactions between people. We additionally follow the guidance of disabled, queer, and nonbinary scholar Leah Lakshmi Piepzna-Samarasinha, who defined present and future communities as networks of people giving and receiving to one another. They envisioned futures of collective responsibility, the building blocks of which are thinking beyond the individual and imagining various relationships between people. While we did not measure the diversity of people students considered, we saw evidence of multiple

shifts that indicate steps towards the community-centred practices recommended by design justice, human centred design, and other socially-engaged practices (Costanza-Chock, 2020; Design Justice Network, 2018; IDEO, 2019).

Both studies show that an instruction aimed at the physical interaction of people and designs promotes richer understanding of humans within design ideas. The simple instruction in our study increased the number and variety of people designers considered in the implications of their designs, essential skills identified by systems thinking literature (Frank, 2000; McKay et al., 2018). An additional related student survey demonstrated that drawing people during idea generation helped students consider social community and a variety of people beyond themselves (Makhlouf et al., 2023). Drawing people in designs supports Design Justice practices engaging with the many diverse people comprising communities potentially affected by design implementations (Costanza-Chock, 2020; Design Justice Network, 2018). Our studies provide an 'easy to implement' step towards considering impact on people more deeply and intentionally early in design processes.

5.1 Limitations

Our goal was to identify a method to support designers in considering people more deeply as they generated design ideas. However, we did not attempt to directly measure the overall 'human-centredness' of the design ideas. Comparing designs on this dimension presents challenges because 'human-centredness' is not unidimensional and may be evident through different qualitative features within designs. In addition, the qualities designers addressed in their design thinking (Study 1) and design idea descriptions (Studies 1 and 2) showed richer considerations of people following the instruction to depict people in design sketches. Observation of *how* designers represented people in their sketches and discussed people's needs identified differences in kinds of human-centred thinking produced by following the instruction to represent people in designs.

In the AB design of Study 1, the instruction always occurred in the second session. This complicates assessing design idea quality because early and late design ideas also differ due to serial order. It is not possible to introduce the instruction to represent people within the first session and then ask participants to ignore it in a second session because they are already informed by the earlier session. In addition, verbalising thoughts through a think-aloud protocol in Study 1 may affect design processes; however, evidence shows speaking thoughts that come to mind (talking aloud concurrently rather than explaining thoughts) does not influence cognitive task outcomes (Ericsson and Simon, 1980; 1993). Think-aloud protocols have contributed important findings to better understanding idea generation (Atman and Bursic, 1998; Cross, 2001; Hay et al., 2017).

The generalisability of our results to practicing designers is limited by the study design using a single design problem, a brief session of solo design, and the participation of student designers. These choices improved experimental control in Study 2, but it also included only mechanical engineering design students. The proposed method of instruction about representing people in concepts is limited in applying only to parts of the design process where sketching occurs. Later stages such as prototyping, for example, do not afford the same opportunities for representing people. It is important to identify methods to support human-centred orientations across design processes. Further work may explore the value of explicit representations of people in promoting centring people

with more advanced designers, other design problems, teams of designers, and other design contexts. Though we did not observe differences between fields of design, disciplines differ in their approaches to centring people, and training materials, methods, and experiences by discipline may identify other methods for facilitating consideration of people during design.

5.2 Implications

The findings from this study show thinking about people when generating design ideas can be enhanced by sketching them interacting with designs. Student designers reported considering more, and more varied, potential end users as well as more diverse needs when asked to include people within design idea sketches. Drawing people within design ideas drew attention to who may use a design and how people may interact with it. Explicitly representing people within design ideas is an easy strategy to implement, and it successfully promoted deeper consideration of people during design, the key definition of human-centred design approaches. Further, making people a focus across design work can support designs more appropriate for the people and contexts in which the design is intended to be situated.

Another implication is to focus attention more specifically on who designers intend as end users of their designs. During idea generation, designers could be asked to clarify which experiences are informing design ideas to prevent perpetuation of their own biases and assumptions. In the absence of explicit experiences and broader perspectives from others, students may unconsciously pull from their own life experiences rather than those of potential users and other stakeholders. Another strategy could be to avoid the use of gendered terms (e.g., "he") that may unconsciously promote limited views of people. Explicit consideration of varied social contexts (e.g., students living in dorms, families with children, international moves, senior centres) may encourage more diverse consideration of people in designs. Identifying people to consider may help designers better describe who their design is for and who it is *not* for, promoting more rich considerations of how people are impacted by designs.

