Online Spatial Skills Instruction for Community College Students in Technical Education

Sheryl A. Sorby
Department of Engineering Education
The Ohio State University

Susan S. Metz
Office of the Provost
Stevens Institute of Technology

Tania Jarosewich
Project Evaluator
Censeo Group

Abstract

Spatial skills instruction for engineering students at 4-year institutions has been accomplished over the past two decades with remarkable results. Numerous 4-year institutions have adopted the spatial skills curriculum aimed at first-year students with weak spatial skills. Adoption at the community college level has not been widespread. In order to accommodate the adoption of spatial skills instruction in community colleges, the SKITTS project has adapted the materials and developed additional supports for online instruction. This paper describes the project and includes preliminary results from initial implementations.

Introduction

The ability to visualize objects and situations in one's mind and to manipulate those images is a cognitive skill vital to many career fields, especially those that require work with graphical images. A long history of research has highlighted the importance of spatial skills in technical professions such as engineering (Maier, 1994), basic and structural chemistry (Barke, 1993), computer aided design software (Sorby, 2000), using modern-day laparoscopic equipment in medical professions (Eyal & Tendick, 2001), and interacting with and taking advantage of the computer interface in performing database manipulations (Norman, 1994). There is evidence that spatial visualization skill predicts course selection and success in physics (Talley, 1973; Kozhevnikov, Motes & Hegarty, 2007), chemistry (Talley, 1973; Wu & Shah, 2004) engineering (Duesbury & O'Neil, 1996; Gerson, et al. 2001) and geology (Kali & Orion, 1996; Orion, Ben-Chaim & Kali, 1997). Recent articles link spatial skills.to creativity and technical innovation (Kell et al. 2013) and to success in programming (Jones & Burnett, 2008). Adolescent spatial reasoning skills predicted choice of STEM majors and careers above and beyond the effects of verbal and math abilities (Wai, Lubinski, & Benbow, 2009) and spatial ability emerged as a consistent and statistically independent predictor of selecting STEM related courses, graduate study, and other measures of STEM attainment. Thus it is now clear that "spatial ability plays a critical role in developing expertise in STEM…" (Wai, Lubinski, & Benbow, 2009). In fact, nearly fifty years ago, Smith (1964) concluded that spatial skills play an important role in 84 different careers.

This project builds on studies that have analyzed the role of spatial skills for success in four-year and graduate college degrees, expanding the focus to technical education. The need to focus on technical education is supported by work of another ATE project, *Individual Differences in Technological Proficiency* (Hull, Glover, & Bolen, 2012). "The spatial domain represents another important ability for technological education. Several tasks performed by technicians require highly developed spatial talent. Prints and schematics are one clear example. Reading a two-dimensional print and transferring the specifications of the print with different views onto a 3-dimensional part requires the ability to recognize patterns, sometimes when the part is not visible. Again, it is important for technological education programs to recognize that basic cognitive abilities, such as spatial visualization, are skills that make technician careers possible and satisfying for some."

Online learning has gained widespread adoption over the past two decades as technology has evolved. In a 2003 review article (Twigg), the state of the art in online learning was categorized according to scheme developed through a multi-year, multi-million dollar project. According to this scheme, there are five broad categories of online learning. The first of these is the Supplemental Model whereby online resources are developed in support of the course, but the course itself is taught in much the same way as before. With the Replacement Model, course components such as lectures are replaced with online resources with class time spent on group work or projects. The Emporium Model was first developed at Virginia Tech for mathematics instruction and is based on the premise that students learn best when they are learning what they want to at their own pace. The Buffet Model takes this one step further and allows students to pick and choose the resources they will use to meet the course objectives. The Fully Online Model is more difficult to implement, but there has been some success in this arena.

In a Meta-analysis of online learning, a key finding was that on average, students in online learning conditions performed better than those receiving face-to-face instruction (US Dept of Education, 2009). The differences were even larger for those studies that compared a blended online/face-to-face course with courses taught entirely face-to-face. This suggests that a hybrid approach is optimal for improving student learning outcomes.

In this project, we are developing online resources to support spatial skills development and are testing these in a variety of classroom settings at the community college level.

