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Investigating Engineering Students' Consideration of People During Concept Generation

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Abstract

Does the act of representing people in sketches change the way students consider people in design? We asked five senior-level mechanical engineering students to generate concepts for a design problem. As students generated concepts, they used a think-aloud protocol to talk through their design processes. In the first session, students generated ideas according to their natural concept generation style. In a second session, we asked them to include representations of "people, a person, or parts of a person" in their sketches while generating concepts. We identified five aspects of these representations in sketches: multiple users, body depictions, physical integration, emotional expressions, and communication. In transcriptions of the think-aloud process, we analyzed the level of generality and word choice when students talked about people in their designs. Our findings indicate that students showed multiple signs of thinking more deeply about their potential users and the users' context when using representations of people in their designs. Asking students to represent people in sketches may serve as a simple intervention that instructors can implement to help students think about people when stakeholders are not present during human-centered design.

Introduction

Design approaches emphasizing attention to people as users have become prominent in many engineering fields and disciplines. They have adopted approaches including ergonomics, user-centered design (UCD), human-centered design (HCD), design thinking, and inclusive design. A unifying theme is to emphasize the need for engineers to consider people who will use their designs in order to create solutions that work for users in real contexts. All of these people-focused design approaches suggest integrating people throughout the design process, seeking to understand users' needs and their contexts holistically [1], [2]. A key emphasis in people-focused design approaches is empathy [3]–[5]. Empathy is viewed as necessary to understand people's experiences and incorporate their perspectives into design decisions. To be effective, empathy requires more than knowing about the user. Rather, the designer has to relate to the user and understand their feelings, experiences, and perspectives [6]. A co-creation design process includes stakeholders as partners in generating ideas [7], but when working on designs independently, deep empathy is often challenging. In concept generation, engineers explore many potential solutions to a problem through sketching and describing multiple ideas [8]–[10]. Unfortunately, there is little evidence on how engineers keep people in mind during concept generation.

To investigate how to support engineering designers in considering people throughout their concept generation we implemented a simple intervention: asking engineers to incorporate representations of people within their concept sketches. In our single session study, mechanical engineering students first generated concepts in response to a design prompt on their own. The students talked aloud as they generated concepts in words and sketches for a short period. Then, we prompted the students to continue generating concepts for the same design task, but asked them to include representations of "people, a person, or part of a person" within their sketches. Finally, we conducted a retrospective interview where students reflected on their concepts across both concept generation sessions. Our research goals were to identify how designers considered people and whether their process changed with the request to explicitly include drawings of people within sketches. The conceptual sketches and associated "think-aloud" transcripts were then analyzed to determine the impact of the representational prompt on engineers' thought processes and design outcomes. With a simple intervention to represent people within sketches, we found several positive effects on how engineers considered people during design.

Background

Human-centered design (HCD) has been an important approach in engineering since the 1980s. This framework is commonly used in design when solutions to problems are developed by involving the human perspective in all steps of the problem-solving process. A variety of design approaches such as Norman's HCD, IDEO's design thinking, inclusive design, and user centered design specify differing methods for focusing on human users during design, but all engage in centering people as key players in developing designs. Human-centered design supports consideration of peoples' context [4], [11]; user-centered design addresses how people interact with designed objects [12]; and inclusive design accounts for all of the ways people are different and accommodating for those differences [13], [14]. Consideration of people early in design is important in meeting higher-level human needs [2], needs which go beyond utility and even usability by addressing people's complex socio-political and emotional contexts.

Considering people helps engineered solutions meet people's functional needs *and* their needs for desirability (*do I want this?*), cultural fit (*does this align with my values?*), and contextual fit (*does this work within my community and environment?*). Accounting for a *wide variety* of people helps engineers identify what are known in disability studies as "openings" [15], "misfits" [16], or "mismatches" [13], [17]. These mismatches are opportunities for engineering solutions to create harmony between bodies and the built world. Design can go beyond meeting basic needs; design can elevate people's experience in the world [14]. One classic example of a mismatch in the inclusive design space is the OXO Good Grips line of kitchen tools. The re-design of the vegetable peeler began with a woman named Betsey Farber who experienced a mismatch between her arthritic hands and an old metal vegetable peeler [14], [18]. Together with her husband, they iteratively designed what are now ubiquitous black rubber handles extended to many other kitchen tools. Farber's mismatch allowed for a design opening that served not only herself, not only people with limited dexterity, but ultimately became a better designed product for anyone who wants to use a vegetable peeler.

Identifying these human "mismatches" begins in the early stages of a design process, often called *front-end design* in engineering [8]. Front-end design includes background research, problem

definition, concept generation, and initial prototyping with the goal to deeply understanding context, constraints, and potential design solutions to inform later stages of design [8], [19]. These early stages have important impacts on the ultimate success of the design outcomes [8]. In some front-end activities, like early prototyping, designers often engage in the design context with users and other stakeholders, and research suggests strategies to meaningfully and effectively engage with users and other stakeholders for those activities (i.e. [20]). Concept generation, however, often occurs independently, meaning engineers will generate concepts on their own or with their team, but often without consultation or engagement with potential users. Design co-creation provides a means to integrate people into concept generation by including stakeholders during design sessions; however, there is a great need to support designers in thinking about human users when design work occurs without user engagement, such as when design research ends and development of early concepts begins.

