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Teaching Engineers to Draw People: Enhancing User-Centered Thinking Through Conceptual Sketching

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Abstract

Considering diverse perspectives is crucial for advancing inclusive engineering design. This Research Paper investigates how teaching different human figure sketching methods influences engineering students' user consideration, idea generation outcomes, sketching preferences, design self-efficacy, and sense of belonging. Ten sketching workshops were conducted across Summer and Fall 2025. Participants received instruction in one of three figure sketching methods seen in **Figure 1** or a control condition with no figure sketching instruction. Students then completed an idea generation task where figure sketching conditions were prompted to include representations of people in their ideas and the control group was not. In Fall, an additional control group was added that prompted to include figures during idea generation with no figure sketching instruction. Finally, pre- and post- surveys were administered with self-efficacy, sense of belonging and preference questions. Results indicate that figure sketching instruction may support more specific user consideration during ideation instead of creating solutions for generic users. Fall workshop results showed differences in idea quantity across conditions, with the fewest observed when students were prompted to include people without figure sketching instruction. Students generally preferred the figure sketching method they were trained on. However, preference did not always align with intended future use. Small but directionally consistent pre–post self-efficacy score increases were observed across conditions and no meaningful changes were observed for sense of belonging. This work aims to further the work on visual communication in engineering design and has implications on how design education is structured, highlighting the importance of including user-centric methods early in the curriculum to shape the next generation of human-centered engineers and designers.

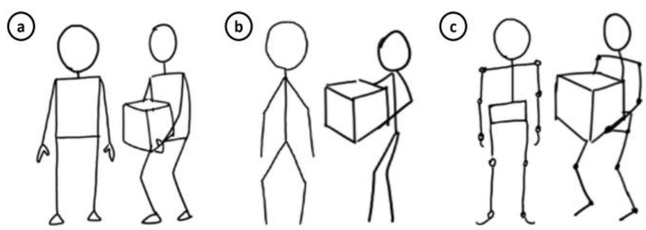

Figure 1. Three different approaches for quick and easy methods to incorporate people into sketches. (a) Box Figure (b) Stick Figure (c) Jointed Figure

Introduction

Design Thinking and Human-Centered Design revolutionized the way design was approached through creating strategies that prioritize user needs and directly involve the customer in the design process. Although these strategies have been implemented across many different phases of the design process, there are generally no explicit strategies to center people during conceptual sketching in the early idea generation stages. Simply asking mechanical engineers to include people during idea generation improved the specificity of user needs considered, leading to more inclusive designs that recognize unique needs of different stakeholders. However, a major drawback was that those who included people in their conceptual sketches produced fewer ideas [1]. We hypothesize that teaching engineers fast and easy person sketching techniques may mitigate these negative effects. This study examines the effects of learning figure sketching techniques on engineering students' design self-efficacy, sense of belonging, and design outcomes, including idea quantity and their consideration of specific user needs. We address the following research questions:

RQ1. Which human figure sketching method has the greatest impact on students' ability to consider a diverse range of users during the idea generation?
H1: The jointed figure may promote consideration of diverse users as the details in this particular figure sketching technique allow differentiation of genders (i.e. men drawn with square hips and women with trapezoidal hips).

RQ2. Does learning different human sketching methods impact the quantity of design ideas generated by students during an idea generation session?
H2: Prior work indicates that telling engineering students to include representations of people, a person, or parts of a person significantly decreased the total number of ideas generated [1]. Teaching quick figure sketching methods may prevent this. It is anticipated that the Stick Figure will be the most preferred among engineers and have the greatest impact on the quantity of ideas as observed in the Summer 2025 pilot [2]. This method is the simplest and allows easy manipulation of the figure**.**

RQ3. To what extent do students' sketching style preferences align with their likelihood to use a particular style in the future, and does this relationship differ by instructional condition (e.g. Stick Figure or Box Figure)?
H3: It is hypothesized that students who had figure sketching instruction will prefer and will intend to use the figure sketching style that they were trained on. Control groups will show less alignment between preferences and perceived future use.

RQ4. Does learning human figure sketching influence students' engineering design self-efficacy and sense of belonging in engineering?
H4: Students may exhibit increased engineering design self-efficacy especially for factors involving customer needs identification, visualization and creativity, specifically factors Identifying Customer Needs and Describe the Problem. Women may exhibit increased feelings of belonging in engineering, supporting the idea that empathy-focused activities and spatial visualization skills like sketching can appeal to women and impact retention of women in engineering [3, 4].

