# WIP Teaching Engineers to Sketch: Impacts of Feedback from an Intelligent Tutoring Software on Engineers' Sketching Skill Development


Donna Jaison
*Department of Multidisciplinary Engineering*
*Texas A&M University*
College Station, TX, USA
donnajaison@tamu.edu

Morgan B. Weaver
*George W. Woodruff School of Mechanical Engineering*
*Georgia Institute of Technology*
Atlanta, GA, USA
mweaver43@gatech.edu

Samantha Ray
*Department of Computer Science & Engineering*
*Texas A&M University*
College Station, TX, USA
sjr45@tamu.edu

Hillary E. Merzdorf
*School of Engineering Education*
*Purdue University*
West Lafayette, IN, USA
hmerzdor@purdue.edu

Kerrie A. Douglas
*School of Engineering Education*
*Purdue University*
West Lafayette, IN, USA
douglask@purdue.edu

Vinayak Krishnamurthy
*Department of Mechanical Engineering*
*Texas A&M University*
College Station, TX, USA
vinayak@tamu.edu

Julie Linsey
*George W. Woodruff School of Mechanical Engineering*
*Georgia Institute of Technology*
Atlanta, GA, USA
julie.linsey@ma.gatech.edu

Karan Watson
*Department of Electrical & Computer Engineering*
*Texas A&M University*
College Station, TX, USA
watson@tamu.edu

Tracy Hammond
*Department of Computer Science & Engineering*
*Texas A&M University*
College Station, TX, USA
hammond@tamu.edu



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***Abstract*—This Research Work In Progress Paper examines empirical evidence on the impacts of feedback from an intelligent tutoring software on sketching skill development. Sketching is a vital skill for engineering design, but sketching is only taught limitedly in engineering education. Teaching sketching usually involves one-on-one feedback which limits its application in large classrooms. To meet the demands of feedback for sketching instruction, *SketchTivity* was developed as an intelligent tutoring software. *SketchTivity* provides immediate personalized feedback on sketching freehand practice. The current study examines the effectiveness of the feedback of *SketchTivity* by comparing students practicing with the feedback and without. Students were evaluated on their motivation for practicing sketching, the development of their skills, and their perceptions of the software. This work in progress paper examines preliminary analysis in all three of these areas.**



***Index Terms*—sketching, formative assessment, feedback, intelligent tutoring system**


## I. Introduction

Assessing student learning is an integral part of teaching effectively along with imparting knowledge and providing healthy learning environments [1]. Assessment can be either summative, formative, or diagnostic [2]. Summative assessment is more passive and does not involve an immediate influence on student learning most of the time although summative assessments can also involve formative feedback [3]. Formative assessment provides information to the students that will enable students to enhance their learning and thereby improve performance [4].

Feedback is an integral component of formative assessment; feedback comprises of information about "how successfully something has been or is being done" [3]. Information provided to students can be called "feedback only when it is used to alter the gap between the actual level of performance and the reference level" [5]. Thus, it is clear that success of an assessment strategy is dependant on the consequences of the assessment on student learning [6]. [3] mentions the importance of obtaining improved work in order to confirm that learning has occurred as a result of provided feedback. Asking the students to re-do the assignment is also another way for confirming that learning has occurred as a result of the provided formative feedback [7]. Feedback not only influences student learning, but also contributes to improving student motivation, and reinforcing behaviors [8].

Sketching is taught to engineering students belonging to different engineering domains. Sketching is an integral part of the engineering design process [9]. One study in fact reported that very few engineering students currently utilize sketching while working on various tasks in design [10]. Studies have shown that sketching enhances spatial ability in engineering students [11]–[13]. Further, spatial ability has been shown to positively impact academic performance of engineering students [14]. Sketching enables engineering designers to communicate their ideas and discuss it with team members as well as stakeholders [10].

Traditionally, sketching is taught in studio learning environments at universities by experienced instructors [15]. The increasing classroom size in engineering course makes it challenging for instructors to provide timely feedback, which is an essential part of learning to sketch [15]. According to [4], giving feedback in a timely manner soon after the submission has occurred is directly linked to the quality of the feedback along with other parameters such as providing relevant feedback according to prior defined criteria of assessment, and directing students to improve their work. Intelligent tutoring systems can be leveraged to mitigate the issue of providing timely and effective feedback with its advanced technology comprising of interactive lessons to provide unique and personalized feedback to learners. *SketchTivity*, is an intelligent tutoring system developed by researchers at Texas A&M university that uses advanced technology to provide timely feedback to learners in order to enhance student learning and motivation. This study is conducted in a graduate mechanical engineering course in order to investigate the effectiveness of the feedback provided by *SketchTivity* on the learners.

