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

Hillary E. Merzdorf Donna Jaison Samantha Ray
Morgan Weaver Dr. Kerrie A. Douglas Prof. Wayne Li
Dr. Vimal Vishwanathan Dr. Vinayak Krishnamurthy Dr. Julie Linsey
Dr. Tracy Hammond

Motivation and Background

Sketching is an essential skill for engineers. Engineering students develop problem representation and problem-solving skills in part through sketching[1, 2]. Communication with fellow engineers and designers depends on the ability to share ideas through sketching [3]. Sketching is important for problem formulation as designers create representations of a problem for problem scoping and communication [4]. Idea fluency and idea generation as measures of design creativity are supported through sketching [5, 6]. Sketching is also an effective approach for developing spatial visualization skills in engineering graphics [7]. Although learning to sketch benefits students in various ways, teaching sketching, assessing sketching skills, and providing individualized feedback to students is challenging. Digital sketching tools can make sketching instruction scalable, and intelligent tutoring features provide personalized instruction and guided practice for skill development [8].

The overarching research goal for this project is to understand the impact of sketching learning in engineering students at multiple universities. This project is motivated by three research goals:

1. Increase sketching skills in undergraduate engineering students
2. Improve understanding of sketching and personalized feedback with multiple measures
3. Evaluate visual communication and creativity skills on a digital platform

To address these goals, we developed SketchTivity, an intelligent sketching tutoring system, to provide students with a tool to practice sketching fundamentals and two-point perspective through exercises at various difficulty levels. The tool measures line quality (e.g., line smoothness and straightness), drawing speed, and geometric and perspective correctness of sketches. Sketch recognition algorithms are robust to the myriad of ways students can draw, allowing them to draw complex sketches with one or more strokes. Feedback at the end of exercises aligns with the sketching techniques taught in classrooms to reinforce good habits. The main goals of this project are to improve engineering students' sketching skills and to study the implications of learning to sketch in the context of idea generation, creativity, and engineering design self-efficacy.

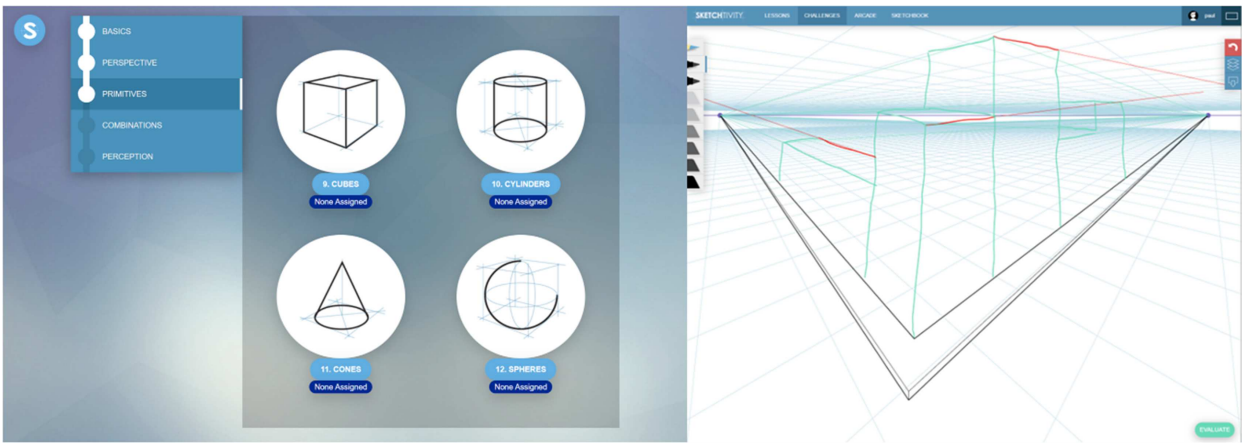

Figure 1: a. (left) SketchTivity lessons page. b. (right) Sketch recognition feedback.

SketchTivity

SketchTivity is an intelligent tutoring application which teaches students perspective sketching through a progression of lessons [8]. Lessons start with basics of lines and 2-dimensional arcs, squares, circles, and ellipses. Students then learn principles of 1-point and 2-point perspective sketching. Primitives are then sketched in perspective as cubes, cylinders, cones, and spheres [9]. Each lesson begins with an instructional video and an explanation of the technique, and students are shown 10 randomly generated prompts for each lesson (see Figure 1a). After sketching each prompt, SketchTivity provides immediate feedback on how closely a sketch matched the prompt using error lines (see Figure 1b).

The sketch recognition algorithms grade sketches on three metrics of Precision, Smoothness, and Speed. Precision and Smoothness are calculated as percentages out of 100%, and speed as pixels per second [10]. After each set of 10 sketches, students view summative feedback in their overall grade on the lesson out of 5 stars, their performance on the three metrics, and custom tips based on metrics with the lowest score (see Figure 2).

Sketching Foundations Test Checkpoints

The software also gives students sketching checkpoints using the Sketching Foundations Test, where they periodically practice horizontal and diagonal lines, squares, circles, and ellipses. Using checkpoints, we randomly assigned students to feedback groups who received regular feedback from the system or control groups who did not, then compared sketching performance between groups [11]. Preliminary results show that students who completed the Sketching Foundations Test at checkpoints had higher sketching scores overall than those who did not, suggesting the benefits of providing students with regular feedback on sketching performance throughout instruction [11].

