Improving Spatial Ability with Mentored Sketching

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Abstract

As the result of a qualitative investigation into spatial ability, a teaching technique called mentored sketching was found to be effective for teaching visualization skills to freshman engineering students. This contribution describes the technique, how it evolved, and comments made by students as to its effectiveness. While mentored sketching emerged as a novel approach for the advancement of student sketching and spatial ability skills, it appears unhindered by class size and provides few constraints as a teaching methodology.

INTRODUCTION

Spatial ability is a critical cognitive ability for many technical disciplines, but particularly engineering fields (Bowers, Raudebaugh, & Beakley, 1987; Miller, 1992; Miller & Bertoline, 1989). Simoneau, Fortin, and Ferguson (1987) contend that engineering graphics is important for two major reasons: "to teach the technical language" and "to develop the students' ability to visualize and solve problems in three dimensions" (p. 5). Due to the importance of these skills, most programs include engineering graphics courses in their curriculum to develop and advance students' spatial abilities (Bertoline, 1987).

At Purdue University, one such course is Computer Graphics Technology 163: Introduction to Graphics for Manufacturing (2007). The advancement of student technical sketching and visualization abilities is one of the major objectives of the course and one practical way this is developed is via freehand sketches that students undertake during their lectures and as homework assignments. The initial intent of the lectures sketches was to not only improve sketching and spatial abilities, but also to encourage the students to attend the lectures. Based on student performance, it appeared that this requirement was working, even though it was an anecdotal observation unsupported by any type of formal research.

During spring semester of 2006, a research study was conducted within CGT 163 (Mohler, 2006). One of the interesting findings of that qualitative study was the student reaction to the lecture and homework sketches. Many liked the lecture sketch methodology and believed that the sketching assignments, when combined with mentored sketching, were a significant aid to their spatial development. A summative conclusion drawn from the study was that the lecture-based approach to sketching actually served as a mentoring activity, one that allowed the students to significantly and concurrently advance both their visualization and sketching abilities.

This contribution will discuss the use of mentored sketching in an engineering graphics course, advocating the use of this teaching method to help students advance their visualization and sketching abilities. Data from the study are provided to support this claim and avenues for future research into this pedagogical approach are provided. To provide a context, the next section presents the relevant literature connected with the subject.

RELATED LITERATURE

Context-specific direct instruction has a positive effect on spatial ability (Baldwin, 1985; Conner, Serbin & Schackman, 1977; Friedlander, 1985; Smith & Litman, 1979; Smith & Schroeder, 1979; Tillotson, 1984). A literal search on spatial ability yields many articles that discuss improvement activities and approaches. Aside from drawing and sketching, a few examples of these include the use of physical models (Miller, 1992), 2D CAD (Mack, 1995), 3D CAD (Shavalier, 2004), 3D animation (Wiebe, 1993), and computer games (Dorval & Pepin, 1986). Regardless of method, most interventions focus on spatial relations (mental manipulation of envisioned objects through rotation or movement) or spatial visualization activities (translation of verbal or visual source imagery into another form).

While some have argued that spatial skills cannot be trained (Levine, 1980; McFie, 1973; Smith, 1964; Witkin, 1969), the bulk of the literature shows that with appropriate design and implementation, a wide range of activities can indeed impact spatial performance. Furthermore, spatial skill can be drastically affected by even limited amounts of training. Rovet (1983) stated that, "it appears that 12 minutes of instruction was roughly equivalent to three years of untutored development (p. 171)."

Contributions such as these often make a call for more spatial ability education, training, and interventions. McArthur and Wellner (1996) acknowledged that the spatial ability of students is becoming poorer due to decreased focus on spatial ability training. The authors would also add that digital tools—which appear to decrease the perceived need to engage in practical activities such as drawing and sketching in the classroom—are also partially responsible for this. Nevertheless, several researchers have highlighted the need for more focus on spatial ability training (Bishop, 1978; Habraken, 1996; Khoo & Koh, 1998; Kyllonen, Lohman, & Woltz, 1984; Lord, 1985; McKeel, 1993; Weinstein, 1984).

SKETCHING AND DRAWING AS AN INTERVENTION

Throughout the spatial ability literature, albeit sparsely, are some investigations that have examined the impact of drawing and sketching on spatial ability. Van Vorrhis (1941) was one of the first researchers who investigated the impact of drawing on spatial ability. He designed 12 instructional units that he used as remediation for students that scored poorly on spatial tests. Students participated in one unit per week for 12 weeks. The instructional units are of import because half of them (unit six through unit 12) required drawing or sketching.