The research questions that will be addressed in this study are the following:

RQ 1: What is the impact of unique personalized feedback provided by *SketchTivity* on the student motivation to practice more sketching?

RQ 2: What is the impact of unique personalized feedback provided by *SketchTivity* in improving the key sketching skills assessment metrics?

RQ 3: What are student perceptions of *SketchTivity's* feedback feature?

## II. Methods

### A. *SketchTivity's Feedback mechanism*

To give feedback on sketch quality with respect to geometric correctness and pen control, the system calculates the precision of the sketch as compared to the prompt and the smoothness and speeds of the strokes (See Fig 1). In general, precision is defined as the average deviation from the prompt. This metric captures how straight lines are and how accurate curves are. Smoothness is the average change in angle along a stroke, e.g., a perfectly straight line would have no change in angle. Speed is the total length of the sketch divided by the time to complete the sketch, excluding time when the pen is lifted. All metrics are normalized to scores out of 100 to give consistent feedback across prompts of different sizes.

After each sketch, students in the feedback condition will see a visualization of their deviation from the prompt (See Fig 1). The area between the input sketch and the perfect sketch defined by the prompt is highlighted in red; examples are given in Figure (See Fig 1). At the end of the group of exercises, the students in the feedback condition see their average scores across the metrics to show them how well they performed. By contrast, students in the no-feedback condition do not receive the visualization of their precision, and the final page only shows a message to confirm that the lesson was completed. Example end screens are given in Figure 2.

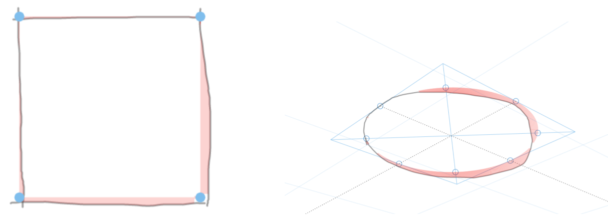

Fig. 1: SketchTivity Precision Visualization

### B. *Participants and Research Design*

The research study was conducted in a graduate mechanical engineering course named Advanced Product Design at Texas A&M university. Students were assigned to complete some of their sketching homework on the *SketchTivity* platform. Students self-reported their sketching expertise, and then they were randomly assigned to one of two experimental conditions controlling for sketching expertise. The two experimental conditions will be referred to as the control condition or the feedback condition. In the feedback condition, students experienced the regular *SketchTivity* tool. In the control condition, students saw the writing prompts, but were not given any of the feedback that *SketchTivity* typically provides. Students were kept blind to the condition they were in by assigning them unique registration codes. However, we did not prevent students from talking about the assignment amongst themselves. Students completed all *SketchTivity* assignments using a tablet and smart pen. If they did not have access to a device of their own, they were loaned one for the duration of the homework. If students could not gain access to a tablet, they were provided with alternative paper assignments.

The course consisted of 64 students with a mixture of in person and remote learning students, although most students were in person. This study only analyzes the students who completed all relevant homework assignments on the *SketchTivity* platform. A total of 40 students fully participated in the homework; 36 in-person and 4 remote learning. Of the students who reported demographic information, 28 were male and 5 were female. Student ages ranged from 22 to 38 with an average age of 24. Of the students who reported race/ethnicity information, 16 were Asian, 14 were white/Caucasian, 3 were Hispanic Latino or of Spanish Origin, and 1 reported other. All students were graduate engineering students, and a vast majority were majoring in Mechanical Engineering. Demographic characteristics were distributed roughly evenly between the two groups.

