Developing Spatial Skills Among Middle School Students

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Abstract

Spatial skills have been the topic of educational research for decades and the importance of well-developed spatial skills to success in STEM fields is well-documented. Gender differences in spatial skills, especially in the area of mental rotation, have been observed in numerous studies. Helping students develop their 3-D spatial skills has been shown to lead to improvements in student success in engineering, particularly for women. Most of the research in spatial cognition conducted to date has been correlational in nature, i.e., spatial skills are correlated with success in engineering or other STEM fields. Graduates of STEM fields typically have highly developed spatial skills, but is this due to developing the skills over the course of study or is it due to "weeding out" of students with low spatial ability from these programs? Are high spatial individuals attracted to STEM disciplines? The answer to these questions is unknown but is likely a combination of these phenomena. The question remains: "If we help individuals develop their spatial skills at a sufficiently young age, can we increase their interest for STEM and their apparent willingness to choose STEM careers?" This paper describes an ongoing study that seeks to answer this question.

Background

Multimedia software and a workbook were developed by Sorby and Wysocki with funding from the National Science Foundation in 1998 (Gerson, et al, 2001). These materials have been the topic of several research studies since then and the primary findings from this body of work are (Sorby, 2001, Sorby, 2005, Sorby 2009, and Veurink & Sorby, 2011):

- 3-D spatial skills can be improved through training and practice.
- Spatial-skills training appears to have a significant positive impact on grades earned in a variety of STEM courses, including engineering graphics.

- Spatial-skills training appears to have a significant positive impact on student retention and graduation in engineering, particularly for women.

Engineering remains one of the least diverse of all STEM fields. Despite millions (perhaps billions) of dollars spent and the concerted efforts of many dedicated professionals, the percentage of women in engineering hovers around 17-18% and has been essentially unchanged for 30 years. While the work in spatial skills training has helped to retain those women who do choose engineering, this is only a piece of the puzzle. If engineering is to become more diverse in terms of gender, we must be able to attract more women into the field.

There is strong evidence to suggest that girls lose interest in science and mathematics in middle school (Catsambis, 1995). By the time most girls get to high school, they have "opted out" of the advanced math and science courses needed for engineering and the girls who do remain engaged with these courses are often attracted to careers in medicine, rather than one of the STEM fields. Thus, it is important to reach young women at a sufficiently young age, if we are to have an impact on their later career choices.

Current Study

In 2010, the authors were awarded a grant from the National Science Foundation through the Gender in Science and Engineering program to conduct a study aimed at improving the spatial skills of middle school students and to determine the impact of this training on those students, particularly the girls. To conduct the study, we partnered with two school districts, Marquette Area Public Schools in Marquette, Michigan, and the Weld Region-8 District, in Fort Lupton, Colorado. Each school district has about 150-200 students per grade level. The Fort Lupton school has a significant Hispanic population with about 70% of the students who speak English as a second language.

During the summer of 2011, one seventh-grade math teacher from each district was trained in the use of the spatial skills curriculum. It should be noted that each district had two teachers responsible for seventh grade math instruction—the untrained teacher served as the "control" teacher for this study. The training sessions were conducted by faculty who have been teaching the spatial skills course at Michigan Tech for numerous years. Training for each teacher was completed in about 10-12 hours of instruction and consisted of time spent on an overview of the data obtained from previous research in spatial cognition followed by the teacher completing each module in the software/workbook, with guidance from the trainer. Teachers were told that they could decide how they wanted to incorporate the materials into their regular mathematics instruction.

The teacher in Marquette decided to intersperse the spatial skills training throughout the academic year, covering one module at the end of each unit in her math course. Thus, the spatial skills instruction became the “fun” thing to do at the end of each unit. The teacher in the Fort Lupton school district chose to focus on the spatial skills training at the beginning of the year and had completed all of the instruction by Thanksgiving.

Students in both the experimental and control groups were administered a number of instruments prior to the start of the spatial skills training. Six of the instruments were used to assess spatial skills and included: 1) the Water-level task, 2) a paper-folding task, 3) a 2-D rotation instrument, 4) ten items from the Purdue Spatial Visualization Test: Rotations (PSVT:R) for measuring 3-D rotation ability, 5) ten items from the Modified Lappan instrument, and 6) ten items from the Mental Cutting Test (MCT). In addition, students completed three attitudinal surveys regarding their job interests and beliefs. The students completed all nine instruments again after completion of the spatial skills training. Students in the control groups completed the pre-/post-instruments at about the same time in the academic year.