Background

Figure sketching and Conceptual Sketches

Incorporating representations of people into conceptual design sketches has been shown to promote attention toward the individuals who will ultimately interact with a system, supporting more user-centered approaches to design [1, 5]. User-centered design focuses on developing solutions that consider the needs, preferences, and experiences of specific end users [6]. We build on this framework by integrating human figure sketching techniques - an approach not currently included in engineering education - to better understand the user and operationalize user-centered design principles. Prior studies demonstrate that when engineers are encouraged to include people or parts of the human body in their sketches, they are more likely to differentiate among user groups and attend to specific stakeholder needs, rather than defaulting to broadly applicable but potentially ineffective "one-size-fits-all" solutions [1, 5]. Representing people in sketches can also prompt consideration of the social, physical, and environmental contexts in which designs will be used [1, 5]. Beyond engineering research, authors in visual communication books have similarly argued that drawing human figures can increase empathy, clarity, and engagement in design work [7, 8]. However, as a drawback, engineers who included human figures generated fewer concepts which has implications on creativity of ideas [1]. One proposed solution to mitigate these drawbacks is to teach fast, low-fidelity figure sketching strategies to equip engineers with the skills and confidence to incorporate people into their conceptual sketches without compromising idea quantity. A range of quick human figure representations exists. **Figure 1** shows three quick and effective methods to incorporate people into sketches [8] that were investigated in this study. The existing literature provides no further guidance on which specific forms should be taught to engineers.

Self-Efficacy and Sense of Belonging

Bandura's Social Cognitive Theory explains how people learn and behave in social contexts [9] with a specific emphasis on promoting self-efficacy [10], and cognitive and behavioral skills [9, 11]. Self-efficacy refers to an individual's belief in their ability to perform specific tasks and is a key determinant of motivation, persistence, and learning. Students with higher self-efficacy beliefs are more likely to engage with learning activities and seek challenges and opportunities to develop new skills [10]. These beliefs are shaped through knowledge acquisition and mastery experiences, in which individuals apply their knowledge and skills to accomplish a task [11]. Bandura identifies mastery experience as the most powerful source of self-efficacy [10]. Without adequate knowledge and practiced skills, even highly motivated individuals may struggle to perform a behavior [9, 11]. Self-efficacy in engineering design has been measured using the Engineering Design Self-Efficacy (EDSE) scale which includes targeted items that measure confidence in design-related activities such as concept generation and evaluation [12]. Recently, the Self Efficacy Engineering Design (SEED) instrument was developed to improve on the EDSE scale and has been validated in an undergraduate engineering population to correlate with students' confidence in completing various design phases [23]. Alongside self-efficacy, sense of belonging has been widely recognized as a critical factor influencing engineering students' engagement [13] and retention [14]. Undergraduate engineering students often report lower levels of belonging compared to graduate students and faculty, suggesting that early academic stages may be particularly vulnerable periods [15]. Additionally, women and students from underrepresented minority groups often experience lower sense of belonging and alienation in engineering compared to men [16, 17], leading to higher dropout rates [18]. These patterns highlight the need for educational interventions that address not only skill development, but also students' perceptions of inclusion and support. Belonging is influenced by a complex interplay of factors such as academic environment [16], self-efficacy [19], prior engineering experience [20], math skill and readiness [21], and diverse representation among peers and mentors [17]. The Psychological Sense of School Membership (PSSM) scale has been validated [22] and has been revised for undergraduate engineering students' sense of belonging within their engineering program [21]. The revised PSSM includes 6 items to assess the extent to which students feel accepted, respected, included and supported in their academic setting and has been validated for use in an undergraduate engineering education context to measure sense of belonging related to math readiness in under-represented minorities [21].

Methods

The classroom, quasi-experimental design investigates the impact of teaching different figure sketching methods (Stick, Jointed, Box) on engineering students' user consideration and design outcomes during idea generation. Additionally, we explore preferences for various figure sketching methods and investigate how learning figure sketching influences engineering design self-efficacy and sense of belonging in engineering.