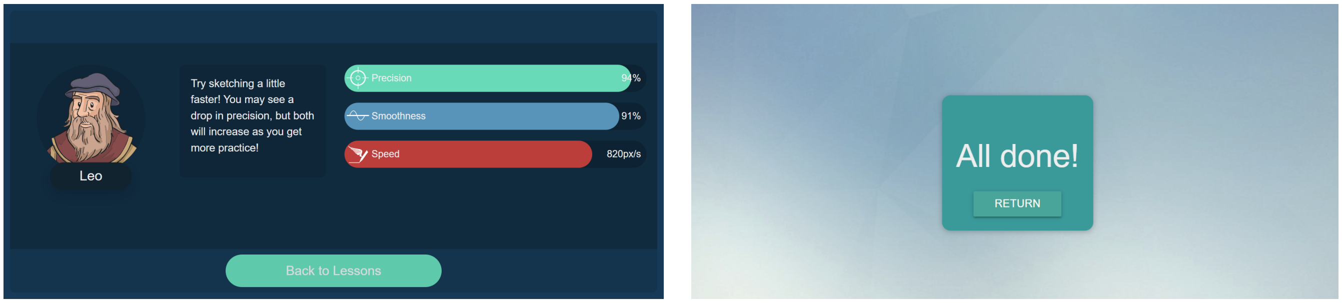


Fig. 2: SketchTivity Results Page: Feedback vs. No Feedback Condition

As a part of this study, we measured students' motivation, sketching performance, along with their perspective about *SketchTivity*. Students' motivation was measured through the number of practice sketches they completed on the software. Students were told to complete each of the 10 lessons in the software at least 3 times adding upto a total of 30 completed lessons per student. Total lessons completed was used as a measure of how motivated they were to practice. Students sketching performance was tracked through periodic sketching checkpoints. These brief tests were automatically prompted in *SketchTivity* to periodically track their progress. The sketching checkpoints did not provide feedback to either experimental condition. The test measures participants sketching precision, smoothness, and speed. Students' perceptions of *SketchTivity* were measured through a post intervention questionnaire. Students were asked a range of questions relating to how satisfied they were with *SketchTivity* and how effective they thought the software was at improve sketching and motivating sketching practice. Participants in the feedback condition were also asked about their preferences for the types of feedback they received.

## III. Results and Discussion

*RQ 1: What is the impact of unique personalized feedback provided by SketchTivity on the student motivation to practice more sketching?*

A Mann-Whitney U test was used to compare the number of lessons completed by students in the control and feedback conditions because the data does not meet the assumptions of a t-test. There was not a significant difference between the average number of lessons completed by students in the control condition (32.7) and the number of lessons completed by students in the feedback condition (34.7), U = 146.5, p = 0.143. This suggests that the *SketchTivity* feedback did not have a significantly motivating impact for students to practice. Few students completed extra practice lessons beyond what was required. Students were required to complete 30 lessons, 3 out of 20 students completed more than 40 in the control condition, but 6 out of 20 completed more than 40 in the feedback condition. This suggests that our lack of significance could be due to a small sample size. However, the power of the motivational impacts of *SketchTivity* is likely limited.

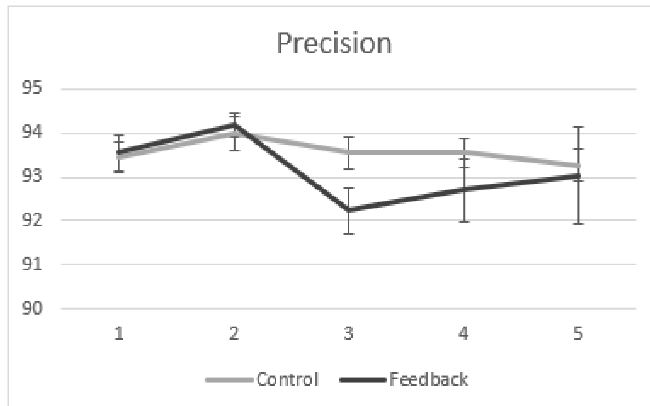


Fig. 3: Precision

*RQ 2: What is the impact of unique personalized feedback provided by SketchTivity in improving the key sketching skills assessment metrics?*

The results of the periodic sketching checkpoints are shown in the Figures 3-6 below. There is a slight trend observed for the smoothness metric showing the feedback group declining. However this was not significantly different with a Kruskal-Wallis H test. For the final observation point H = 2.083, p = 0.149. However, this trend could be due to the feedback group over focusing on other metrics leading to lower smoothness scores. There was no clear trend observed for the other two metrics. Neither experimental condition clearly improved during the course of instruction. This suggests that students may require more practice before significant improvements are measurable.

