SketchTivity: Improving Creativity by Learning Sketching with an Intelligent Tutoring System

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Abstract

Sketching is a skill closely tied to creativity and a powerful tool for exploring and expressing ideas and becoming a more well-rounded communicator. Conventional sketching instruction employs traditional mediums such as pen and paper in studio environments to convey these fundamentals to students. However, this approach limits the bandwidth and capability of instructors to give timely and individualized feedback, and students often struggle with low self-efficacy and motivation. An intelligent tutoring system can leverage sketching pedagogy to give students personalized feedback outside of classroom hours, which can potentially improve self-efficacy, motivation, and creativity in the students. Additionally, the inclusion of games and gamified lessons can offer a more engaging and motivating experience for them.

This research is aimed at developing intelligent interactive lessons, challenges, and games that teach sketching fundamentals while evaluating their effectiveness in terms of improved sketching ability in the students, increased self-efficacy with respect to sketching ability and creativity, motivation to practice sketching, and idea generation capability. Ongoing work will be focused on developing creative challenges and measuring effects of the system on creative self-efficacy and idea generation in its users.

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Introduction

Drawing is a valuable lifetime activity that is closely tied to creative endeavors, [16, 31, 9], is uniquely tailored to each individual [10], has been shown to improve visual communication ability and benefit internal thought processes [28], can improve students' general academic achievement and problem-solving thinking [38], elevates awareness of and attention to details of surroundings [24], hones analytical skills [6], stimulates both halves of the brain [27], improves peripheral skills in writing, critical thinking, and brainstorming [6], and improves three-dimensional spatial recognition skills [29].

This research is focused on a form of drawing known as design sketching or conceptual sketching, which is often shortened to just *sketching*. Sketching is a tool for visual communication and idea generation and has practical purposes in many disciplines including design, engineering, science, research, and education. Despite its value, it is not often taught formally outside of design disciplines such as Industrial Design.

Background and Motivation

Sketching is traditionally taught in studio environments by experienced instructors. However, valuable expert

feedback from instructors is less available as classroom size increases and less accessible beyond classroom and instructor office hours [11]. An additional constraint is that for studio environments that involve students sharing their work to the rest of the class, those students who have low self-efficacy tend to be less motivated to participate and share their work. Sketching as a skill requires extensive practice (Figure 1) and is significantly affected by self-efficacy [1] such that students with low self-efficacy are less confident in their ability, unmotivated to practice, and tend to be discouraged by their more skilled peers [17]. This problem affects people of all ages and may be rooted in childhood as many children seem to decline in spontaneous art from around age 7 [15] and this has been found to be caused by a decrease in self-efficacy as it relates to sketching and artistic pursuits in general [26].

Not only is self-efficacy important for being motivated to practice and improve one's sketching ability, it also plays a role in creativity and creative performance. This *creative self-efficacy* has been shown to correlate with better creative performance [30]. Those who believe they can be creative tend to naturally perform better in creative endeavours.

The opportunity is to improve upon traditional pedagogy in teaching sketching by providing real-time feedback to students via sketch recognition. Sketch recognition is the automated recognition of hand-drawn diagrams by a computer. It may be possible to greatly improve student sketching ability, motivation, and creative self-efficacy with this approach, while empowering human instructors to give more personalized feedback and instruction within their limited bandwidth. Additionally, this approach may allow for a more diverse and inclusive audience to learn

Figure 1: A student practicing sketching cubes in a traditional setting with pen and paper. Cubes are a crucial fundamental primitive for sketching in 3D.

Figure 2: A student practices sketching cubes using SketchTivity on a Cintiq drawing tablet. They receive real-time feedback and can practice many cubes in a short time frame.

Figure 3: This creative challenge allows students to practice sketching a city street in two-point perspective and is intentionally open-ended to encourage divergent thinking.

sketching, not just those attending universities and enrolled in specific programs.

Related Work

Related work in this area has included other sketch-based intelligent tutoring systems for drawing [8, 5, 19, 37, 3] computer-assisted art applications [12, 22, 14], and creativity support tools focused on divergent idea production [7, 36, 16]. This work is differentiated in that it teaches specifically design sketching, and it teaches it in a way more analogous to teaching a *language* of visual communication, rather than teaching how to sketch only specific objects. Students learn fundamental skills that can be used to sketch any 3-dimensional object from their imagination. In this way, the system has a broader impact and focus on creativity than other tutoring systems, while encouraging idea generation that will be focused and based in realistic scenarios.