How can engineers (and students) keep people in mind when users are not present? Our previous work introduced our hypothesis that representing people during conceptual sketching may help engineers more deeply consider who their users are and their users' contextual concerns [21]. This study seeks to investigate idea generation with mechanical engineering students to capture a qualitative assessment of how they think about people during conceptual design.

Students' thought processes while creating concepts may suggest ways to understand and shift their attention to people during design. To capture insights on who engineering students are designing for and the specificity and variety of users they consider, we asked students to talk aloud as they designed. Identifying information about people may guide students' thinking, and its qualities may suggest how they are thinking about human users. In this qualitative study, we examine a small group of student engineers as they design concepts for a problem and analyze their concepts and "design talk" for signs of centering people in their idea generation processes.

Method

The goal of this study was to explore the effects of representations of people in conceptual sketches on engineering students' considerations of potential users. The following research questions guided our study:

1) How do engineering students talk about people and represent them within early conceptual designs?
2) When prompted to include depictions of users within their sketches, how does students' thinking about concepts change?

For the first question, we directed our analysis how they represented people before and after being prompted to do so. The second question directed our experimental and analytical methodology, prompting us to incorporate a think-aloud protocol into the study and inductive analysis of patterns we identified across concepts.

Participants

This study included five mechanical engineering undergraduate seniors from a large Midwestern university. Four students identified as male; one student identified as female. One student identified as white, one as Indian, one as Latinx, and two as Asian. Students were recruited

through an email to a senior-level mechanical engineering design course. Each student received $25 as compensation for participating in the study.

Data Collection

Data collection occurred through a single one-hour session with each student. We asked students to generate solutions to a design prompt (see Figure 1) created to be accessible to undergraduate engineering students and lead to diverse design outcomes.

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.

Figure 1: Design problem provided to students.

The study session used a "think aloud" protocol during the two design sessions in order to capture students' thinking about people while creating their concepts. Instructions for the think-aloud process followed Atman and Bursic's (1998) description of verbal protocol analysis [22]. Students first practiced thinking aloud with a practice problem to confirm they understood the protocol. During the study, if students stopped talking aloud at any time, the facilitator prompted them to, "please keep talking."

The one-hour study included two idea generation sessions of 15 minutes each (see Figure 2). During the first session, students generated as many concepts as possible to solve the presented design problem. Students were instructed to create a sketch and written description for each concept they generated. They were free to include any information they chose in their concepts and descriptions (including information about users).

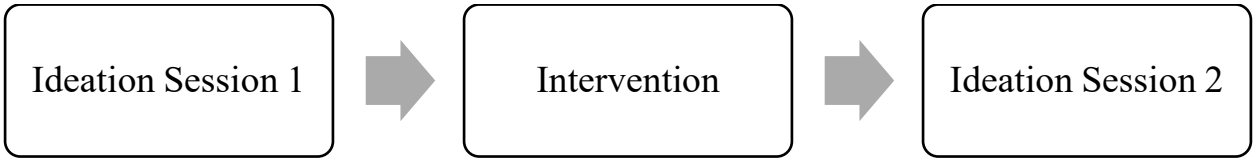


Figure 2: Task sequence in study procedure.

Next, we introduced an intervention: We instructed students to represent "people, a person, or parts of a person" in their sketches. We used this phrasing to allow students to show a single person or multiple people as well as a close-up perspective of a hand operating a phone application, for example. We also provided five example sketches to illustrate how people can be represented within concept sketches (samples in Figure 3). Then, in a second ideation session,

students were asked to continue generating as many concepts as possible to the same design problem.

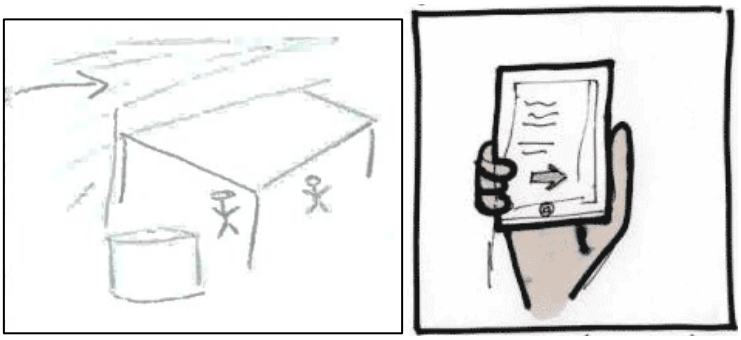


Figure 3: Two (of five) examples provided to students that include representations of people.

Data collected for each student included their set of sketches, written concept descriptions, and transcriptions of the think-aloud protocols. Two example concepts from different students are shown in Figure 4, and one student's entire data set is included in the Appendix.