Participants

Two sets of workshops were conducted during the Summer 2025 and Fall 2025 semesters. In total, data was collected from ten workshops across both semesters as shown in **Table 1.** All participants were recruited from the same first-year mechanical engineering introduction to sketching and CAD course at a public university in southeast US. The course was taught by the same instructor for both semesters to control for instructor-related differences. During Summer 2025, six workshop sessions were conducted towards the end of the semester, two Stick-Figure, two Box-Figure, one Jointed-Figure, and one Control group. Each course section was randomly divided into two workshop groups, with one group facilitated by a PhD student in mechanical engineering and the other by a mechanical engineering professor. Each workshop session included 19-21 participants. During Fall 2025, data was collected in the beginning of the semester from four additional workshops conducted across four course sections, facilitated by the same PhD student. These workshop sessions were not split and had participant counts of 48, 48, 45, and 35. Four experimental conditions were implemented during the Fall semester: a *Stick-Figure* group, a *Box-Figure* group, a Control group that received no figure sketching instruction and no prompting to include people in idea generation (*Control-no-Figures*), and Control group that received no figure sketching instruction and were explicitly prompted to include people in their idea generation designs (*Control-with-Figures*). The additional *Control-with-Figures* condition (in which participants were prompted to include people without receiving sketching instruction) was introduced to isolate the effect of figure sketching instruction from the potential confound of explicitly prompting participants to include figures, which may influence idea quantity.

This paper reports different outcome measures by semester. Data from four of the Summer 2025 workshops examine the user needs considered in participants' design ideas (RQ1), while data from the Fall 2025 workshops are used to analyze idea quantity (RQ2), preferences (RQ3), as well as engineering design self-efficacy and sense of belonging (RQ4). The four workshops were analyzed to represent each experimental condition facilitated by the same instructor to reduce instructor differences.

Table 1. Distribution of participants (N) across workshop conditions by semester, including instructor type for Spring 2025 and Fall 2025 control and figure sketching conditions.

Semester	Workshop Condition	Workshop Instructor	N	Time
Spring 25	Stick Figure	ME PhD Student	21	9:30-10:45am
Spring 25	Box Figure	ME PhD Student	19	9:30-10:45am
Spring 25	Jointed Figure	ME PhD Student	20	9:30-10:45am
Spring 25	Control	ME Professor	20	9:30-10:45am
Spring 25	Stick Figure	ME Undergraduate Student	17	9:30-10:45am
Spring 25	Box Figure	ME Professor	19	9:30-10:45am
Fall 25	*Stick-Figure*	ME PhD Student	46	9:30-10:45am
Fall 25	*Box-Figure*	ME PhD Student	37	5pm-6:15pm
Fall 25	*Control-no-figures*	ME PhD Student	47	9:30-10:45am
Fall 25	*Control-with-figures*	ME PhD Student	45	2pm-3:15pm

Study Design

Workshops were conducted during the final 90 minutes of the 2-hour 45-minute lab sessions. Participants first completed a pre-workshop survey consisting of 24 items from the Self-Efficacy for Engineering Design (SEED) instrument [23] and six items from the Psychological Sense of School Membership (PSSM) scale [21]. Minor contextual wording adjustments were made to reflect the participants' enrolled major (e.g., replacing "General Engineering" with "Your Major"), while preserving the original item structure and Likert response format. Following the survey, participants engaged in a 30-minute instructional session. In the figure sketching conditions, this session introduced a specific person sketching method (Stick, Box, Jointed), covering construction of a basic standing figure as well as techniques for conveying motion, action, and interaction with objects through guided practice (e.g. figures shoveling, hammering, taking photos, and riding a bike). The control conditions focused on sketching the same set of objects used in the figure sketching sessions (e.g. hammer, shovel, camera, bike) without any human figures and thus, object context was held constant while figure construction instruction varied across conditions. After instruction, all participants completed a 30-minute concept generation task focused on designing solutions to "help people move" [1, 5]. The prompt included different problems faced by people who are moving homes and can be seen in [1,5]. Participants in the figure sketching and *Control-with-Figures* conditions were explicitly instructed to include representations of people or parts of a person in their concept sketches in their prompt, whereas the other control group received no requirement. Upon completing concept generation, participants were given a pen of a different color, asked to number each concept, and responded to two reflection questions of: “Who is this idea for?” and “Who do you imagine would use it?” These prompts were adapted from prior work [1, 5]. Finally, participants completed a post-workshop survey that repeated the pre-survey measures and included two additional items assessing participants’ perceptions of figure sketching and their likelihood of using the techniques in future design tasks.

Results

All analyses were conducted in R (version 4.4.2). The user needs considered were analyzed for the Summer 2025 workshops only. Analysis of post reflection questions and user needs for the Fall 2025 workshops is ongoing and therefore not included.

RQ1. Which human figure sketching method has the greatest impact on students’ ability to consider specific users during the idea generation?

Two raters independently evaluated all sketched ideas and associated reflection responses for the Summer 2025 workshops using thematic analysis guided by a pre-established coding framework from prior work [1, 5]. The first rater was a fourth-year undergraduate student in biomedical engineering with a minor in psychology, and the second was a PhD student in mechanical engineering, both authors of this paper. The raters demonstrated strong interrater reliability (Cohen’s $\kappa = 0.83$), indicating a high level of coding consistency.