Current Deployment

SketchTivity is a web-based system built in HTML5. This allows for use on a wide variety of devices and operating systems, which is ideal for the long-term deployment and evaluation of the project. It is currently deployed in two courses at Georgia Institute of Technology - An introduction to Engineering CAD course for undergraduate Mechanical Engineering Students, and a beginner sketching course for undergraduate Industrial Design students. Outside of formal testing which is described later, students have logins to the system and can use the system at their leisure provided they have a tablet and an internet connection. A limited number of Wacom Cintiq drawing tablets are provided to the students as well. Components and features of the system are described below:

Interactive Lessons

The interactive lessons are arranged in a mastery-based [4] approach. They cover sketching fundamentals like lines, circles, planes, ellipses, 2-point perspective, cubes (Figure 2), cylinders, etc. They utilize sketch recognition algorithms to give real-time feedback on the accuracy of forms as well as line quality (smoothness) and speed.

Challenges

Challenges allow for students to begin trialing their sketching skills in creative exercises that test their ability to transfer knowledge (Figure 3). These open-ended tasks can be done in any number of ways, and are therefore interesting approaches to measuring creativity and idea generation.

Profile

The student and instructor profiles visualize data gained from the system on performance over time and lesson completion (Figure 4). This could empower students to better self-regulate their learning [25] while also empowering instructors to personalize their instruction.

Arcade

A game called *ZenSketch* has been developed that allows students to practice their line work (Figure 5). More games will be developed to assist with fundamental sketching skills. These games are intended to increase self-efficacy and motivation to practice in the students.

Completed Work

The system has been formally evaluated over the past two years, and has resulted in conference publications [32, 33, 18], a demo [34], a book chapter [35], and an accepted journal paper upon revisions [21].

Students using the software had increased sketching and visualization self-efficacy skills when compared with students who were using pen and paper [32]. Students sketching speed and accuracy improved significantly through the use of the system ($p < 0.001$) [20]. Statistical significance remained when we examined progress on each form independently ($p < 0.05$) and each student independently ($p < 0.05$). Motivation also seemed high as all students submitted more than the required number of sketches to complete the lessons. Qualitative data in the form of feedback on the user experience design of the system has been very positive and has aided in continuous design improvements. In particular, the students seem to appreciate the real-time feedback as well as the provided scaffolding of the perspective grid and lines, as it helps them grasp perspective easier and allows them to practice more forms in a shorter period of time than traditional practice methods.

Figure 4: A profile which may help motivate students to self-regulate their learning experience.

Figure 5: *ZenSketch*, a novel sketch-based game developed to help students practice line work.

Ongoing Work

Initial findings have been promising with respect to the efficacy of the system to improve sketching ability, motivation, and sketching self-efficacy in students, however the ongoing research questions relate to how improvements and knowledge gained via the system can transfer to subsequent sketches and affect creativity in the dimensions of creative self-efficacy, and divergent idea generation.

In addition to developing and testing more advanced lessons which will continue to teach more nuanced concepts of sketching such as combining primitives to form more complex objects, the opportunity is to continue developing creative challenges which test transfer of knowledge and skills and idea generation capability. It has been found that exercises closer to real-world scenarios

can better facilitate learning [23], so there will be an emphasis on realistic scenarios where creativity and visual communication is important such as the design of products or communicating ideas visually that must be understood by others such as sketching a map, or explaining an abstract concept.

Trajectory of Research

A comprehensive study is planned for the 2017-2018 school year at Georgia Tech where the system will be deployed in an Mechanical Engineering introduction to CAD course along with an Industrial Design sketching fundamentals course. In addition to measuring effects of the system on sketching ability in students, there will be a heavier focus on measuring creative self-efficacy and divergent thinking. Sketching ability data will be gained via sketch recognition features, and creative self-efficacy data will be gained via a modified self-efficacy scale [2]. Sketch data in the creative challenges will be acquired via the online platform and subsequently analyzed in terms of divergent thinking, and fluidity of ideas [13].

The study will also involve control groups who do not use the software in an effort to see the impact of the software in comparison to conventional methods for teaching sketching.

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