For example, one unit required students to draw mirrored versions of objects, another required that they draw flipped and rotated versions of objects, and the remaining four required that a visualized object be drawn. Van Vorrhis found that students who participated in the instructional units significantly improved on the spatial tests and course exams. These students also received high marks for their final course grade. While Van Vorrhis was predominantly looking for an improvement in spatial ability, of importance to this contribution is the how of the intervention, namely through sketching and drawing.

Following this work, Blade and Watson (1955) acknowledged the impact of mechanical drawing on spatial ability of students. While they stated that spatial ability could be improved through "relevant academic experience," theirs is the one of the earliest to acknowledge the importance of drawing in the development of spatial skill. They also acknowledged other appropriate experiences as well, but gave primacy to drawing.

In 1975, Stringer used a combination of learning activities to determine the effect on spatial ability. The activities were composed of physical activity with tangible objects and drawings of those objects. However, the former was the primary focus. Because the author included both type of activities, he was unable to determine the impact of sketching alone. Additionally, he only found significance on one measure of spatial ability—the one, as he acknowledged, that was most like the activities the students performed. While not directly supporting or negating the use of drawing or sketching, his finding does support later contributions that acknowledge the context-specific nature of effective materials (Alias, Black & Gray, 2002; Tillotson, 1984). Consequently, Braukmann and Pedras (1993) reiterate this by specifically stating that not all drawing activities improve spatial skills. Having a context or discipline specific application for spatial activity is critical; abstracted instruction has little effect.

McKeel (1993) investigated the effects of an instructional intervention (part of which included a sketching component) on spatial ability. However, she did not find that spatial ability was impacted by the intervention. It should be noted that a very small part of her intervention required sketching and the participants were required to sketch the assembly of an object based on memory—in most cases, after watching someone else put the object together. McKeel acknowledged several factors that likely affected her findings, none of which negatively reflect on the sketching or drawing and its potential impact on spatial ability.

Roorda (1994) examined the impact of sketching within an engineering graphics course. She found that sketching is not highly correlated with typical subject areas such as algebra, calculus, chemistry, and physics. She noted that sketching gets little attention in these disciplines and therefore the results were rational. Nevertheless, Roorda (1994) acknowledged that freehand sketching could be an effective means to develop the visualization abilities of engineering students, as demonstrated through her practical examples in the article. Face validity is easily established between engineering graphics and drawing or sketching. Drawing and sketching is a natural language for engineering, and is foundational to understanding or explaining it.

In a later study, Orde (1996) examined the relationship between drawing ability and spatial ability. While the data did not present any significant relationship or predictability between them, the author acknowledged that extraneous factors may have impacted the results of the study.

Sorby and Górska (1998) investigated spatial ability improvement across graphics courses from one institution. In their contribution, the authors acknowledge activities that appear to impact spatial development. They found that the largest spatial skill increase was associated with three courses that relied heavy upon sketching and hand drawing activities. They concluded that these activities seemed to greatly enhance visualization skills.

In a subsequent contribution, Leopold, Górska, and Sorby (2001) conducted an international examination of the visualization ability of engineering students across three institutions. Their conclusions acknowledged the importance of "hands-on" problem solving and specifically, sketching, in the development of spatial abilities relative to engineering students.

Alias, Black, and Gray (2002) investigated the impact of sketching activities on the spatial visualization ability of engineering students. While the prescribed tasks included a wide range of activities, the authors required participants to sketch observed and imaginary objects. While they surprisingly found no gender differences—males and females responded similarly to the intervention—they did find that their instructional treatments significantly impacted student spatial skill. Aside from demonstrating a positive effect due to sketching, the authors highlighted the importance of concrete, practical activities and the integration of spatial training throughout the engineering curriculum.

Work by Contrero, Naya, Company, Saorin, & Conesa (2005) have experimented with electronic sketching and found that it provides potential in improving student spatial ability. The authors note that the use of the digital sketching provides a contemporary slant to teaching both sketching and visualization. The authors found that using the digital sketching tool allows educators to ensuring a minimum level of visualization ability. Subsequent work describes the evolution of the digital tool and further application to engineering graphics (Company, Contrero, Piquer, Aleixo, Conesa, & Naya, 2004).

Of these of 10 studies, seven acknowledge the positive impact of sketching or drawing on spatial ability. While other examples (or counter-examples) may exist, the seven noted here provide supporting evidence for the use of sketching and drawing activities as an intervention for improving spatial ability. Yet, none address the impact of sketching or drawing combined with a mentoring approach. Uniquely, the results from the present study seem to point to a teaching methodology that, when combined with activities that have shown positive results (sketching or drawing), reinforces or magnifies the effect, at least in the eyes of the students.