Figure 2 presents the total number of ideas across the 13 identified user descriptors. In Fig. 2, user descriptor categories are defined as follows: Specific Preferences and Values (people with lifestyle or value-based traits), Support (people with or without help of social community), Specific Age Group (age-defined users), Financial Resources (monetary constraints or access), Non-Monetary Skills/Resources (access to knowledge, tools, or expertise), Own Particular Possessions (people with distinct belongings), Physical Environment (environmental constraints such as stairs or weather), Physical Ability (strength, mobility, or disability), Organized (organized/disorganized users), Scheduling and Stress (time pressure or workload constraints), Specific Occupation (profession-based needs), Movers/Moving Companies (professional movers as users), and All People (broadly generalized users). Descriptors and examples can be found in [1,5]. **Table 2** shows the statistics of the significant comparisons using a chi-square test.

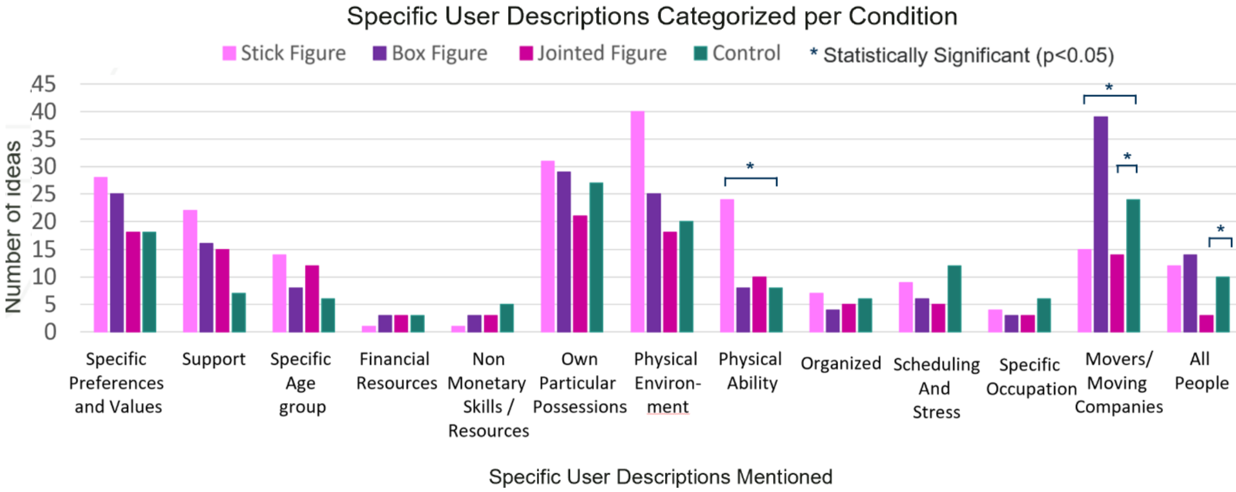

Figure 2. Frequency of ideas categorized for user descriptors mentioned across four sketching conditions (Stick-Figure, Box-Figure, Jointed-Figure, and Control). Asterisks indicate statistically significant differences between conditions using a chi-square test ($p < .05$).

Table 2. Significant chi-square comparisons of user type categories between figure sketching conditions and the control condition. Counts (n) reflect the total number of ideas in which each user descriptor was mentioned. Reported p-values are uncorrected.

User Descriptor Category	Comparison Group (n)	Control Group (n)	Chi Square (df = 1)	p-value
Physical Ability: People with particular physical ability	Stick (24)	Control (8)	2.92	0.05
Movers/Moving Companies: People who are not the primary user, specifically movers and moving companies	Jointed (14)	Control (24)	3.86	0.04
	Stick (15)	Control (24)	9.47	0.002
" All people"	Jointed (3)	Control (10)	3.54	0.05

Overall, **Figure 2** shows that participants in the figure sketching conditions had more ideas with a broader range of user descriptors and needs compared to the control condition, with some categories showing statistically significant differences between groups (**Table 2)**. The values in **Table 2** reflect the total number of ideas mentioning a particular user type (e.g., “physical ability”) across all students in that condition. Differences in the distribution of user needs considered were evaluated using chi-square difference tests, comparing each figure sketching condition to the control condition. Similar analysis was done in prior work [1]. The Stick-Figure group had more ideas that considered users physical abilities compared to the control group. In contrast, the control group identified significantly more generic users such as “movers” or “moving companies,” than the Jointed-Figure group. Furthermore, the Control group had significantly more ideas that were for “all people” or “everyone” where no specific users were mentioned compared to both the Jointed- and Stick-Figure groups. These patterns are consistent with prior findings demonstrating that figure-drawing may encourage designers to consider more specific user groups [1, 5]. The Jointed-Figure instruction included techniques to differentiate sketches of men and women which may impose additional cognitive or representational details that promote unique gender categorizations. The other figure sketching techniques do not have approaches that indicate gender. Interestingly, users' financial resources, non-monetary skills/resources, and organization/scheduling stress showed low frequencies across all figure sketching conditions, indicating that figure sketching may primarily influence attention to physical, embodied, and situational user attributes rather than economic or logistical factors. However, further analysis with a bigger sample size is needed to confirm these observations.