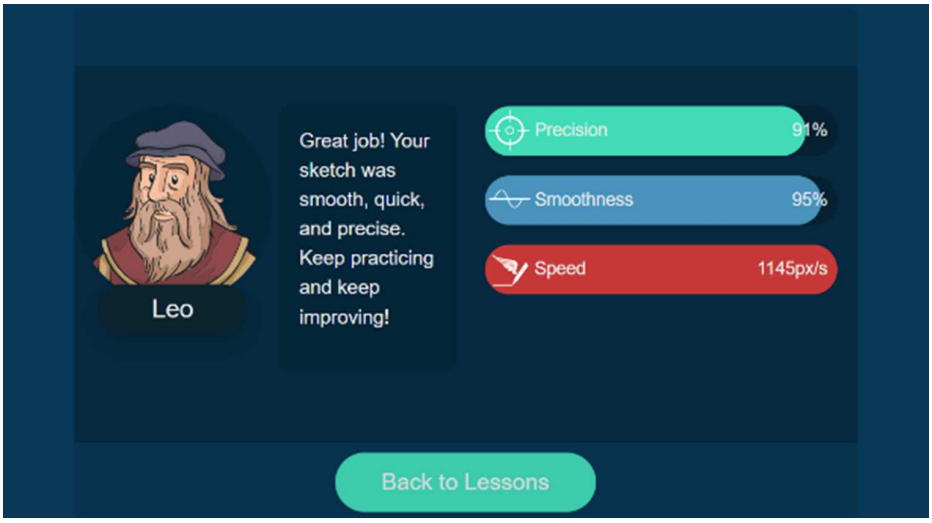

Figure 2: SketchTivity lesson feedback screen.

Student Perceptions of SketchTivity Feedback

As another aspect of the sketching checkpoints study, we surveyed students on their ratings of immediate and summative feedback and personalized sketching tips, their overall thoughts on SketchTivity's effectiveness for learning and practicing 2-point perspective sketching, and its impact on their motivation for practicing and improving sketching skills [12]. Questions were scored on a scale of 1 (Very Satisfied) to 7 (Very Unsatisfied). Students from three universities completed the survey with approximately 20 students in each feedback and no feedback group [12]. This poster shares our preliminary results of student perceptions between groups and overall satisfaction with SketchTivity's feedback features for teaching and encouraging sketching.

Instructor Experiences Teaching Sketching

SketchTivity has been implemented across three universities in undergraduate mechanical engineering courses for engineering graphics. Instructors incorporated an average of four weeks of sketching instruction into their lesson plans, giving students the opportunity to practice freehand sketching with SketchTivity as a part of engineering graphics instruction. We wished to discover how SketchTivity can support instructors outside of mechanical engineering by investigating how instructors from several different fields perceive and teach sketching. We interviewed 7 instructors from civil engineering, construction science, architecture, and architectural engineering about their sketching instruction practices, their thoughts about sketching's importance for engineers and the engineering curriculum, and their perceived importance of SketchTivity's metrics for sketching. This poster will share our preliminary results of themes from each interview topic, discussing any similarities and differences across disciplines.

Sketching Skill Assessment

Informed by a systematic literature review and expert consultation, we developed an Object Assembly Sketching skills test to benefit engineering educators in teaching and assessing perspective sketching skills through spatial reasoning exercises [13]. The test asked students to assemble 3-dimensional shapes using mental imagery and mental rotation, and to sketch assembled objects in 1- and 2-point perspective. Sketches were graded on representation accuracy, precision, scale, proportion, converging lines, line smoothness, and line weight. We conducted a pre-post intervention study of sketching skills improvement in two sections of an engineering graphics course, with approximately 45 students in each section, across two semesters [13]. Students completed the test before and after four weeks of sketching instruction and practicing with SketchTivity. Two raters graded 200 sketches and calculated inter-rater reliability. Results showed improved grading reliability between samples with practice and discussion. This poster will present our Object Assembly Sketching test rubric and reliability results grading perspective sketches.

K-12 Sketching Education Outreach

We plan to test SketchTivity's usability and educational value for K-12 students by sharing it at a children's science, technology, engineering, art, and math (STEAM) museum in Spring 2023. We will set up a learning station with tablets and smart pens where visiting students can try sketching exercises in an informal learning environment. Researchers were present to demonstrate the system and help students learn about perspective sketching. We note any usability challenges for young children in terms of the software interface, reading level of instructions, or difficulty with sketching actions. We will observe students' engagement with SketchTivity in terms of how long they spend at the learning station and how many sketches and lessons they complete. We also plan to discuss the learning impact with educators and museum staff. From this outreach opportunity, we hope to understand the interest of young children in learning sketching with SketchTivity for future research on K-12 sketching education. This poster will share our usability testing methods and preliminary findings, along with recommendations for software interface improvements.

Conclusions

This project supports sketching instruction in undergraduate engineering through the implementation of an intelligent tutoring system. SketchTivity has the potential to support instruction in perspective sketching with personalized feedback. To summarize, through this poster, we would like to expand the reach of our free Intelligent Tutoring system that could be used in any university to improve sketching skills in engineering students. We will also present our most recent findings since ASEE 2022 based on our ongoing research.

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