Resource Development

The curriculum includes ten spatial skills modules[34], which SKIITS is enhancing in the following ways:

- **Revising current software resources.** The team is updating existing curriculum modules (i.e., background and exercises) with the latest technologies so that students' responses to multiple-choice exercises are recorded and available to the faculty member for grading and feedback. In addition, the software is being rewritten into HTML5 so that it will be internet-based for anytime, anywhere access.
- **Video mini-lectures**. The team has professionally developed 2-8 minute video introductions to the ten module topics, which are available through a common internet-based hosting site for use with a variety of computer platforms for anytime, any device access.

- **Video how-to instructions.** Approximately 24 new videos of about 2-3 minutes each provide step-by-step instruction for difficult concepts for several exercises, including the first isometric sketch, which can be daunting for students with weak spatial skills.
- **Industry examples of spatial skills.** Each module will include short video and/or written "inspirational" segments about the importance of well-developed spatial skills for successful technician careers.

The spatial skills course includes sketching-based workbook exercises that previous studies have demonstrated contribute to improved spatial skills. To fully automate the course, one of the project partners at UC San Diego is developing an iPad app that students use to for sketching exercises. The app automatically grades the student's work and provides feedback to the student and faculty member. However, since not all institutions will be willing to require student access to an iPad in order to complete the spatial skills course, paper-and-pencil workbook sketching exercises are still available.

Implementation

The project includes four community college partners: Community College of Baltimore County (CCBC, Baltimore, MD), Del Mar College (Corpus Christi, TX), McHenry County College (Crystal Lake, IL), and Tidewater Community College (Norfolk, VA). The faculty partners at each community college administered the Purdue Spatial Visualization Test: Rotations (PSVT:R) to students in technician and certificate programs that each community college identified as having a strong spatial skills component. The courses covered a variety of topics in a variety of technical education skills areas including: Introduction to Geographic Information Systems, Robotics Fundamentals, Design and Creation of Games, Computer-Aided Design Graphics, Building Information Modeling Architecture, Parametric Modeling Solidworks, Blueprint Reading for Manufacturing, Civil Engineering Drafting, Electronic Fundamentals with Computer Applications, and Electrics Circuits. Students who correctly answered fewer than 70% of the items were invited to participate in a spatial skills training course offered on campus. Each faculty partner designed the spatial skills training course to best meet students' needs, typically offering the 10 curriculum modules over 4-5 sessions using video lectures and drawing tutorials. At all four community colleges, students met with their instructor during a scheduled spatial skills workshop time. Faculty scheduled classes at several different times each week to allow students to choose the more convenient time. Two partners used the sketching iPad app developed for this project; remaining partners used the traditional paper and pencil sketching exercises. Community college faculty recruited students, developed strategies for retaining students in the course, taught the course, and submitted data about student participation and outcomes. All of the students who completed a PSVT:R at the start of the semester, those who completed the spatial skills course and those who did not, were invited again at the end of the semester to complete the PSVT:R to provide evidence of outcomes and create a set of comparison data.

Results

Over the two-years of the project to date, 981 students completed a PSVT:R assessment. Since completing the PSVT:R was voluntary, over the two project years, only 38% of students (N=377) completed both of the pre- and post-PSVT:R assessments. A majority of students who completed the pre-test (N=539) was eligible for the course. The fact that 61% of students had poor spatial skills confirms the need for a spatial skills intervention for community college students in technical education programs. Female students had a significantly lower average mean score than did males. A statistically significantly higher percentage of female students (79%) as compared to male students (56%) was eligible for the Spatial Skills Course based on PSVT:R pre-test scores. There was a statistically significant difference on PSVT:R pre-test scores based on students' race / ethnicity. Caucasian students had significantly higher scores than did Hispanic/Latinx, African American, and students who preferred not to answer or fell into different racial/ethnic categories. A higher percentage of Hispanic/Latinx (71%) and African American students (76%) as compared to white students (54%) was eligible for the spatial skills course. However, since we did not request a socioeconomic status (SES) indicator, differences in race/ethnicity could be due to SES.