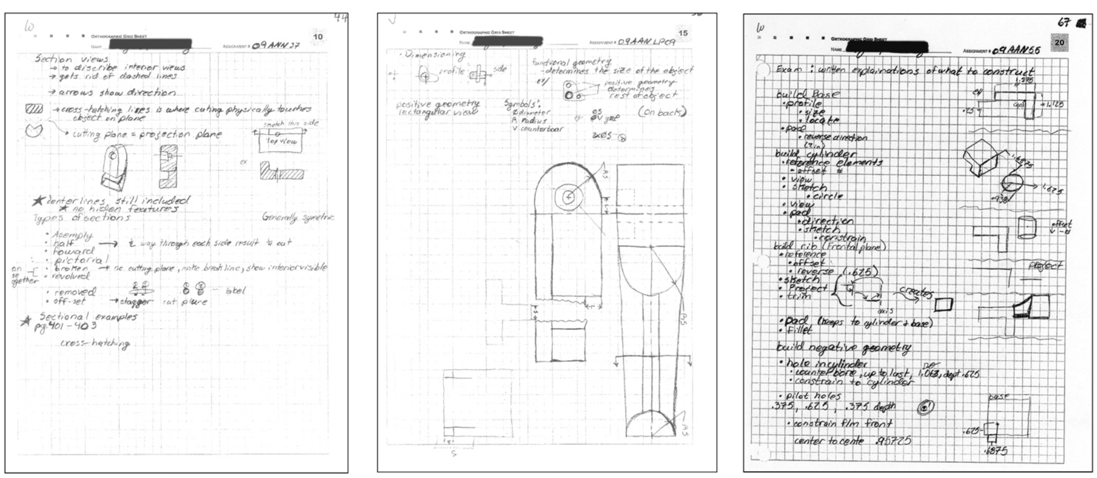
COMPUTER GRAPHICS TECHNOLOGY (CGT) 163

CGT 163 is an introductory course in computer graphics applications for mechanical and aeronautical related professions. Objectives focus on visualization, sketching, graphic standards, and problem solving strategies for engineering design. The course also emphasizes the proper use of parametric solid modeling for design intent.

As a two credit-hour course with an annual enrollment of approximately 950 students, the course meets three times each week. There is a one hour theory lecture, a one hour laboratory preparation lecture, and a two hour laboratory. The theory lecture and laboratory preparation lecture are mass lectures that break out into multiple laboratory divisions of approximately twenty students.

The purpose of the laboratory preparation lectures are to prepare students so that they will be ready for the exercises that are to be completed during the laboratory meetings, much like a chemistry or physics class. Typically sketch assignments and CAD demonstrations are delivered in the laboratory preparation sessions. Although attendance may be required, laboratory preparation lectures cannot be used to administer graded assignments, quizzes, or examinations.

The challenge of any large mass lecture course is attendance; even more so when one cannot administer activities for a grade. With those who do attend, gaining and maintaining attention is also a challenge. To address both of these issues, the author came up with the novel idea of having



(a) (b) (c)

Figure 1: *Example of student sketch-based notes relative to (a) section views, (b) dimensioning, and (c) construction procedures.*

the students turn in required "notes" at the conclusion of each lecture as proof of attendance. As shown in Figure 1a-c, the difference was that these notes were annotated freehand sketches of engineering graphics concepts, the aim of which was to engage the students in active learning, attempting to focus their attention.

The observed advantages of sketch-based notes are that they:

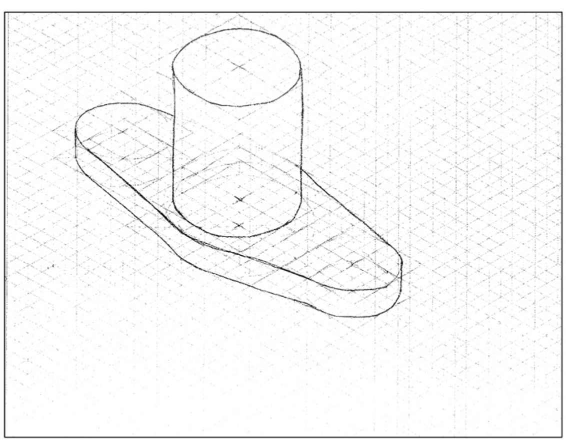
- Encourage students to attend the lectures.
- Allow for an interactive lecture where students cannot lose interest.
- Allow students more experience constructing engineering sketches.
- Help to advance the spatial abilities of the students.
- Allow the instructor to do mass mentoring of proper sketching techniques.
- Provide an opportunity for greater interactivity between the instructor and the students.