Unfortunately, the teacher at Fort Lupton left the district at about the time that the spatial skills instruction was complete and we became concerned that the teachers' departure might have affected students' willingness to complete the post-test instruments. It seemed possible that the short-term results from this research may have been compromised by the sudden departure of the teacher although we expect that even if so, subsequent waves of data collection would not be affected. Given our concern, we decided to conduct the experiment again the following year at both districts, a modification to our original plans that also has the advantage of providing additional samples on which to test the effects of the curriculum.

For the second year of the study, the untrained teacher in each district went through the spatial skills training and incorporated the materials as they saw fit in their regular mathematics instruction. The teacher in Marquette chose to incorporate the spatial skills training throughout the year, as did her colleague in the previous year. The teacher in Fort Lupton chose to focus on the spatial skills training at the end of the academic year, rather than the beginning. Table 1 outlines the research design for this study.

Table 1. Research Methods (shading denotes spatial skills training within math course)

	Marquette		Fort Lupton	
	Teacher 1	Teacher 2	Teacher 1*	Teacher 2
Year 1				
Year 2				

* In Year 2 of the study, teacher 1 at Fort Lupton was a new teacher hired to fill the position for the person who vacated the district during the previous year.

In addition to the pre- and post-testing with the instruments designed to assess spatial skills and attitudes towards STEM careers and learning, we are gathering data from each district regarding:

- Standardized math and science scores
- Grades in math and science courses

- Gender and ethnicity

Results to Date

There is a great deal of data being generated by this study and analysis is still underway. There were issues with the collection of the data from Fort Lupton, so data from this district is not included in this paper. As expected, there were significant gender differences on most of the spatial tasks in the district for which those data have been analyzed. Table 2 includes the pre-test data by gender for year 1 of the study.

Table 2. Average Pre-test scores by gender for Marquette

	Males	Females
Paper Folding (20 pts possible)	7.9 (0.5)	6.5 (0.4)
2-D Rotation (30 problems with multiple correct answers each)	38.2 (2.0)	30.1 (2.0)
PSVT:R (10 pts possible)	3.3 (0.3)	2.5 (0.3)
MCT (10 pts possible)	2.0 (0.5)	1.4 (0.2)
Lappan (10 Pts possible)	2.2 (0.3)	1.4 (0.3)
Water-Level (6 pts possible)	2.9 (0.2)	2.2 (0.2)

NOTE: Standard errors are in parentheses.

For the data presented in Table 2, statistically significant gender differences exist for 5/6 spatial ability tests that were administered. The only exception was MCT which was the most difficult test and may have suffered from a floor effect.

At the end of the intervention, students in both the experimental and control groups were post-tested with the same instruments. Table 3 includes these results for the first year of the study for Marquette.

Table 3. Pre-/Post-Test Scores for Marquette Schools

	Experimental Group		Control Group	
	Average Pre-Test	Average Post-Test	Average Pre-Test	Average Post-Test
Paper Folding	6.0 (0.5)	9.0 (0.6)	6.3 (0.5)	7.6 (0.6)
2-D Rotation	30.9 (2.3)	39.4 (2.6)	28.2 (2.0)	38.6 (2.3)
PSVT:R	2.3 (0.3)	3.2 (0.4)	2.6 (0.3)	3.3 (0.3)
MCT	1.0 (0.3)	2.9 (0.3)	1.2 (0.3)	1.7 (0.3)
Lappan	1.1 (0.3)	2.6 (0.3)	1.4 (0.3)	2.0 (0.30)
Water-Level	2.6 (0.3)	2.9 (0.2)	2.2 (0.2)	2.4 (0.2)

NOTE: Standard errors are in parentheses.

For 2-D rotation and PSVRT;R, all students improved significantly from pre- to post-test. For Paper Folding, Lappan, and MCT, the experimental group improved more from pre- to post-test than did the control group.

Conclusions

This study is a work in progress. Seventh grade students in two school districts have participated in spatial skills training to determine the impact of this training. It is hoped that not only will the students improve their spatial skills, but that they will also perform better in their math and science courses and state-level testing, and that their interest in STEM will increase as a result. Results from this research will be reported in future EDGD conferences.

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