ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #38336

Sketchtivity, an Intelligent Tutoring Software: Broadening Applications and Impact

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Sketchtivity, an Intelligent Sketch Tutoring Software: Broadening Applications and Impact

Motivation and Background

Freehand sketching is a powerful skill in engineering design [1, 2]. Freehand sketching empowers designers in the early stages of design to express ideas, communicate with stakeholders, and evaluate concepts at a rapid pace. However, teaching sketching in engineering education poses unique challenges for the classroom. Sketching in other domains is often taught in studio-style courses where instructors can provide personalized feedback on technique. This type of feedback is not possible in typical large entry-level engineering graphics courses. To address this problem, Sketchtivity was developed as an intelligent tutoring software to aid instructors in providing feedback on sketching. Using a tablet and smart pen, learners receive real-time personalized feedback on sketching practice. The main goals of this project are to improve sketching instruction methods, understand the educational efficacy of Sketchtivity, and work towards improving the feedback and content of Sketchtivity.

Beyond investigating how to improve sketching ability, this project also aims to better understand how sketching skill impacts design activities. Many studies have demonstrated the importance of sketching for design [1, 2]. However, few studies have shown the influence of sketching ability on different design tasks [3]. This project seeks to better understand the importance of sketching ability through analyzing the relationships between sketching skill and design activities and improving the evaluation of sketching skill. To better understand how sketching ability can unlock creative potential in engineering design, this project investigates the relationship between sketching skill and idea generation ability. This project is also developing a new measure for sketching skill driven by a systematic literature review of sketching evaluation. The literature review and newly developed measure will bring new understanding to what we are measuring when we evaluate sketching skill in design.

In summary, this project has two main focuses: improving sketching ability and better understanding the importance of sketching ability for engineering design. This paper summarizes work completed towards these goals thus far. This paper reviews Sketchtivity and its capabilities, significant findings on improving sketching abilities, preliminary analysis on the relationship between idea generation and sketching ability, and lastly, work towards improved evaluation of sketching skill.

Sketchtivity

Sketchtivity is an intelligent tutoring system designed to instruct and provide feedback on freehand sketching activities. Sketchtivity guides learners through a progression of sketching lessons (Figure 1a) starting with basics such as lines, arcs, squares, and circles and progressing to more complex combinations of primitives. The lessons have brief explanations and a short instruction video to guide learners in best practices for sketching. Each lesson provides the learner with several randomly generated drawing prompts. Sketchtivity offers immediate feedback in the form of error lines which show the difference between the drawn stroke and the correct or ideal path shown in Figure 1b. At the end of the exercises, the lesson provides summative feedback providing average scores for *precision*, *smoothness*, and *speed*.

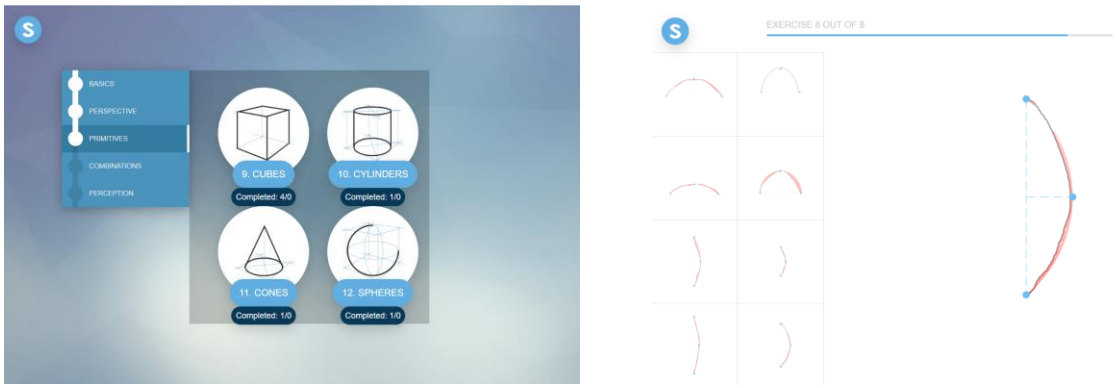

Figure 1: a. (left) Sketchtivity lessons page; b. (right) Sketchtivity immediate feedback

Sketchtivity has been implemented in engineering classrooms at three universities across the United States. Sketchtivity presents a fun learning environment where students can practice freehand sketching. The software helps to offload some of the work of the instructor while providing immediate feedback to students.

Improving Engineering Sketching Skill

Sketchtivity supports users in learning two-point perspective sketching techniques. Three factors to improve sketching skill were investigated: instruction type, instruction length, and the use of Sketchtivity for practice. For instruction type, two-point perspective sketching techniques were compared to what was traditionally taught in engineering programs, which mostly consists of isometric and orthographic views. For instruction length, students were compared who received either 3 weeks or 6 weeks of sketching instruction. And lastly, the efficacy of Sketchtivity was evaluated by comparing students who practiced solely on paper to those who practiced on paper and with Sketchtivity.

Analysis of sketching skill development showed that students who received two-point perspective sketching instruction improved their freehand sketching skill more than those who received traditional engineering sketching instruction [4]. Traditional isometric and orthographic views are usually practiced using straight edges or grid paper, which challenge freehand sketching skills less. Analysis further showed that students receiving 6 weeks of sketching instruction greatly outperformed those receiving 3 weeks [4]. Some engineering students are not receiving adequate training to improve their freehand sketching skills. Lastly, no differences were observed for students who used the Sketchtivity platform compared to those who only practiced on paper [4]. Further work is needed to better measure the effectiveness of Sketchtivity in the classroom. Future work will more effectively isolate the impacts of the feedback provided by Sketchtivity on sketching skill development.