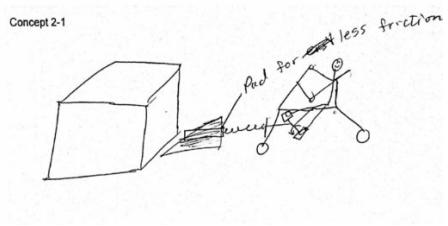
Example Student Concept		
Sketch:	**Written Concept Description:**	**Think-Aloud Transcription:**
	1. App/online organize resources and requires 2. Robot/Machine	"The user requirement can be finding other people to help them to move. So I think first, maybe an app to clearly... No, to organize resources, 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."
	Bike style pedals to push slider under heavy objects and move objects around	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.

Figure 4: Examples of student concepts, including sketch, written description, and transcription of think-aloud protocol during concept generation.

Results and Analyses

The analysis presented in this paper includes 35 concepts generated by 5 senior-level mechanical engineering students. The mean number of concepts generated by students across both sessions was 7.0 (SD=2.5). The number of concepts generated by students ranged from 4 to 10. The number of concepts each student generated in each ideation session is shown in Table 5. On average, more concepts were created in Session 1 than in Session 2.

Table 5: Number of concepts generated by each student per ideation session.

Student	Ideation Session 1	Ideation Session 2	Total
S1	4	3	7
S2	6	4	10
S3	3	2	5
S4	2	2	4
S5	5	4	9
Total:	20	15	35
Average:	4.0	3.0	7.0
Std Deviation:	1.6	1.0	2.5

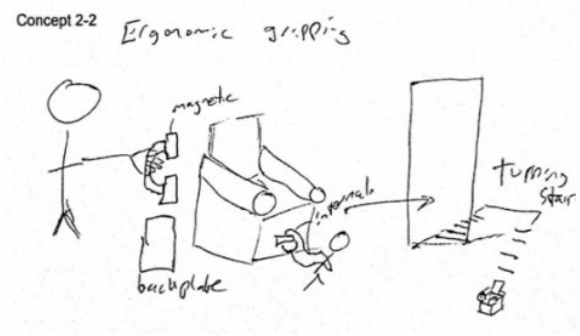
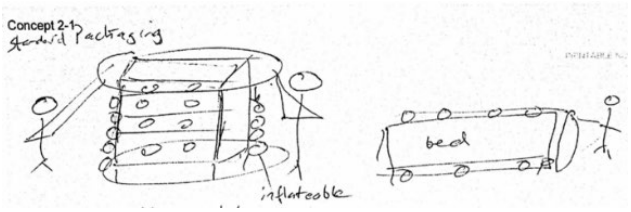
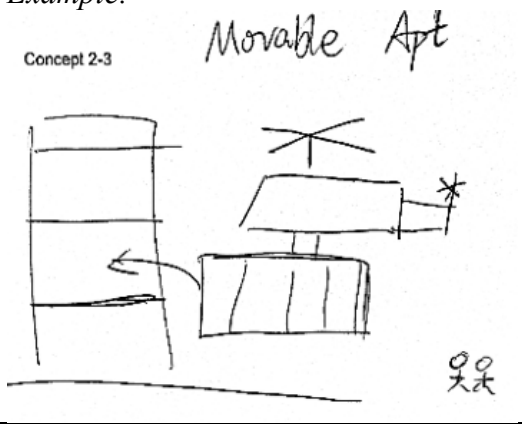
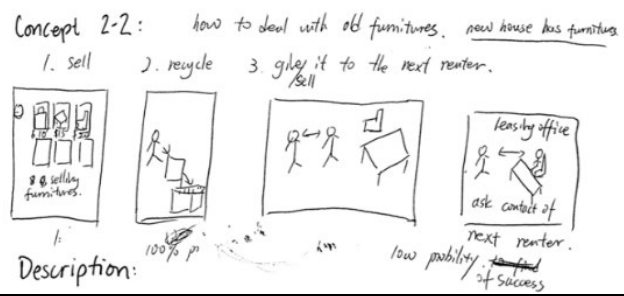
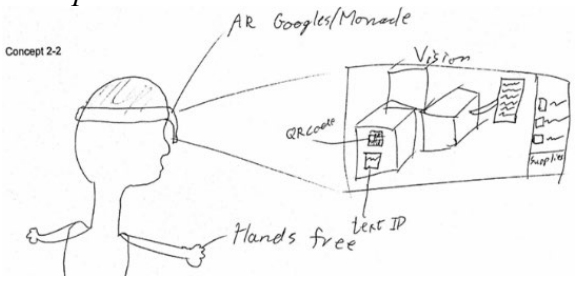
In our analyses, we were interested in identifying variations in students' representations of users in their designs. We considered physical representations of humans in the concept sketches and how students described people in their think-aloud protocols. We developed measures of specificity (discussing people in general, a particular person, etc.) and the words used to describe them. We then considered the differences in these measures in comparing the pre- and post-intervention ideation sessions.