6 Conclusion

To promote considering people during idea generation, we introduced an instruction to represent people in design idea sketches in two studies with student designers. The findings suggest that drawing people within idea sketches can help designers think more deeply about who may interact with their designs and how people may be impacted. The think-aloud protocols revealed changes in design thinking following the instruction, such as including emotional or physical contexts, a wider variety of stakeholders, and more specific experiences. Across both studies, we observed that including people in design idea sketches promoted considering people's physical, emotional, and experiential interactions within designs. The simple intention to include representations of people interacting with design ideas can assist designers in centring humans in design processes.

Acknowledgements

Professors Eytan Adar and Sophia Brueckner collaborated in the design of the first study. This project was funded by the University of Michigan M-Cubed grant U064092 awarded to Seifert, Daly, Adar, and Brueckner. The research reported in this publication was also supported by the National Science Foundation (NSF) division of Engineering Education and Centers (EEC) in the CAREER program, grant #1943805. The studies were reviewed by the University of Michigan IRB and found exempt, #HUM00169175 and #HUM000170992.

References

Akin, O. and Lin, C. (1995) 'Design protocol data and novel design decisions', *Design Studies*, Vol. 16, No. 2, pp.211–236.

Alzheimer's Association (2018) *We are Alfred: VR Helps Students Experience Dementia*, Medical Design and Outsourcing, 24 July, https://www.medicaldesignandoutsourcing.com/we-are-alfred-vr-helps-students-experience-dementia/

Artacho, M.A., Ballester, A. and Alcantara, E. (2010) 'Analysis of the impact of slight changes in product formal attributes on user's emotions and configuration of an emotional space for successful design', *Journal of Engineering Design*, Vol. 21, No. 6, pp.693–705, https://doi.org/10.1080/09544820902875058

Athavankar, U.A. (1997) 'Mental imagery as a design tool', *Cybernetics and Systems*, Vol. 28, No. 1, pp.25–42.

Atman, C.J., Adams, R.S., Cardella, M.E., Turns, J., Mosborg, S. and Saleem, J. (2007) 'Engineering design processes: a comparison of students and expert practitioners', *Journal of Engineering Education*, Vol. 96, No. 4, pp.359–379, https://doi.org/10.1002/j.2168-9830.2007.tb00945.x

Atman, C.J. and Bursic, K.M. (1998) 'Verbal protocol analysis as a method to document engineering student design processes', *Journal of Engineering Education*, Vol. 87, No. 2, pp.121–132.

Bannon, L.J. and Ehn, P. (2013) 'Design matters in participatory design', *Routledge International Handbook of Participatory Design*, 1st ed., Routledge.

Bearman, M., Palermo, C., Allen, L.M. and Williams, B. (2015) 'Learning empathy through simulation: a systematic literature review', *Society for Simulation in Healthcare*, Vol. 10, No. 5, pp.308–319, https://doi.org/10.1097/SIH.0000000000000113

Bennett, C.L. and Rosner, D.K. (2019) 'The promise of empathy: design, disability, and knowing the 'other'', *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, Glasgow, Scotland UK, pp.1–13, https://doi.org/10.1145/3290605.3300528

Bødker, S. (2015) 'Third-wave HCI, 10 years later–participation and sharing', *Interactions*, Vol. 22, No. 5, pp.24–31, https://doi.org/10.1145/2804405

Bradshaw, T.K. (2008) 'The post-place community: contributions to the debate about the definition of community', *Community Development*, Vol. 39, No. 1, pp.5–16, https://doi.org/10.1080/15575330809489738

Buchenau, M. and Suri, J.F. (2000) 'Experience prototyping', *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, New York, NY, pp.424–433, https://doi.org/10.1145/347642.347802

Burleson, G., Sienko, K.H. and Toyama, K. (2020) 'Incorporating contextual factors into a design process: an analysis of engineering for global development literature', *Proceedings of the ASME 2020 International Design Engineering Technical Conference*, August, Virtual, Online, https://doi.org/10.1115/DETC2020-22634

Buxton, B. (2007) *Sketching User Experiences: Getting the Design Right and the Right Design*, Morgan Kaufman, San Francisco, CA.