RQ2. Does learning different human sketching methods impact the quantity of design ideas generated by students during an idea generation session?

Figure 3 shows the mean number of distinct ideas generated per individual student in the Fall 2025 workshops. Idea quantity was assessed using participants' self-reported counts of distinct concepts produced during the design task. The research team visually examined all submitted sketches to ensure that numbered concepts reflected substantively different solutions rather than obvious duplicates. The mean and standard error can be seen in **Figure 3**.

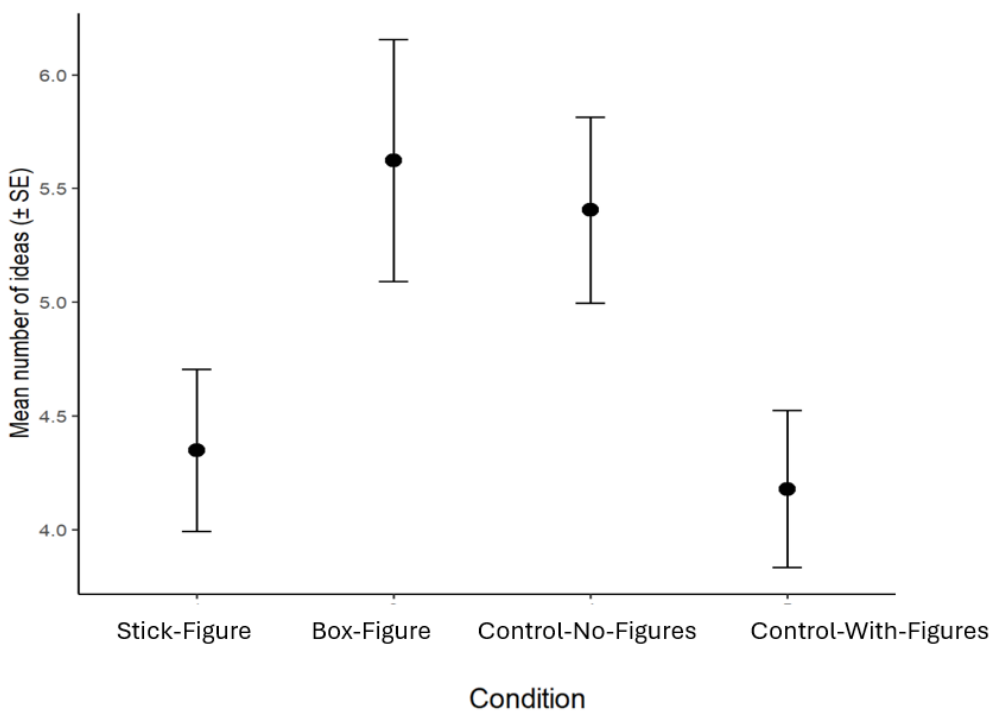

Figure 3. Mean number of ideas generated across conditions. Points represent condition means and error bars indicate ±1 standard error.

A one-way ANOVA revealed a significant effect of condition on the number of ideas generated ($F(3,171) = 3.14$, $p = 0.027$). Because the assumption of normality was violated, additional analyses that do not rely on normality or equal-variance assumptions, a Welch ANOVA (Welch $F(3, 91.63) = 3.02$, $p = 0.034$) and a Kruskal–Wallis test (Kruskal–Wallis χ^2 (3) = 8.31, $p = 0.040$) were also conducted, both of which yielded consistent results. However, posthoc pairwise Tukey and Wilcoxon comparisons did not identify statistically significant pairwise differences and none of the p-values were below 0.05. The absence of significant pairwise differences suggests that the omnibus effect is driven by modest differences across multiple conditions rather than a single dominant contrast. Participants in the *Box-Figure* condition produced the highest mean number of concepts (5.62, SE = 0.53), followed closely by the *Control-no-Figures* group (5.40, SE = 0.40). The *Stick-Figure* condition resulted in a lower average number of concepts (4.34, SE = 0.35), while the *Control-with-Figures* group yielded the lowest mean (4.17, SE = 0.34). The lowest average occurred in the *Control-with-Figures* condition, suggesting that asking students to include people without giving them any figure drawing prompt may increase cognitive effort and reduce the number of ideas generated. The *Control-with-Figures* finding is consistent with prior work [1, 5] and underscores the importance of figure sketching instruction and skill development. However, unlike the Summer 2025 cohort, the *Stick-Figure* group did not generate a higher number of concepts in the Fall 2025 study [2]. One possible explanation is the timing of the lab sessions: in the Fall, the Stick Figure condition was conducted at the 8 a.m. lab session, whereas the other conditions met in the afternoon, which may have influenced participant engagement and ideation performance.