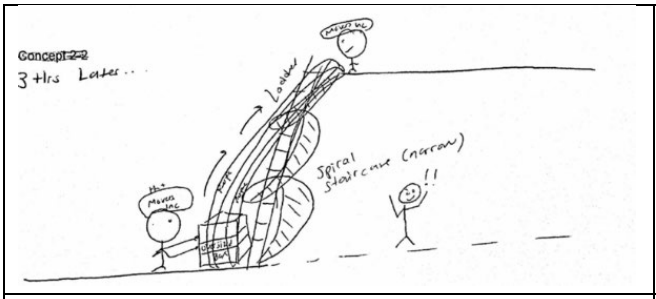
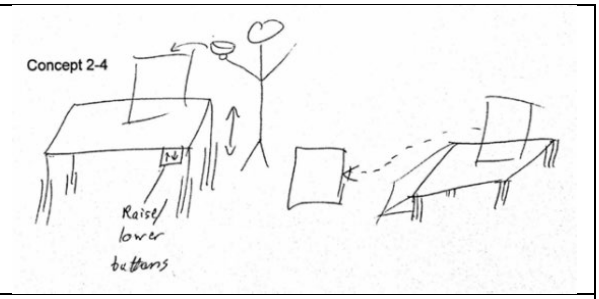
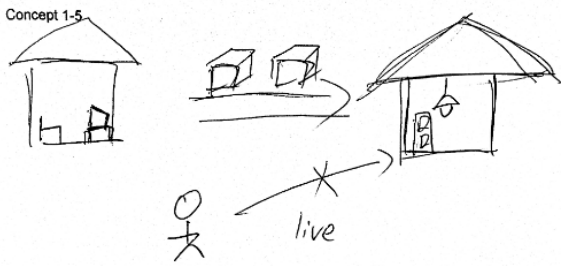
Representations of people in sketches

We iteratively developed a qualitative categorization scheme for sketches based on patterns identified by the research team while examining the data [23]. The categories (shown in Table 1) address specific representations of people as the focus of investigation. Each category was dichotomous, with concepts categorized as present ("Yes" or "No") for each category, but never both nor neither.

Table 1: Definitions of categories capturing aspects of people representations in sketches.

Sketch explicitly depicts emotion	
+ Person displays emotion (positive or negative e.g., smile, sad face, crying, etc.)	- No display of emotion for person

Example: *Smiling* 	*Example*: 
Person is physically integrated with concept	
+ Person interacts with aspect of the concept	- Person is an observer (stands separately)
Example: Stacking materials 	*Example:* 
Depicts a person's full body	
+ Person is depicted in a full-body image	- Only a portion of the person is depicted
Example: 	*Example:* 
Multiple people are represented	
+ More than one person depicted	- Only one person is represented
Example:	*Example:*

	
Communication is displayed	
+ Communication between people is shown (e.g., speech bubbles, text messaging)	- No communication displayed
Example: Web page posting 	*Example:* 

All sketches were scored by two authors and discrepancies in categorization were discussed to consensus [24]. Table 2 shows the percent agreement and Cohen's *kappa* for each category, showing satisfactory agreement for each category [25].

Table 2: Agreement and inter-rater reliability for categorization of person representations.

Representation Category:	**Sketch displays emotion**	**Person is physically integrated**	**Depicts full body**	**Multiple people represented**	**Communication is displayed**
Percent Agreement	100%	88.2%	94.1%	88.2%	87.9%
Cohen's kappa	1.000 – perfect agreement	0.534 – moderate agreement	0.765 – substantial agreement	0.768 – substantial agreement	0.602 – moderate agreement

Representations of People in Think-Aloud Protocols

A second part of analysis examined what students said aloud about people while generating concepts. For example, the "user" identified for the provided design problem was often a person who is moving, but students also talked about other potential stakeholders such as family, friends, or a moving company helping the person moving. We iteratively identified two measures of students' references about people during concept generation: generality of reference and direct references.

Students' references to people were characterized following a level of generality analysis. We inductively identified four categories to capture the different descriptions students gave when referring to people: at the most general level (as "everyone"), as a type of person, as a specific individual, and most specifically, as the designer themselves (as "me" or "I"). Definitions and examples of each category are shown in Table 3.

Table 3: Reference categories capturing the level of generality in discussions of people while generating concepts.

Terms Refer to:	**Definition**	**Examples**
Everyone	Intended to apply to 'everyone' generally, no specific type of person or actual person identified. Includes "everyone," "people," "person," "we," "they," "he/she/they," and the generic "you" [26].	"The *user* requirement can be finding *other people* to help *them* to move" "Say there are a few boxes, and after *you* moved to a new place, *you'll* know which thing's in which box."
Type of Person	Refers to people with certain qualifications or contexts, typically descriptors such as "tall people" or "people with a big family." Also includes hypotheticals and people defined by their societal roles, such as "renter" and "homeowner."	"So I have to talk with the guy, with the leasing office to ask contact of *next renter* if they have one." "I will draw *a muscular person* with little bulges on the arms to show that *he's a mover*."
Specific Individuals	References to particular, known individuals, such as, "my brother" or "this friend of mine."	"My friend asked me to help him moving [sic]…"
The Self (Me or I)	References from the student's own personal experiences or references to themselves as the user.	"So when *I* first moved to Ann Arbor*, 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"

Note that in the course of narrating their design processes, students also referred to themselves in their role as designer; for example, "Now I'm going to focus on other people to help them move." In such cases, students used "I" in narrating their process but did not refer to themselves as the user, nor mention their own experiences. These types of "I" references were excluded as self-references. Only one student mentioned a "specific individual" while creating their concept

and it occurred during the second ideation session: “My friend asked me to help him moving [sic], I would [do it] but I really expect appreciation.”