Carroll, J.M. (1997) 'Human-computer interaction', *International Journal of Human-Computer Studies*, Vol. 46, No. 4, pp.501–522, https://doi.org/10.1006/ijhc.1996.0101

Center for Socially Engaged Design (2020) *Socially Engaged Design Process Model*, https://csed.engin.umich.edu/socially-engaged-design-process-model/

Charmaz, K. (2006) *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*, Sage, London.

Cohen, J. (1960) 'A coefficient of agreement for nominal scales', *Educational and Psychological Measurement*, Vol. 20, No. 1, pp.37–46, https://doi.org/10.1177/001316446002000104

Costanza-Chock, S. (2020) *Design Justice: Community-Led Practices to Build the Worlds We Need*, MIT Press, Boston, MA.

Creswell, J.W. (2013) *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, Sage Publications, London.

Cross, N. (2001) 'Design cognition: results from protocol and other empirical studies of design activity', in Eastman, C.M., McCracken, W.M. and Newstetter, W.C. (Eds.): *Design Knowing and Learning: Cognition in Design Education*, Elsevier, pp.79–104.

Cross, N. (2008) *Engineering Design Methods: Strategies for Product Design*, 4th ed., Wiley, Hoboken, NJ.

Cross, N. (2021) *Engineering Design Methods: Strategies for Product Design*, 5th ed., John Wiley and Sons, Hoboken, NJ.

Dahl, D.W., Chattopadhyay, A. and Gorn, G.J. (2001) 'The importance of visualisation in concept design', *Design Studies*, Vol. 22, No. 1, pp.5–26, https://doi.org/10.1016/S0142-694X(99)00028-9

Daly, S.R., Seifert, C.M., Yilmaz, S. and Gonzalez, R. (2016) 'Comparing ideation techniques for beginning designers', *Journal of Mechanical Design*, Vol. 138, No. 10, p.101108, https://doi.org/10.1115/1.4034087

Design Justice Network (2018) *Design Justice Network Principles*, https://designjustice.org/read-the-principles

Dieter, G.E. and Schmidt, L.C. (2013) *Engineering Design*, 5th ed., McGraw-Hill, Philadelphia, PA, USA.

DiSalvo, C., Clement, A. and Pipek, V. (2013) 'Communities: Participatory design for, with, and by communities', *Routledge International Handbook of Participatory Design*, Routledge, New York, NY.

Duquenoy, P. and Thimbleby, H. (1999) 'Justice and design', *Human-Computer Interaction–INTERACT'99*, IOS Press, Edinburgh, UK, pp.281–286.

Dym, C.L. and Little, P. (2004) *Engineering Design: A Project-Based Introduction*, 3rd ed., John Wiley & Sons, Hoboken, NJ.

Ericsson, K.A. and Simon, H.A. (1980) 'Verbal reports as data', *Psychological Review*, Vol. 87, No. 3, pp.215–251.

Ericsson, K.A. and Simon, H.A. (1993) *Protocol Analysis–Verbal Reports as Data*, MIT Press, Boston, MA.

Flower, A., Burns, M.K. and Bottsford-Miller, N.A. (2007) 'Meta-analysis of disability simulation research', *Remedial and Special Education*, Vol. 28, No. 2, pp.72–79.

Francis, M. (1983) 'Community design', *Journal of Architectural Education*, Vol. 37, No. 1, pp.14–19, https://doi.org/10.1080/10464883.1983.11102642

Frank, M. (2000) 'Engineering systems thinking and systems thinking', *Systems Engineering*, Vol. 3, No. 3, pp.163–168.

Freeman, R.E. (2010) *Strategic Management: A Stakeholder Approach*, Cambridge University Press, Cambridge, UK, https://doi.org/10.1017/CBO9781139192675

Gero, J.S. and Tang, H.H. (2001) 'The differences between retrospective and concurrent protocols in revealing the process-oriented aspects of the design process', *Design Studies*, Vol. 22, No. 3, pp.283–295, https://doi.org/10.1016/S0142-694X(00)00030-2

Goel, V. (1995) *Sketches of Thought*, MIT Press, Boston, MA.