Impact of Sketching Skill on Engineering Design

Engineering design challenges spatial reasoning skills with the need to perceive how things will interact in the physical world. Because of this dependence on visual-spatial reasoning, engineering designers' idea generation abilities are likely connected to their ability to represent concepts through sketching. Part of this project is working to better understand the relationship

between sketching skill and idea generation ability. Engineering designers generated solutions to an engineering design prompt for 45 minutes and then completed a test of sketching skills. Preliminary analysis was conducted on the quantity of ideas generated and overall sketch quality. In the initial run of the experiment, students were told upfront that their sketching and idea generation skills would be evaluated. On the second iteration of data collection, the priming language implying sketch evaluation was removed, and students were kept blind to the knowledge of a later sketch evaluation. The scatter plots for the two conditions, with and without sketch evaluation priming, are shown in Figure 2.

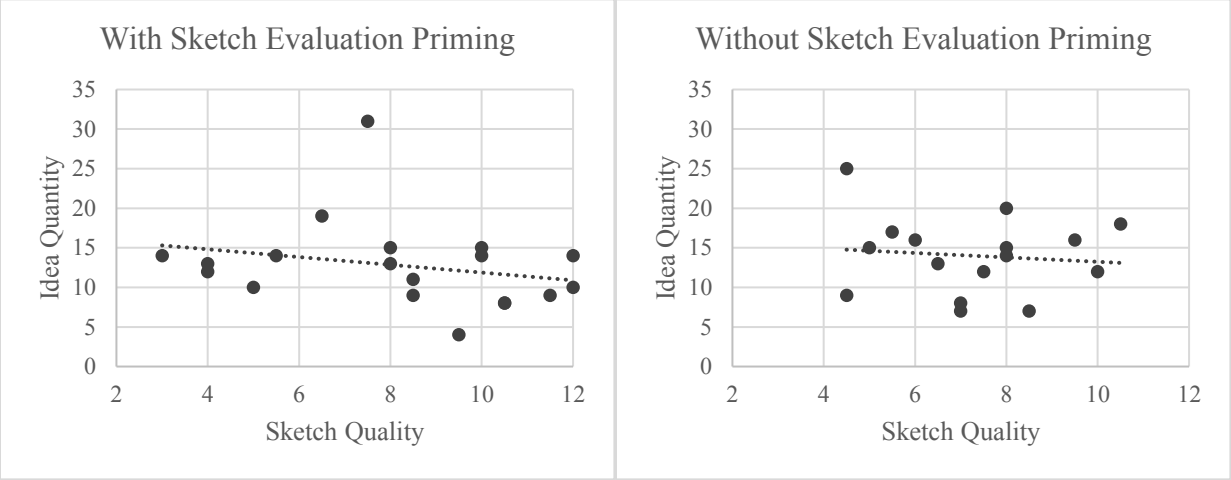

Figure 2: Scatterplots of idea generation quantity by overall sketch quality

Analysis using multiple linear regression showed that the sketch evaluation priming language had a negligible impact on ideation behavior. Also, the overall relationship with sketching skill and sketch quality was not significant [5]. This preliminary analysis suggests that sketching skill and ideation productivity are largely independent, which implies that all designers should be able to produce ideas equally regardless of sketching ability.

Evaluating Sketching Skill

In design literature, there is little to no consensus on how to evaluate sketching skill. Because sketching is such an interdisciplinary skill, sketching activities have been assessed through a variety of metrics, constructs, and practices. As part of this project, a systematic literature review is being conducted on sketching evaluation in engineering education. This literature review aims to provide clarity on what types of evaluations are used in different contexts, the cognitive theory behind assessments, and evaluation of the quality of assessments used in different fields. We found that relatively little research clearly articulates sketching constructs and metrics, and more often that sketching is used as a way to demonstrate learning. Many classroom sketching interventions use spatial ability tests as outcome measures, rather than directly assessing sketching. Sketching assessment is an interdisciplinary topic with diverse practices across fields. Further work will analyze sketching practices in various disciplines, with the goal of providing engineering design and education communities with recommendations on sketching assessment collected from the literature.

This literature review is also intended to guide the development of a new assessment of sketching skills. An assessment is currently being piloted at several universities in undergraduate mechanical engineering design classrooms [6]. Using object assembly tasks requiring mental imagery and mental rotation, learners are assessed on their ability to sketch in 1-point and 2-point perspective. Sketching skills are evaluated on representation accuracy, line smoothness, symmetry, line smoothness, scale, proportion, converging lines, and precision. Pilot data show consistent performance on metrics across tasks, and reliable scoring by task using the rubric. Many students displayed creativity and skill when drawing in perspective, and open-ended object assembly tasks allowed for unique responses. Future work will improve interrater reliability of the measurement and add measures to evaluate creativity and aesthetics of responses, as well as develop new open-ended object assembly tasks for this instrument.

Conclusions

Sketching is a valuable tool in engineering design. Sketchtivity has the potential to offload work for engineering instructors while providing instant feedback to students. Future work will seek to better understand the impact of the software on sketching skill development. Preliminary analysis shows that sketching ability and ideation productivity are likely independent suggesting that, regardless of skill, all designers are able to generate many ideas. Improved understanding of sketching evaluation will make way for more intentional and meaningful study of sketching in engineering education. All of the pieces of this project come together to provide a stronger understanding of the how and the why for improving sketching in engineering education.

Acknowledgements

This work is supported by the National Science Foundation IUSE program through award numbers 2013504, 2013612, 2013575, and 2013554. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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