Across the protocol transcripts, two authors categorized all references to people across these four categories. Any discrepancies in categorization were discussed to consensus, meaning the authors came to a single agreed-upon decision for each reference. Table 4 shows the percent agreement and Cohen’s *kappa* for each category, showing satisfactory agreement for each category [25].

Table 4: Agreement and inter-rater reliability for categorization of references to users.

Category:	**Everyone**	**Type of Person**	**Specific Individuals**	**Self**
Percent Agreement	100%	92.1%	97.2%	91.7%
Cohen’s kappa	1 – perfect agreement	0.821 – almost perfect agreement	N/A – too few to calculate reliability	0.719 – substantial agreement

Sketch representations

From the total set of 35 sketches, 18 included representations of people, and 12 of those occurred in the second session. Table 6 includes the total number of sketches each student generated, how many sketches included representations of people, and how each students’ sketches were categorized according to five key aspects: multiple users, user’s body, physical integration, emotion, and communication.

Table 6: Proportion of sketches corresponding to coding category (out of all sketches) by session for each student. Increases in 2nd session are highlighted.

	S1		**S2**		**S3**		**S4**		**S5**	
Sketch Depictions	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
Number of Sketches	4	3	6	4	3	2	2	2	5	4
People represented	0	1.00	0	1.00	1.00	.50	0	.50	.60	.75
Multiple people	0	1.00	0	0	0	0	0	.50	.20	.50
Peoples’ full bodies	0	1.00	0	.75	1.00	.50	0	.50	.60	.75
Physical integration	0	1.00	0	1.00	1.00	.50	0	.50	.60	.50
Emotion	0	.33	0	.50	.66	0	0	0	0	0
Communication	0	0	0	0	.33	0	0	.50	.20	.25

Several observations from these categories demonstrate change in students’ representations of people from Session 1 to Session 2. As Table 5 shows, S1, S2, and S4 did not include *any* representations of people in their sketches until prompted to do so. S5 represented *more* people in their sketches in Session 2.

After the intervention, sketches from S1 and S2 considered more user emotion, physical integration, and full body depictions. S1 also increased their consideration of multiple people. Showing the most change, S4 increased their consideration of physical integration, full body of the user, multiple people, and communication following the intervention. Only S3 showed *more*

consideration of people during Session 1 in displays of emotion, physical integration, full body depictions, and displays of communication.

In sum, the introduction of the intervention appears to have motivated most students to include more representations of people within their concept sketches in Session 2.

Think-aloud Protocols

Protocols from the concept generation sessions included explicit references to people in almost all (97%) concepts. Only one concept had no references to people, and it was generated during the first ideation session. References are shown by session in Table 7.

Table 7: Distinct references to people in students' think-aloud transcriptions.

Student	References to people in Session 1	References to people in Session 2
S1	Friends, homeowner, I, kids, mover, our, person, they, their, trustee, user, we, wife, you, your	Homeowners, movers, our, packers, people, person, someone, their, they, user, we, your
S2	Everyone, family, friend, people, you, your	Movers, people, person, they, user, you, your, yourself
S3	Bob, baby, driver, family, he, his, kids, movers, people, person, Sally, she, somebody, them, Tina, VP of sales, you, your **Note: Bob, Sally, and Tina were hypothetical names the student gave to an imagined user – not known, specific individuals.*	A little stick figure, he, him, his, I, movers, owner, person, they, workers
S4	People, person, they, us	Friends, guy, him, I, me, my, people, renter, them, we, you
S5	He, his, people, person, she, users, you, yourself	Anyone, her, he, his, people, person, she, you, your

Students often included universal references in the form of a generic "you" or other general terms, such as "he," "they," or "people." In proportion to the number of ideas generated, "everyone" and "type of people" references appeared with about the same frequency in Sessions 1 and 2. However, instances of the students discussing personal past experiences or referring to themselves as the user occurred much more frequently *after* the intervention.

Students used many different words to describe people while generating concepts, including hypothetical users (i.e. "a homeowner who is VP of sales"). Students used universal terms (i.e. "you," "people," "person") across all concepts, and the greatest variety of reference terms appeared in the first ideation session of S3 (18 different terms). S2, S4 and S5 used a greater variety of terms in the second session than the first.