RQ3. To what extent do students' sketching style preferences align with their likelihood to use a particular style in the future, and does this relationship differ by instructional condition?

Preferences and intended future use for figure sketching approaches were evaluated using two ranking questions on the post survey: (Q1) What style of human figure sketching do you prefer? (Q2) What human figure sketching method are you most likely to use in the future? During the post-survey, all participants were shown standardized examples of the three figure styles side-by-side and independently ranked their preference and intended future use. For each workshop condition (Stick, Box, Control-no-Figures, Control-with-Figures), the proportion of respondents selecting a given technique as their top choice was calculated.

Table 3 shows the percentages of those who chose each figure sketching method as their top ranked for each of the four conditions, the alignment percentages between preference and intended use and Cohen's kappa to quantify agreement beyond chance. For each participant, alignment was coded as a binary outcome indicating whether the same method (Stick, Box, or Jointed) was ranked highest in both Q1 and Q2. The results suggest that the workshop condition and idea generation prompt had an impact on participants' preferences for figure drawing methods. Participants in the *Box-Figure* condition showed highest alignment (70.3%) with moderate and statistically significant agreement ($\kappa = 0.40$, $p = 0.002$) between preference and intended future use. Participants in the *Stick-Figure* condition showed a relatively balanced preference between the Stick (42.8%) and Box (46.9%) figures for the "most liked" question, however, majority (77.5%) reported that they would be most likely to use Stick Figures in the future resulting in low agreement ($\kappa = 0.11$). This suggests that while Box Figures may be perceived as visually appealing, Stick-Figures may be viewed as more usable which may be a direct effect of skill development for this condition.

Table 3. Quantitative survey results for Question 1 "What style of human figure sketching do you prefer?" and Question 2 "What human figure sketching method are you most likely to use in the future?", and Alignment of top method chosen for Q1 and Q2 in terms of percentage, and Cohen's Kappa.

Workshop Condition	Question 1 – Most liked			Question 2 – most likely to use in future			Q1 and Q2 Alignment	
	% stick	% box	% jointed	% stick	% box	% jointed	% Alignment	Cohen's κ
Stick Figure (n= 46)	42.8	**46.9**	10.2	**77.5**	12.2	10.2	47.8	0.11(p=0.18)
Box Figure (n= 37)	27	**59.5**	13.5	24.3	**72.9**	2.7	70.3	0.4(p=0.002)
Control no figures (n= 47)	34.0	**53.1**	12.7	**76.6**	14.8	8.5	42.6	0.11(p=0.15)
Control with figures (n= 45)	**48.8**	37.7	11.1	**62.2**	11.1	22.2	62.8	0.38(p<0.001)

Interestingly, participants in *Control-no-Figures* showed low alignment between preference and intended use, preferring *Box-Figures* but reporting greater likelihood of using *Stick-Figures* in the future. In contrast, participants in *Control-with-Figures* preferred and intended to use the Stick Figure with 62.8% alignment and moderate significant agreement ($\kappa = 0.38$, $p < 0.001$). The differing patterns observed between the two control conditions suggest that explicit expectations to include figures, even in the absence of formal instruction, influence how students evaluate and anticipate using figure sketching methods. When figure inclusion is framed as an expectation, students may gravitate toward methods they perceive as efficient and cognitively accessible, even without prior training.

RQ4. Does learning human figure sketching influence students' engineering design self-efficacy and sense of belonging in engineering?

