Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #49160

BOARD # 253: IUSE Sketchtivity Project Recap: Key Insights, Challenges, and Next Steps for Design Tools

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IUSE Sketchtivity Project Recap: Key Insights, Challenges, and Next Steps for Design Tools

Introduction

Sketchtivity is an intelligent tutoring software that aids in student learning of sketching fundamentals through providing individualized feedback to freehand sketching activities [1]. The project has explored the role of freehand sketching in engineering design education and has found that learning with the software can improve spatial visualization skills [2], creative problem solving [2], and self-efficacy [3], through enhancing students 2-point perspective freehand sketching skills. A study investigating a sketch-based game ZenSketch also indicated that students with improved sketching skills were more adept at idea generation and exhibited higher engagement in the design process [4]. Recent work launched the Sketchtivity software across four different universities and demonstrated the possibility to effectively teach sketching fundamentals such as basic shapes and 2-point perspective drawing in as short as 3-5 weeks [5]. The initiative has raised the critical question for future research of *what sketching skills, knowledge, and representation forms do engineers need to learn to draw effectively?* To investigate this, further studies aim to examine specific sketched forms in the engineering context. One study examines how product sketches are perceived, focusing on preferences and perceived creativity and functionality. This study and future work will employ surveys to measure perceived characteristics and subjective opinions and preferences, emphasizing the need to explore the differences between ranking and rating scales as survey design tools for assessing these perceptions. This paper evaluates the effectiveness and usability of rating and ranking methods for measuring preferences of different line styles to supplement the initial study and future sketching instruction work.

Background

Survey researchers in engineering design most commonly measure subjective preferences and psychological metrics using ranking and ordering techniques. Prior work investigating end user preferences and perceived creativity of sketch characteristics such as representation style [6] and sketch quality [7] have used rank scale methods. The study investigating end user preferences of product representation found no clear preference for a particular sketch line style [6]. Although rating methods are gaining popularity, ranking methods have frequently been the top choice. Rating scales have participants assign a numeric value to indicate their level of preference or agreement with a statement. A major limitation with using rating scales is with systematic and personal biases that can lead to inaccurate results [8]. Rating scales are more susceptible to respondents interpreting scale points differently and inconsistently (e.g. "strongly agree" and "agree" could differ widely across participants), and rating based on a central or extreme opinion, which can lead to inaccuracies in the data [8]. Many researchers treat rating data to be interval data with equal measurement units within the scale instead of as ordinal data leading to skewed results and incorrect conclusions [9]. Studies have found that several factors can influence ratings such as wording of end point labels [10], left or right handedness [11], and carelessness and fatigue [12], and are more susceptible to recency bias where participants tend to give higher ratings to objects seen later on [13]. On the other hand, ranking questions often task participants with ordering objects through a comparison of the objects against one another. While this creates a clear ordinal scale, it is often criticized as being less informative as rankings do not capture nuances of intensity or equivalence of preferences, forcing respondents to order objects that may be virtually equal [8]. Although ranking scales reduce personal biases compared to rating scales, they are still susceptible to question framing biases and are more cognitively draining due to the need to compare items [8]. Research comparing the two ranking and rating scales have been conducted in social research and suggests that both methods are effective in capturing preferential data and the choice should be based on whether intensity of preference or direct comparison is sought [8]. Despite the significance of this question, little empirical work compares the two methods directly, and none in the engineering design context. The work addresses the key question of: what are the differences between ranking and rating scales for survey design and how does this affect usability when measuring preferences in engineering design.

Methodology

The study compares the validity of rating vs ranking scales as survey design methods in measuring engineer preferences of sketched product ideas in a between-subjects, computer-based, repeated measures experiment. The preferential assessment was chosen to explore what sketching styles should be taught to engineers. 10 different products were chosen within 3 product groups of spacecrafts, chairs, and toasters to capture a diverse range of highly complex engineering systems and consumer products. The 10 products were Orion, Gateway, Crawler, Amoebe Chair, Leaf chair, Flower chair, Doodle Toaster, Coffee-maker/Toaster, Horizontal Toaster, and Crumb Tray Toaster. The spacecraft images were chosen from the NASA “Learn how to draw Artemis” series based on the technical and complex design features that captures more engineering related products. Within the chairs, the Amoebe chair was used [6] and two additional chair designs of varying complexity were chosen for comparison. The toaster images represent a functional consumer product that engineers may be more familiar with and were selected from a previous study investigating the effects of sketch quality on user perception of creativity [7]. Images from prior studies were used to investigate whether similar findings emerge in technical engineering participants compared to end users with no technical background. Figure 1 shows 3 of the 4 sketch styles considered, (S) Single Line (V) Variable thickness line (F) Feathered Line and (HF) Heavily feathered Line, and correspond to line styles seen in industrial design, illustrative cartoons, and fine art sketching, respectively. The fourth Heavily Feathered style (HF) is similar to the feathered line style with more exaggerated feathered lines and can be seen in [14]. All sketches were drawn