While some may perceive the development, collection, and distribution of 425 sketches a week as burdensome, the benefits have far outweighed the logistical overhead.

STUDY OVERVIEW

The purpose of the study conducted in CGT 163 was to elicit, describe, and analyze the experiences and perspectives of individuals with varying levels of spatial ability (Mohler, 2006). Participants were identified as high or low in spatial ability based on Vandenberg Mental Rotations Test score (Vandenberg & Kuse, 1978). Data sources included long interviews, talk-aloud tasks, focus groups, and researcher journal entries and observation notes. In the study, 12 students participated in in-depth interviews and eight students participated in one of two focus groups, totaling 20 participants in all. The sample size and selection methods was representative of phenomenological studies (Creswell, 1998; Dukes, 1984; Morse, 1994; Patton, 2002; Rieman, 1986).

Interviewees participated in three, 90-minute sessions. The first was aimed at eliciting experiences that the participant believed affected their spatial ability. The second interview required that participants solve three problems using a talk-aloud technique (Lodge, Tripp, & Harte, 2000; Nielson, Clemmensen, & Yssing, 2002). The final interview was used as a summative activity, having the participant reflect on the development of their spatial ability during the semester, their learning in the course, and their participation in the study.



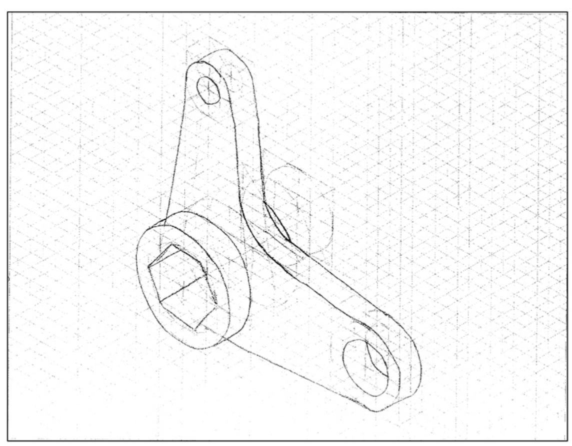


Figure 2: *Two examples of mentored sketching from the same student.*

Data relative to mentored sketching emerged as a result of the third and final interview with the participants. The researcher expected that sketching assignments or modeling software assignments would be acknowledged as significant activities. However, as the next section details, students acknowledged the mentored sketching sessions as most beneficial.

Qualitative Data Relative to Mentored Sketching

The mentored sketch sessions required that the students draw (in class) the solution to various problems in real time with the instructor. Figure 2 demonstrates examples of mentored sketches from the course.

Students acknowledged that the mentored sketching sessions helped in several ways. First, the mentored sketching helped the students see (in real time) how to think and to approach spatial problems. For example, one participant stated:

> …doing the sketches in class, seeing the teacher being up there and doing the sketches, you can see how they sort of go about doing the problem and you follow along and I think that really helps you process and understand. You know when you're given an example and you, not only like "here's the example" but also work through it with them at the same time I think that really helps.

When asked what thing in the class most helped him develop spatially, another student said:

> Um, I would just say it's the, like on the Wednesdays and you sit down and the professor's doing the, you and the professor are basically doing the same thing and he's just basically guiding you through the mental steps and stuff…that, really, really helps.

Students acknowledged that the mentored sketching also helped them learn terminology and have a realistic understanding, systematically, of how to accomplish the tasks. Of her experience, a student said:

> …the lecture sketches help a lot. Just because you know its an example of what you're going to do for your homework. And you have somebody going through it with you, step by step, mostly. So I think that's really effective…

The mentored sketches also provided the students an example that they could refer to if they had trouble solving their homework problems; the mentored sketches would do problems similar (but not the same as) their homework problems.

The prior participant excerpts document only a few of the student comments provided as a result of this study. While many acknowledged the importance of other course activities, such as use of the parametric modeling program, textbook, and multimedia components, all 12 interviewees acknowledged mentored sketching as effective, most acknowledging that it not only helped them in the course but also helped them to significantly improve their spatial ability.

CONCLUSIONS

The advancement of spatial and sketching abilities is a very important learning outcome for many entry level engineering graphics courses. Mentored sketching emerged as a novel approach for the advancement of both sketching and spatial abilities. The approach appears unhindered by class size and provides few constraints as a teaching technique. While the focus of the qualitative study was not aimed at an examination of mentored sketching as a teaching methodology, it became clear that participants thought it a high impact element of the course. Future studies are planned that will investigate the relationship between the mentored sketching sessions and course performance and spatial improvement using both qualitative and quantitative methods.

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