We were particularly interested in investigating use of the generic "you" to refer to users because previous work indicates the generic 'you' can be used to make meaning and extend personal experiences to others [26]. We considered the number of times students referred to users with the generic 'you' compared to the total number of times they referenced people and the number of

words they spoke during each ideation session, shown in Table 8. Four students (S1, S2, S3, S5) referred to users with a generic 'you' *less* often in Session 2 than in Session 1. Note that student 4 made only 7 references to people while generating concepts in the first session; but in the second session, they talked about people much more frequently (50 references).

Table 8: Students' use of the generic 'you' when referring to people. Decreases in use of the generic 'you' are highlighted in second session scores.

	Session 1			**Session 2**		
Student	**Generic "you" (Proportion of all references)**	**All person references**	**Total words**	**Generic "you" (Proportion of all references)**	**All person references**	**Total words**
S1	0.28	74	888	0.07	46	864
S2	0.80	89	1590	0.63	72	1247
S3	0.13	62	1156	0.00	27	1066
S4	0.00	7	330	0.16	50	451
S5	0.46	48	618	0.35	31	429
Average	0.33	56	916	0.24	45	811
SD	0.31	31	486	0.25	18	365

Discussion

Overall, we found the prompt for students to represent people in sketches led to many changes. Students rarely included representations of people in their sketches on their own. After the intervention, all students represented people in their sketches in the second session. Four of five students' sketches showed an increase after the intervention in representations of people across depiction categories. Further, students' use of referential terms was more specific and less general following the intervention.

After the intervention, students also generated fewer concepts (by 1 or 2). This difference may reflect a slowing of concept generation due to additional time needed to consider how to represent users in the concepts as they created them. However, fewer concepts may have been generated due to idea exhaustion [27] in the second session.

The intervention appeared to be needed: Three of the engineering students in our study *never* represented people in their sketches until they were prompted to do so. They began including people after being prompted, showing major changes in their sketching outcomes. For example, they were more likely to consider how the users would be physically integrated with the design. Physical integration seems critical for mechanical engineering designs requiring direct interactions with users' bodies. In addition, consideration of emotions occurred more often for some after the intervention, and this may indicate an increase in empathy for potential users' feelings and perspectives [6].

Further, added design elements depicting communications between people may indicate that students are thinking more deeply about the people's contexts. Zoltowski and colleagues noted that one way students demonstrate better understanding of their users and design context is by taking more factors and complexity into consideration [1]. This increased consideration of

connections between people could be a sign that representing people may promote deeper thought about users' contexts.

While two of the students showed little improvement in their representations of people, our findings suggest the act of representing people in sketches may support consideration of people in design in terms of their emotional reactions, how they will physically interact with the designed product, and how they communicate with others. Representations of people are not always necessary in design, but their presence may encourage attention to specific elements of human-centered design; for example, if a sketch does not include a person, there is no visual explanation offered for how a user might physically engage with a product, potentially hindering further design development or communication. Further research is needed to examine the roles of the qualities of representations on design outcomes.

While students showed a range of ways (such as gendered and self-referential terms) to describe people during their design sessions, they often used a generic 'you' to refer to potential users. Most students used the generic "you" much less frequently after the intervention. During design, using a generic 'you' may entail extending a student's personal experiences, biases, and assumptions onto their user without examining the needs and context of the user. Orvell and colleagues suggest that the generic 'you' allows people to make meaning from their life experiences by expressing norms and extending those norms beyond the self [26]. By not referring specifically to a user or type of user, students may unknowingly extend their own personal experiences onto the people they are considering. Ideally, designs would be informed by specific experiences so that guiding information comes from real-life, contextualized scenarios.

In contrast, other generic terms may prevent students from extending their own experiences onto others. Naming the user with generic terms such as "she," 'movers," or "the person" may be enough to remind students that they are not designing for themselves. The practice of referring to the generic 'you' while designing could be perpetuating the thought that engineers are designing for others when in reality, they are designing for themselves. Further research will have to unpack whether replacing a generic 'you' with a more specific term such as 'movers' or a different pronoun such as 'him' is an improvement. It is possible that the use of more descriptive words such as 'movers' indicates that the student has a specific type of person in mind when designing. Similarly, even assigning a pronoun to a user may add some level of description and consideration for gender or number of people. Both scenarios would seem to improve upon a disembodied, ambiguous, undefined 'you.' Overall, the findings suggest that the intervention led students to talk about people more frequently and in different ways, linking the act of representing people during conceptual design to changes in students' design thinking.

Greater attention to how students describe *who* they are designing for more specifically—types of individuals vs. the self—is particularly compelling for further research. When designing, it may be helpful to clarify which experiences are informing design decisions in order to prevent perpetuation of engineers' own biases and assumptions. In the absence of explicit experiences and needed information, students may unconsciously pull from their own life experiences rather than potential users' and other stakeholders'. Another area of potential concern is gendered terms (most often "he" and "him") which may unconsciously promote a gendered view of users and

limit the generalizability of designs. Explicitly considering different types of people (e.g., students living in dorms, families with children, international moves) may be a useful strategy in encouraging and assessing the diversity students consider during design. Are students considering people who use wheelchairs? People who are tall? People who work full-time? Identifying language around the types of people to consider may help designers better describe *who* their design is for and who it is *not* for; ideally, this attention to people during design will promote more consideration of the humans who will use their designs.