Goldschmidt, G. (1992) 'Serial sketching: visual problem solving in designing', *Cybernetics and Systems*, Vol. 23, No. 2, pp.191–219.

Goldschmidt, G. (1994) 'On visual design thinking: the vis kids of architecture', *Design Studies*, Vol. 15, pp.158–174.

Gray, C.M., McKilligan, S., Daly, S.R., Seifert, C.M. and Gonzalez, R. (2019) 'Using creative exhaustion to foster idea generation', *International Journal of Technology and Design Education*, Vol. 29, No. 1, pp.177–195, https://doi.org/10.1007/s10798-017-9435-y

Hay, L., Duffy, A.H., McTeague, C., Pidgeon, L.M., Vuletic, T. and Grealy, M. (2017) 'A systematic review of protocol studies on conceptual design cognition: design as search and exploration', *Design Science*, Vol. 3, No. 10, p.e10.

Holtzblatt, K., Wendell, J.B. and Wood, S. (2004) *Rapid Contextual Design: A How-to Guide to Key Techniques for User-Centered Design*, Elsevier, Amsterdam, NL.

IDEO (2015) *The Field Guide to Human-Centered Design*, ISBN: 978-0-9914063-1-9, https://www.designkit.org/resources/1.html

IDEO (2019) *The Human-Centered Design Toolkit*, https://www.ideo.com/journal/design-kit-the-human-centered-design-toolkit

Inclusive Design Research Center (n.d.) *Philosophy: What is Inclusive Design?*, OCAD University. Retrieved 27 January, 2023 from https://idrc.ocadu.ca/about/philosophy/

Institute of Design at Stanford (n.d.) *An Introduction to Design Thinking: Process Guide*, Retrieved 4 April, 2022 from https://web.stanford.edu/~mshanks/MichaelShanks/files/509554.pdf

International Organization of Standardization (2019) *Ergonomics of Human-system Interaction–Part 210: Human-Centred Design for Interactive Systems* (ISO 9241-210; Version 2).

Jobin, A., Ienca, M. and Vayena, E. (2019) 'The global landscape of AI ethics guidelines', *Nature Machine Intelligence*, Vol. 1, pp.389–399.

Kafer, A. (2013) *Feminist, Queer, Crip*, Indiana University Press, Bloomington, IN.

Karimi, P., Rezwana, J., Siddiqui, S., Maher, M.L. and Dehbozorgi, N. (2020) 'Creative sketching partner: an analysis of human-AI co-creativity', *25th International Conference on Intelligent User Interfaces*, New York, NY, pp.221–230, https://doi.org/10.1145/3377325.3377522

Khurana, A. and Rosenthal, S.R. (1998) 'Towards holistic 'Front Ends' in new product development', *Journal of Product Innovation Management*, Vol. 15, No. 1, pp.57–74, https://doi.org/10.1111/1540-5885.1510057

Kouprie, M. and Visser, F. (2009) 'A framework for empathy in design: stepping into and out of the user's life', *Journal of Engineering Design*, Vol. 20, No. 5, pp.437–448.

Landis, J.R. and Koch, G.G. (1977) 'The measurement of observer agreement for categorical data', *Biometrics*, Vol. 33, No. 1, pp.159–174.

Larkin, J. and Simon, H. (1987) 'Why a diagram is (sometimes) worth ten thousand words', *Cognitive Science*, Vol. 11, pp.65–99.

Laut Design (2023) *Product Design: Great Brands Make Products People Love*, https://laut design.com/product-design/

Macfie, R.L., Hay, L.A. and Rodgers, P. (2023) 'A framework for understanding mental imagery in design cognition research', *Proceedings of the International Conference on Engineering Design. ICED23*, Bordeaux, France, https://doi.org/10.1017/pds.2023.18

Makhlouf, T.E., Murphy, L.R., Daly, S.R. and Seifert, C.M. (2023) 'Who is this design for? Promoting consideration of people during concept generation', *ASME 2023 International Design Engineering Technical Conference*, Boston, MA.