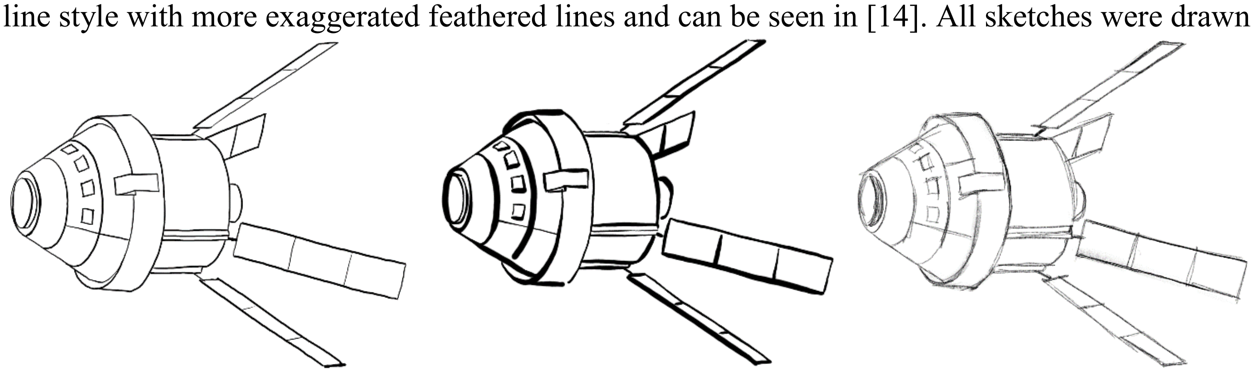

Figure 1: Orion spacecraft in 3 styles, left – single line (S), middle – variable line (V), right – feathered line (F).

using the Procreate app by one of the authors who is a graduate mechanical engineering student with a BS and MS in mechanical engineering and a minor in industrial design with extensive training in fine art.

77 students across 2 different graduate level mechanical engineering courses at a public university in Southern US voluntarily participated in the study. In Spring 2023, 40 students enrolled in an additive manufacturing course completed an online Qualtrics survey that asked participants to rank each of the 10 products sketches in different line styles based on what they liked the most, where a higher rank indicated a greater preference. In Fall 2024, 37 students in an open-systems engineering design course completed a similar Qualtrics survey, but rated the sketches instead of ranking them with scale points 1- Do not like at all, 2- Slightly like, 3- Moderately like 4- Like a lot and 5- Love it. The study was approved by the institutions IRB and participants were informed about the confidentiality of their data and were able to choose to be compensated with either extra credit for their respective course or a $10 amazon gift card. In the first course, 39 students opted for extra credit, while 35 students did so for the second course. Each question showed the sketch styles in a random order to account for order bias. The preference question asked participants to rank/rate the ideas based on what they like the most. The question followed a similar study investigating user preferences of product representations and was intentionally left open ended to allow participants to interpret it freely and gauge instinctive gut preferences [6]. As with any highly controlled experiment an attention check question was added to filter out inattentive responses. However, the question was deemed to be confusing and several errors were identified and so responses that failed this question were still considered in this data analysis.

Data Analysis

For the analysis of the ranking method, the raw rank scores were directly used (n = 40). For the analysis of the rating method, the raw rated data (n = 35) was converted into ranks, where the raw rated values were ranked for each product. This reduced the rating scale from 5 to the number of products considered (3 for the spacecrafts and chairs, 4 for the toasters), allowing for a comparison of rate and rank scales. When multiple sketch styles received equal rating (i.e. ties) their ranks were averaged to capture equivalent preferences in the ranked conversion. Two data points were excluded from the rated data analysis as the respective participants assigned identical ratings to all items, preventing meaningful differentiation in their responses. The study design allowed for a statistical comparison between rating and ranking scales to determine differences between the two methods, therefore providing insight into the usability of these methods in empirical survey designs for aggregate (or mean) value preferences in engineering design.