Implications

Our findings indicate that, on their own, mechanical engineering students may design concepts without depicting people in their designs. However, when prompted to draw people, students included depictions with meaningful considerations of user experiences in terms of how people interacted with the concepts, how people felt (displayed emotion) during use, and how people communicated with other users. These features of concept sketches suggest explicitly considering representations of people in sketches may promote deeper thinking about the user and their context during design. While further studies are needed to determine the impact of user representations on design outcomes, the present findings suggest there may be positive effects for engineering students pursuing human-centered design approaches. Instructors might ask engineering students to draw people in all of their concepts in order to reinforce attention to the user and encourage more specificity in how they are described and referred to during the design process. Encouraging students to represent people in their concepts is easy to implement and appears to promote deeper consideration of users and contexts during design.

Limitations

This study is an initial exploration of how engineering students represent people in a human-centered design task. Our qualitative study included 5 mechanical engineering students and just one design problem, so future work should extend the paradigm to include more students, other design disciplines, and other design problems and contexts to test hypotheses and draw generalizable conclusions. Additional approaches to understanding designers' "talk" about people in their design processes may add to understandings of design thinking about people and its impact on outcomes. For example, using "ladders of abstraction" (decision ladder or the recognition-primed decision model) in analyzing designers' use of descriptions of users may identify how students consider the larger design context [28]. Finally, this study includes only an initial concept generation task rather than a complete design process, and individual work of short duration rather than more typical, longer term and team design work.

Conclusion

How are humans considered during Human-Centered Design? When students generated concepts on their own, few included representations of human users within their designs. However, after we asked them to continue generating concepts while including representations of people in their sketches, we saw students add several potentially relevant features (such as emotion and communication) to their sketches. These representational features may provide further positive impacts as designs are developed and communicated to others. Students often described their users in general terms, but following the intervention, they decreased their use of the generic 'you,' indicating more specificity about who their users are and who their users are not. Some

students also demonstrated deeper consideration of their users' contexts in their sketches including representations of people. Overall, prompting students to consider how to represent people in their sketches may be a simple strategy for encouraging designers to think more deeply about the specific people who will use their designs.

Acknowledgments
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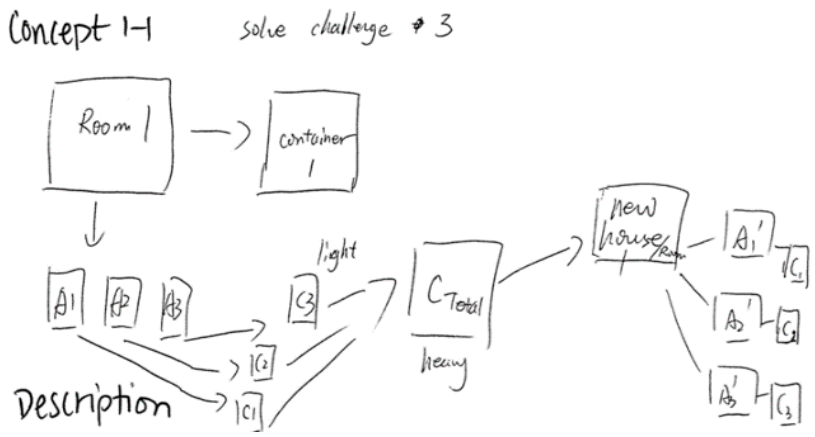
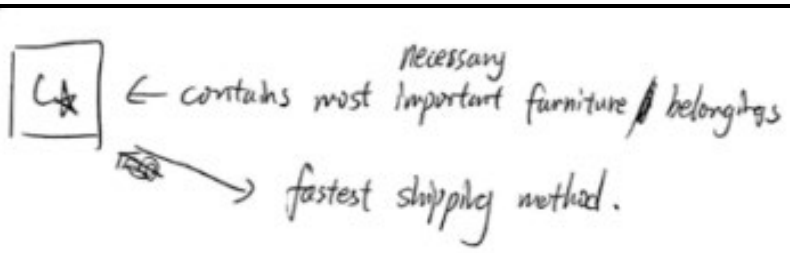
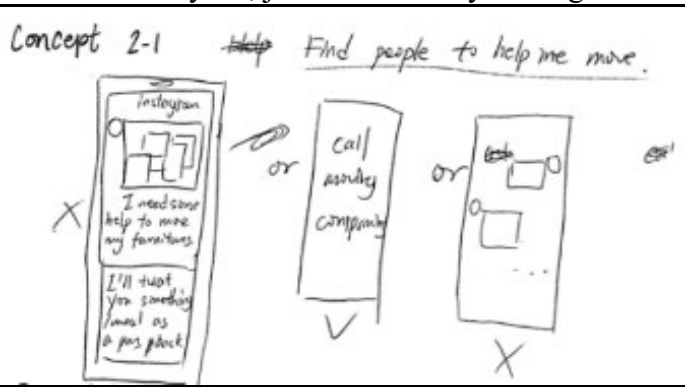
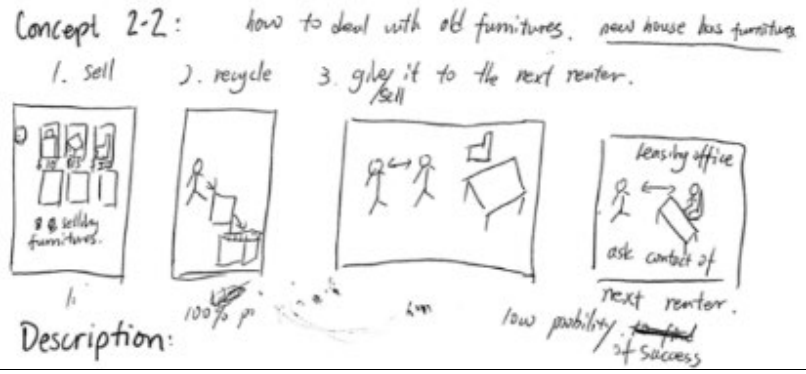
Appendix