The self-efficacy data reported in **Table 4** was obtained in the pre- and post-surveys that used the SEED instrument. **Table 4** shows the post – pre median difference scores and p-values of the Wilcoxin Signed-Rank tests for each condition across the six engineering design self-efficacy measures. The exact wording for the questions can be found in [23]. Median change scores were used to summarize pre–post differences because the self-efficacy measures were collected using Likert-type scales and exhibited non-normal, bounded, and tied distributions. Medians provide a more robust estimate of within-participant change and are less influenced by small shifts across individuals than means. This approach aligns with the use of the Wilcoxon signed-rank test, which is based on ranks rather than mean differences. The results indicate that figure sketching instruction and workshop participation were associated with small, directionally consistent increases in several self-efficacy dimensions, particularly idea generation and system-level design. Across all conditions, significant gains were observed consistently in Describe the Problem, Generate Design Concepts, and System-Level Design, suggesting that participation in the workshops may increase their self-efficacy in these design activities.

Table 4: Median Difference Scores and Wilcoxon Signed Rank test p-values comparing pre- and post- self-efficacy score

Workshop Condition	**Self-Efficacy Questions Dimensions, Post-Pre Median Difference and Wilcoxon Signed Rank (p-values)**					
	Identifying Customer Needs	***Describe the Problem***	***Describe the Design Specs***	***Generate design concepts***	***Select Best Concept***	***Conduct System Level Design***
Stick-Figure (n= 45)	**0.33 ($p<0.001$)**	**0.25 ($p<0.001$)**	**0 (0.02)**	**0.33($p<0.001$)**	0(0.08)	**0.40 ($p<0.001$)**
Box-Figure (n= 36)	**0.5 ($p<0.01$)**	**0.5($p<0.001$)**	0(0.15)	**0.5 (0.012)**	**0.33 (<0.001)**	**0.40 (0.040)**
Control-no-Figures (n= 47)	**0.33(0.003)**	**0.25(0.007)**	0 (0.270)	**0.50(<0.001)**	0.33 (0.082)	**0.40 ($p<0.001$)**
Control-with-Figures (n= 45)	0 (0.162)	**0.25(0.005)**	0(0.797)	**0.33 (<0.001)**	0 (0.483)	**0.4($p<0.001$)**

The figure sketching conditions were associated with more consistent and larger median self-efficacy shifts for Identifying Customer Needs relative to the control conditions. The *Stick-Figure* condition showed small but consistent median increases across most design dimensions, with the largest gains observed for Identifying Customer Needs, Describing the Problem, Generating Design Concepts, and Conducting System-Level Design. Although Wilcoxon tests indicated directional consistency for several dimensions, median changes remained modest, suggesting minor rather than substantial gains in confidence. In contrast, the *Box-Figure* condition exhibited selective median improvements, particularly for Identifying Customer Needs and Describing the Problem, while no median change was observed for Describing Design Specifications. Considering the specific items associated with these dimensions, these findings suggest that learning to sketch basic human figures may support students' ability to reason about user needs, intentions, and constraints. Notably, the *Control-with-Figures* condition showed no median change in Identifying Customer Needs, indicating that merely prompting participants to include figures without training may support ideation-related confidence but does not meaningfully enhance self-efficacy related to user-centered evaluation. No significant improvements were observed in the sense of belonging questions.

The pattern of self-efficacy results observed in Fall 2025 differs from those reported in our prior study for Summer 2025 [2]. While earlier findings suggested that gains in design self-efficacy were primarily associated with figure sketching instruction, the current results show significant pre–post increases across all conditions. This difference is likely attributable to the timing of the intervention within the semester. In the Summer study, workshops were conducted after students had completed instruction in CAD and multiple design representations, resulting in more calibrated self-efficacy judgments that were sensitive to instructional differences. In contrast, the Fall workshops were conducted at the beginning of the semester, when students had only received basic sketching instruction. At this stage, completing a structured design task may constitute a strong mastery experience regardless of condition, leading to broader increases in self-efficacy and attenuated differences between instructional approaches. Importantly, while Wilcoxon p-values frequently indicated statistical significance, these effects reflect directional consistency rather than practical gains. The median differences suggest that brief instructional interventions, whether figure-based or not, may modestly influence confidence in early-stage design activities, but do not substantially alter broader self-efficacy beliefs over a short time frame.

Discussion

This study investigated how teaching different human figure sketching methods influences engineering students' user consideration, idea generation outcomes, sketching preferences, and perceptions of design self-efficacy and belonging during early-stage ideation. Findings are summarized below by research question.

RQ1. Which human figure sketching method has the greatest impact on students' ability to consider a diverse range of users during the idea generation?