Results and Discussion

Figure 2 shows the plotted mean rankings and rating for all 10 products for each sketch style for the two rank and rate scale groups. The spacecrafts and chairs had 3 products depicted in 3 sketch styles while the toasters had 4 products and an additional heavily feathered (HF) line style. The graph shows that in most cases rank and rate scale types exhibit similar trends with the single line style as the most preferred among engineers with some differentiation in the preferences of the variable line and feathered line styles depending on product. For the toasters, the heavily feathered

(HF) line was consistently the least preferred. Some divergence between the two methods is visible, particularly in the Flower chair, Coffee-Maker/Toaster and Horizontal toaster where the rank scale appears to show greater differentiation between the line styles and can be explained by the nature of the ranking scale design that forces clearer comparisons between the options compared to the rate scale which allows for more flexible scoring, leading to compressed variability in responses.

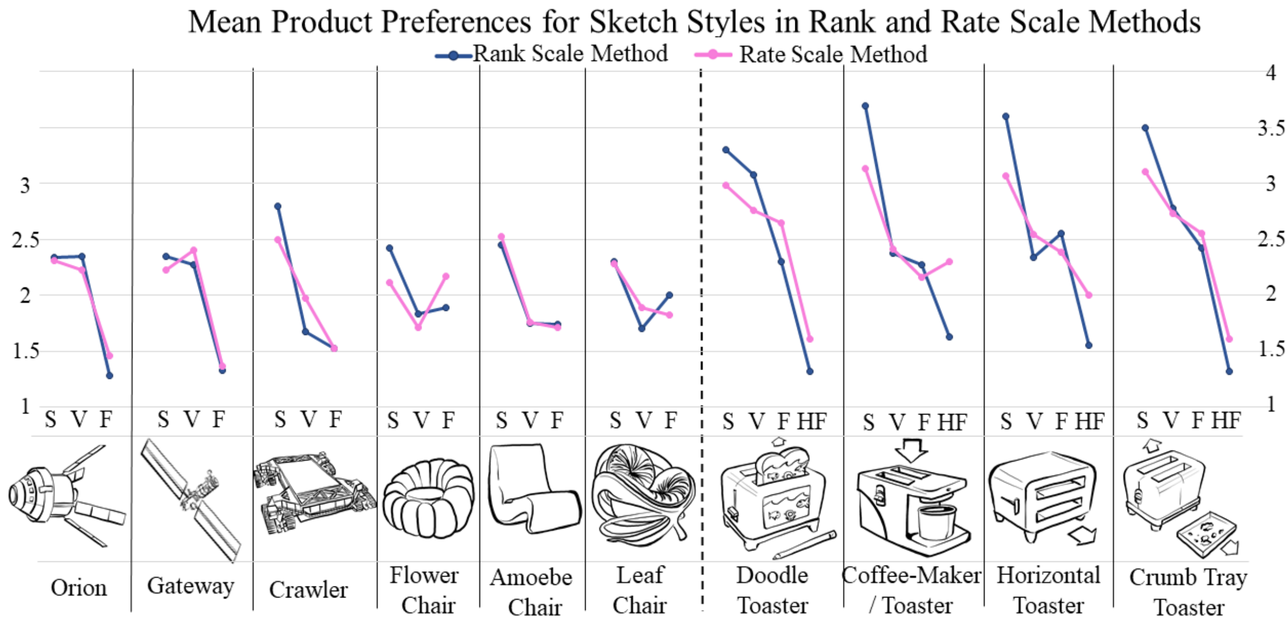

Figure 2: Average preference of each sketch style for 10 products comparing ranking and rating where 1 – like the least, and 3 or 4 – like the most. All images in Variable Line (V).

Preferences between the variable line style and the feathered line style vary significantly by product type and it is suspected that this may be due to the nature of the products. For more complex products with a higher number of line strokes there is a distinct preference for the variable line style suggesting that cleaner line styles may better communicate highly detailed products. A major limitation identified in this study come from the fact that the images may have been difficult for participants to see clear visual differences between line styles if their device type and screen size were smaller. Future work aims to conduct similar studies on paper.

Conclusion

Both ranking and rating scales reveal similar overall trends and point to the need for engineers to learn and utilize the single, clean line style seen in Industrial Design for within team feedback. Therefore, both scale types are suitable for determining usage of sketch styles in the engineering education context. However, the ranking shows a more pronounced variation suggesting it may better differentiate preferences when comparing sketch styles relatively while rating shows a more compressed range due to participants ability to rate multiple options equally. The use of either scale type should be carefully selected based on the needs of the study and should depend on whether the goal of the research is to capture fine grained distinctions between responses or prioritize comparison of items relative to one another.

Acknowledgements

The work was a part of the National Science Foundation under IUSE Grant # 2013504. The authors would also like to thank Dr. Maria Yang and Dr. Barry Kudrowitz for sharing supplemental materials from their studies that were not found in their original papers.

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