Of the students eligible for the spatial skills course, only 95 (18%) completed the voluntary course at one of the partnering institutions despite the fact that instructors tried to accommodate student schedules by offering sessions on several different days and at different times. A positive and statistically significant outcome of participating in the spatial skills course was an increase in PSVT:R scores from the pre-test (45%) to post-test (51%). Another positive and statistically significant outcome was that eligible students who completed the spatial skills course earned a higher grade in their credit-bearing course than did eligible students who did not complete the spatial skills course. Eligible students who did not complete the spatial skills course earned a grade of a C in the credit-bearing course, while students who took the spatial skills course, even with the extra work and time required to attend the voluntary sessions, earned a final grade of B. A higher percentage of students who completed the spatial skills course earned a passing grade in the credit-bearing course (i.e., A, B, C; 85%) than did eligible students who did not complete the spatial skills course.

Conclusions

There are many challenges in implementing the spatial skills curriculum at a community college as compared to a university. University adaptations of the spatial skills course typically involve testing students during orientation or sometime prior to their first year of enrollment. Community college students tend to go in and out of enrollment, do not always declare a STEM curriculum, and do not follow a "standard" first-year curriculum. Developing online resources to support these students could enable a larger percentage of community college students in need of spatial skills training to actually take part in the training. Community college students have evaluated the materials developed to date positively. Future plans include the development of additional online resources.

Acknowledgement

The authors gratefully acknowledge the support of the National Science Foundation for this project through grant number HRD-1407123.

References

Barke, H.D. (1993). Chemical education and spatial ability. *Journal of Chemical Engineering*, *70(12): 968-971.*

Duesbury, R. & O'Neil, H. (1996). Effect of type of practice in a computer-aided design environment in visualizing three-dimensional objects from two-dimensional orthographic projections. *Journal of Applied Psychology 81(3): 249-260.*

Eyal, R. & Tendick, F. (2001). Spatial ability and learning the use of an angled laparoscope in a virtual environment. In J. D. Westwood et al, (Eds.) *Medicine Meets Virtual Reality (*pp. 146-152). Amsterdam: IOS Press.

Gerson, H., Sorby, S., Wysocki, A., & Baartmans, B. (2001). The development and assessment of multimedia software for improving 3-D spatial visualization skills. *Computer Applications in Engineering Education, 9 (2) 105-113*.

Hull, Darrell M., Glover, Rebecca J., & Bolen, Judy A. (2012). Indivudal Differences in Technological Proficiency: Project Findings.

Jones, S. & Burnett, G., (2008). Spatial ability and learning to program. *Human Technology, Vol. 4 (1), pp. 47-61.*

Kali, Y. & Orion, N. (1996). Spatial abilities of high-school students in the perception of geologic structures *Journal of Research in Science Teaching, 33, 369-391*.

Kell, Harrison, J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2013). Ceativity and Technical Innovation: Spatial Ability's Unique Role. *Psychological Science*, 24.9, 1831- 1836. http://pss.sagepub.com/content/early/2013/07/10/0956797613478615, DOI: 10.1177/0956797613478615.

Kozhevnikov, M., Motes, M., & Hegarty, M. (2007). Spatial visualization in physics problem solving. *Cognitive Science, 31(4), 549-579*Maier, P. H. (1994). Raeumliches vorstellungsvermoegen. Frankfurt A.M., Berlin, Bern, New York, Paris, Wien: Lang.

Norman, K.L. (1994). Spatial visualization-A gateway to computer-based technology. *Journal of Special Educational Technology, XII(3), 195-206*

Orion, N., Ben-Chaim, D. & Kali, Y. (1997). Relationship between earth science education and spatial visualization. *Journal of Geoscience Education 45: 129-132.*

Smith, I. M. (1964). Spatial ability - Its educational and social significance. London: University of London.

Sorby, S. A. (2000). Spatial abilities and their relationship to effective learning of 3-D modeling software. *Engineering Design Graphics Journal, 64(3), 30-35*

Talley, L.H. (1973). The use of three-dimensional visualization as a moderator in the higher cognitive learning of concepts in college level chemistry. *Journal of Research in Science Teaching, 10, (3) 263-269.*

Twigg, C. A., (2003). Improving Learning and Reducing Costs: New Models for Online Learning, Educause Review, Sept/Oct 2003. https://net.educause.edu/ir/library/pdf/ERM0352.pdf

US Department of Education. (2009). Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies. www.ed.gov/about/offices/list/opepd/ppss/reports.html

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), *817-835*. DOI:10.1037/a0016127

Wu, H, & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education, 88(3), 465-492*.