McDonagh, D., Denton, H. and Chapman, J. (2009) 'Design and emotion', *Journal of Engineering Design*, Vol. 20, No. 5, pp.433–435, https://doi.org/10.1080/09544820902915300

McKay, A., Baker, R., Chittenden, R. and de Pennington, A. (2018) 'A framework for students to visualise the implications of design decisions in global supply networks', *International Conference on Engineering and Product Design Education*, London, UK.

McNeill, T., Gero, J.S. and Warren, J. (1998) 'Understanding conceptual electronic design using protocol analysis', *Research in Engineering Design*, Vol. 10, No. 3, pp.129–140, https://doi.org/10.1007/BF01607155

Miaskiewicz, T. and Kozar, K.A. (2011) 'Personas and user-centered design: how can personas benefit product design processes?', *Design Studies*, Vol. 32, No. 5, pp.417–430, https://doi.org/10.1016/j.destud.2011.03.003

Molenbroek, J. and de Bruin, R. (2005) 'Enhancing the use of anthropometric data', *Human Factors in Design, Safety, and Management*, Shaker Publishing, Maastricht, NL, pp.289–297.

Murphy, L.R., Daly, S.R. and Seifert, C.M. (2022) 'Idea characteristics arising from individual brainstorming and design heuristics ideation methods', *International Journal of Technology and Design Education*, Vol. 33, pp.1–42, https://doi:org/10.1007/s10798-021-09723-0

National Research Council (U.S.) (1991) *Improving Engineering Design: Designing for Competitive Advantage*, National Academy Press, Washington, DC.

Norman, D. (2013) *The Design of Everyday Things: Revised and Expanded Edition*, Basic Books, New York, NY.

Norman, D.A. and Draper, S.W. (1986) *User Centered System Design: New Perspectives on Human-Computer Interaction*, CRC Press, Hillsdale, NJ.

Nuseibeh, B. and Easterbrook, S. (2000) *Requirements Engineering: A Roadmap*, pp.35–46.

Orvell, A., Kross, E. and Gelman, S.A. (2017) 'How 'you' makes meaning', *Science*, Vol. 355, pp.1299–1302, https://doi.org/10.1126/science.aaj2014

Osborn, A.F. (1963) *Applied Imagination: Principles and Procedures of Creative Problem-Solving*, 3rd rev ed., Scribner.

Pahl, G., Beitz, W., Feldhusen, J. and Grote, K-H. (2007) *Engineering Design: A Systematic Approach*, 3rd ed., Springer-Verlag, London, UK, http//www.springer.com/us/book/9781846283185

Piepzna-Samarasinha, L.L. (2018) 'Care webs: experiments in creating collective access', *Care Work: Dreaming Disability Justice*, Arsenal Pulp Press, Vancouver, BC, Canada.

Purcell, A.T. and Gero, J.S. (1998) 'Drawings and the design process: a review of protocol studies in design and other disciplines and related research in cognitive psychology', *Design Studies*, Vol. 19, No. 4, pp.389–430.

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design Fundamentals and Methods*, John Wiley & Sons, Hoboken, NJ.

Sanders, B-N.E. and Stappers, P.J. (2008) 'Co-creation and the new landscapes of design', *CoDesign*, Vol. 4, No. 1, pp.5–18, https://doi.org/10.1080/15710880701875068

Schön, D.A. (1983) *The Reflective Practitioner: How Professionals Think in Action*, Basic Books, New York, NY.

Schütze, M., Sasche, P. and Römer, A. (2003) 'Support value of sketching in the design process', *Research in Engineering Design*, Vol. 14, pp.89–97.

Shah, J.J., Kulkarni, S.V. and Vargas-Hernandez, N. (2000) 'Evaluation of idea generation methods for conceptual design: effectiveness metrics and design of experiments', *Journal of Mechanical Design*, Vol. 122, No. 4, p.377, https://doi.org/10.1115/1.1315592

Shah, J.J., Smith, S.M. and Vargas-Hernandez, N. (2003) 'Metrics for measuring ideation effectiveness', *Design Studies*, Vol. 24, No. 2, pp.111–134, https://doi.org/10.1016/S0142-694X(02)00034-0

Shah, J.J., Vargas-Hernandez, N., Summers, J.D. and Kulkarni, S. (2001) 'Collaborative sketching (C-sketch)–an idea generation technique for engineering design', *The Journal of Creative Behavior*, Vol. 35, No. 3, pp.168–198, https://doi.org/10.1002/j.2162-6057.2001.tb01045.x

Shum, A., Holmes, K., Woolery, K., Price, M., Kim, D., Dvorkina, E., Dietrich-Muller, D., Kile, N., Morris, S., Chou, J. and Malekzadeh, S. (2016) *Inclusive Design Toolkit*, Microsoft Design.