Results from the Summer 2025 workshops indicate that figure sketching instruction supports more specific and diverse user consideration compared to the control condition. In particular, the Stick-Figure condition was associated with increased mention to users' physical abilities, while the Jointed-Figure condition showed reduced reliance on abstract or non-specific user categories. These findings are consistent with prior work suggesting that drawing human figures can cue embodied and situational reasoning about users. Continued analysis of the Fall 2025 workshops hopes to validate these claims with a bigger sample. Interestingly, low frequencies of economic and logistical user attributes across all conditions suggest that figure sketching may primarily support attention to physical and experiential aspects of use rather than broader contextual constraints, however, a larger sample is needed to confirm this hypothesis.

RQ2. Does learning different human sketching methods impact the quantity of design ideas generated by students during an idea generation session?

Idea quantity was operationalized as the total number of distinct concepts generated per participant during the 30-minute ideation task. Participants were instructed to number each different solution and this self-numbered count was used as the measure of idea quantity. The Fall 2025 workshops revealed differences in idea quantity across conditions, with no single condition driving the overall significant effect. Participants in the *Box-Figure* and *Control-no-Figures* conditions produced the highest mean number of concepts, while the *Control-with-Figures* condition produced the fewest. This suggests that prompting students to include people and explicitly telling them to include representations of people may increase cognitive load and constrain ideation. Figure sketching instruction appears to mitigate this burden, though it does not uniformly increase idea quantity. Differences between the Summer and Fall results further suggest that contextual factors, such as timing of the workshop within the semester and time of day may affect ideation.

RQ3. To what extent do students' sketching style preferences align with their perceived future use, and does this relationship differ by instructional condition?

Preference and alignment analyses demonstrated that instructional condition influenced how students evaluated and anticipated using figure sketching methods. Participants in the *Box-Figure* condition exhibited the strongest alignment between preferred and intended methods, indicating that this approach may be perceived as both appealing and usable when explicitly taught. In contrast, participants in the *Stick-Figure* condition often preferred *Box Figures* but reported a greater likelihood of using *Stick Figures* in the future, suggesting that learning the method may outweigh preference when students consider future design practice. The contrasting patterns observed between the two control conditions further indicate that explicit expectations to include figures shape method evaluation, even in the absence of formal instruction of figure sketching methods.

RQ4. Does learning human figure sketching influence students' engineering design self-efficacy and sense of belonging in engineering?

Across all conditions, small but directionally consistent increases in several design self-efficacy dimensions were observed, particularly for Describing the Problem, Generating Design Concepts, and Conducting System-Level Design. Median change scores indicate that these gains were minor, suggesting incremental shifts in self-efficacy. Figure sketching conditions showed more consistent median increases for Identifying Customer Needs relative to the control conditions and may particularly benefit user needs identification. However, no meaningful changes were observed for sense of belonging. Differences between the Summer and Fall results suggest that timing within the semester plays a critical role, with early-semester workshops likely producing broad mastery-related confidence gains regardless of condition, thereby attenuating instructional differentiation.

Conclusion

The findings of this study have implications for how sketching and representation are taught in early engineering design education. The results suggest that human figure sketching instruction is most impactful as a cognitive cue for user-centered thinking, rather than as a mechanism for increasing idea quantity or producing large shifts in self-efficacy over short time frames. Educators seeking to promote consideration of specific users may benefit from incorporating figure sketching into ideation instruction. Simply asking students to include people in their sketches, without providing tools or techniques for doing so, may increase cognitive load and constrain ideation. The preference and alignment results indicate that students distinguish between what they find visually appealing and what they perceive as usable in practice. While more detailed figure styles (e.g., Box Figures) may be preferred aesthetically, simpler representations (e.g., Stick Figures) may be viewed as more efficient and transferable to future design work.

With all studies, this study comes with several limitations. First, the workshops were conducted within a single first-year mechanical engineering course at one institution, which may limit the generalizability of the results. Second, workshop conditions in Fall 2025 were assigned at the section level rather split. Although the course structure and instructor were held constant across semesters to reduce variability, there is the possibility of confounds such as section-level dynamics, time-of-day effects, or cohort differences. For example, differences in lab timing between conditions, particularly the early-morning *Stick Figure* may have influenced engagement and ideation performance independently of instructional condition. Third, idea quantity and design self-efficacy outcomes relied on self-reported measures. Although validated instruments were used where possible, self-reports may be subject to response bias, calibration effects, or short-term shifts in perception following an instructional activity. The results in this study likely only apply to design problems where users have widely varying needs such as when moving from one location to another and the results are likely influenced by the design prompt. Finally, the analysis of user needs considered was limited to the Summer 2025 dataset, and analysis of Fall 2025 reflection responses is ongoing. As a result, conclusions regarding user consideration are based on a subset of the collected data, limiting the ability to draw strong conclusions about the influence of figure sketching on these aspects of user needs consideration.

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