Table A1: One student's entire data set (including all sketches, written concept descriptions, and think-aloud transcriptions.

Concept Number	Concept Sketch	Written Concept Description
Concept 1-1		1. Separate a room into multiple areas 2. Pack everything in one area to one container 3. Put multiple containers into a big container for transportation Then things are organized

1-1 Think-aloud transcription: "Design a way to help people move households. For example, do they need a box for expensive household? They do. How to keep organized. Keep organized. So for keep organized it's better to just wrap up the whole thing in one room so everything in this room goes to, let's say, room one goes to one box or container. Yeah, container one. Room one to container one. And room two or can we, when people only need to move one room, then they can separate one room to several areas A-1, A-2, A-3. Then furniture belonging to these areas will go to separate containers. Yeah. Let's say C-1, C-2, C-3. These containers go to one big container. C-total. Right. C-total might be so heavy. Three light containers. Light containers can be moved by a person. Heavy container should be moved by a vehicle or vehicles. So basically that's how a moving company works. Is there a more creative way to move that? Make sure to consider physical settings. Physical settings. This container. This container will move to new house. New house. It probably takes time to bring everything out of the container as well. So new house, well, each room, they should be similar rooms or areas. Area-1 prime, Area-2 prime, Area-3 prime. The house has these areas or rooms. Go to each area, then each area has the containers. C-3. So this might be a good way to keep belongings organized. Just pack everything. Wait. First separate by room to multiple areas to pack everything in one area to one container then pack multiple containers. Okay. Let's put multiple containers into a big container for transportation. One container multiple. Then things are organized. This is a way to solve challenge three."

Concept 1-2		Pack all necessary
1-2 Think-aloud transcription: "Continue living while belongings are in transit. Just find a new house with furniture or make one container become the most important, contains most important, furniture or most necessary furniture for belongings and to speed up the use. Shipping method because yeah, just all necessary. All right."		
Concept 2-1		Call moving company is the most convenient way to solve this challenge, but it costs a lot
2-1 Think-aloud transcription: "Okay. Help finding others to help them move concept one. Write a title first. Help finding people, find people to help move. Call them. Or instant message like Instagram. Sending a picture of all my belongings, things. I need some help to move my furniture. And I'll treat you to something or a meal as a payback. That's stupid. Or just call a moving company. Or moving companies. Moving companies or ask my friends will they help me move. Sorry I can't. All right. Call moving company. Moving company if the most convenient way to solve this challenge. But it costs a lot. Because money can give you convenience. And if my friend asked me to help him moving, I would but I really expect appreciation."		
Concept 2-2		Try 1, 3 First, it cannot find anyone to buy it, then go to the recycle site to recycle furniture
2-2 Think-aloud transcription: "How to deal with old furniture. Concept one is to sell it. How do I sell it? Or recycle? Recycle? Sell? Sell to recycle? Three, I'll give it to the next renter. Give or sell. To sell it I need to post all the pictures of furniture like a bed, like a chair, and say mark the price like 10, 15, 20. Mark the price and say selling furniture. Recycle. I		

have to go to actual sites to givemy furniture to the recycling place or give to the next renter. If give 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. That's the best way to deal with the old furniture but it's hard to find the contact of the next renter. So I have to talk with the guy, with the leasing office to ask contact of next renter if they have one. If not, to deal with old furniture, what's the best way? Tedious, tedious, tedious. The best way is to recycle it. No. Low probability to find. It's sort of hard to find someone to buy it. If you want to recycle it you always can recycle. It's 100% probability of success. Or we can try the first two, try to sell it or find the next renter. If you cannot find them, then go to recycling. That's still the best way. But to recycle it, you have to move them to the recycle site. It's also a lot of work to do. Or you have to deal with that. In this case, new house has furniture already. This is a case that new house has furniture. If the new house don't have furniture, just move. Yeah. Just move. So try one or three if you cannot find anyone to buy it, then move everything and go to recycle site, furniture recycle."