*RQ 3: What are student perceptions of SketchTivity's feedback feature?*

Students were surveyed on how effective *SketchTivity* was for teaching sketching and motivating practice. There was not a significant difference between the control and feedback conditions for how effective they thought the software was for teaching sketching (U = 143.5, p = 0.757) or how effective the software was for motivating practice (U = 119.5, p = 0.273). However, students in the control condition reported being significantly more satisfied with the software (5.78) than

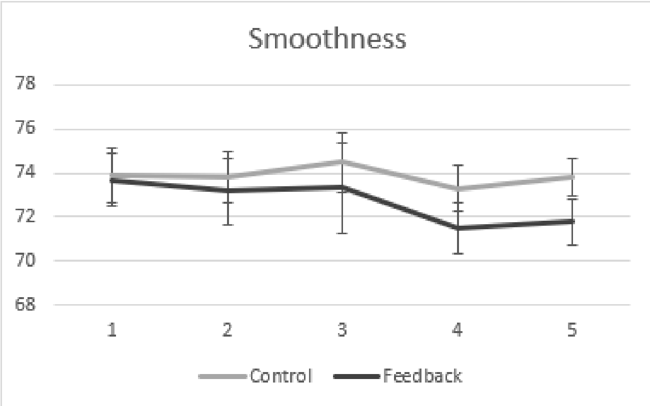


Fig. 4: Smoothness

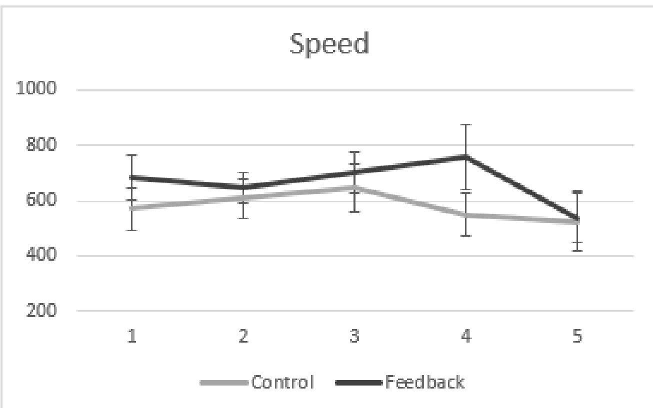


Fig. 5: Speed

students in the feedback condition (4.88), U = 93.5, p = 0.040. This could be due to issues and frustrations with the feedback provided.

Lastly, we analyzed the perspectives of the feedback group on types of feedback provided by the software. Students ranked two types of feedback: the immediate feedback that displays red lines showing their precision errors in real time and the summative feedback which displays the average scores after they complete a lesson. For helpfulness at improving sketching skill, immediate feedback ranked higher (1.29) than the summative feedback (1.94) with 1 being most helpful. For motivation for practice, the immediate feedback (1.65) was ranked similarly to the summative feedback (1.47).

## IV. Limitations and Future Work

The analysis in this study is limited by several factors. The sample size was smaller than desired and all of the data was from a single class. In future work, we will expand the sample size and collect data from a variety of classrooms. In data collection, there were issues with automatically triggering the checkpoint assessment. The periodic test was triggered each time students logged in, which disrupted the intended regular intervals of measurement. This limited the amount of data we had for the study. Lastly, the intervention of sketching practice

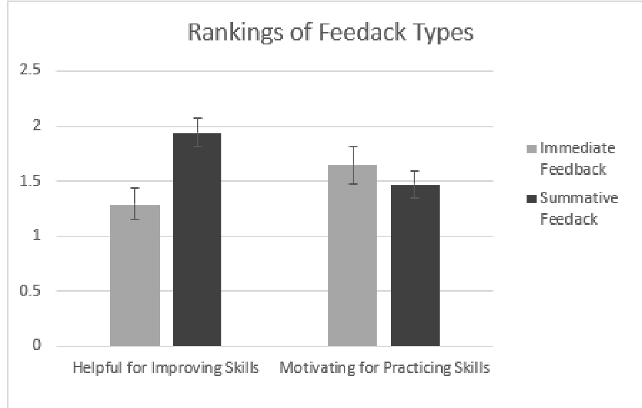


Fig. 6: Rankings

could be too small of a window for enacting real skill change in students. Future work will expand the amount of sketching practice students complete.

## V. Conclusions

Technology has influenced teaching and learning in all areas of education, and the impact of technology in sketching education is no different. Sketching is currently taught not only by experienced faculty in traditional studio learning environments but also through digital intelligent tutoring systems [16]. Intelligent tutoring systems have a potential to contribute to enhanced student learning in a unique way by modelling a human tutor by providing a personalized one-on-one learning environment [17]. Intelligent tutoring systems such as *Sketchtivity* have the potential to mitigate the challenges of teaching sketching in large traditional engineering classroom environments by providing timely feedback that is crucial for student learning.

Our initial findings indicate that students found the immediate feedback on precision most helpful for improving sketching skills; immediate feedback and summative feedback were equally helpful for different people at motivating sketching practice. No differences in motivation for practice or skill improvement were detected between the two groups. Future work will expand data collection to understand how much practice is necessary to improve students' sketching skills.

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