Siebers, T. (2008) *Disability Theory*. University of Michigan Press, Ann Arbor, MI.

Singleton, W.T. (1971) 'Ergonomics and community needs', *Applied Ergonomics*, Vol. 2, No. 1, pp.37–43, https://doi.org/10.1016/0003-6870(71)90009-3

Stompff, G., Smulders, F. and Henze, L. (2016) 'Surprises are the benefits: reframing in multidisciplinary design teams', *Design Studies*, Vol. 47, pp.187–214, http://dx.doi.org/10.1016/j.destud.2016.09.004

Suwa, M. and Tversky, B. (1997) 'What do architects and students perceive in their design sketches? A protocol analysis', *Design Studies*, Vol. 18, pp.385–403.

Suwa, M., Purcell, T. and Gero, J. (1998) 'Macroscopic analysis of design processes based on a scheme for coding designers' cognitive actions, Vol. 19, No. 4, pp.455–483, https://doi.org/10.1016/S0142-694X(98)00016-7

Trucchia, V. (2020) 'Story of a storyboard', *OpenLab at City Tech*, 10 September, https://openlab.citytech.cuny.edu/comd1112-fall2020-noriega/2020/09/10/story-of-a-storyboard/

Ullman, D.G., Wood, S. and Craig, D. (1990) 'The importance of drawing in the mechanical design process', *Computers and Graphics*, Vol. 14, pp.263–274.

Valkenburg, R. and Dorst, K. (1998) 'The reflective practice of design teams', *Design Studies*, Vol. 19, No. 3, pp.249–281.

Van Dijk, J. (2009) 'Cognition is not what it used to be: reconsidering usability from an embodied embedded cognition perspective', *Human Technology: An International Journal on Humans in Environments, ICT*, Vol. 5, No. 1, pp.29–46.

van Someren, M.W., Barnard, Y.F. and Sandberg, J.a, C. (1994) *The Think Aloud Method: A Practical Approach to Modelling Cognitive Processes*, Academic Press, London, p.0127142703978012714270 8, https://dare.uva.nl/search?identifier=7fef37d5-8ead-44c6-af62-0feeea18d445

Wilson, C. (2006) 'Brainstorming pitfalls and best practices', *Association for Computing Machinery*, Vol. 13, No. 5, pp.50–63.

Wonjun, L., Youn-kyung, L. and Richard, S. (2014) 'Practicing somaesthetics: exploring its impact on interactive product design ideation', *Proceedings of the 2014 Conference on Designing Interactive Systems*, Vancouver, BC, Canada, pp.1055–1064, https://doi.org/10.1145/2598510.2598561

Yang, M.C. (2009) 'Observations on concept generation and sketching in engineering design', *Research in Engineering Design*, Vol. 20, No. 1, pp.1–11.

Yilmaz, S. and Daly, S.R. (2016) 'Feedback in concept development: comparing design disciplines', *Design Studies*, Vol. 45, pp.137–158.

Yock, P., Zenios, S., Makower, J., Brinton, T., Kumar, U., Watkins, J., Denend, L., Kummel, T. and Kurihara, C. (2015) 'Inital concept selection', *Biodesign: The Process of Innovating Medical Technologies*, 2nd ed. Cambridge University Press, Cambridge, UK, pp.250–267.

Zhang, T. and Dong, H. (2009) *Human-Centred Design: An Emergent Conceptual Model*. Include (2009) *Royal College of Art*, London, 8 April, www.hhc.rca.ac.uk/2084/all/1/proceedings.aspx

Zoltowski, C.B., Oakes, W.C. and Cardella, M.E. (2012) 'Students' ways of experiencing human-centered design', *Journal of Engineering Education*, Vol. 101, No. 1, pp.28–59.