Work In Progress - Identifying Undergraduate Courses Which Develop and Enhance Spatial Abilities

Susan K. Donohue
The College of New Jersey, sdonohue@tcnj.edu

Abstract – **One skill set important to student success in engineering studies is spatial abilities; consequently, research in the assessment of skill levels and methods of improving weaknesses is robust. As part of our preliminary investigation into research questions regarding the impact of various teaching/learning methods on the development and enhancement of spatial abilities for different student demographics, we administered a survey of undergraduates at two institutions in an effort to identify courses they believe are effective in achieving those objectives. The survey results affirm the efficacy of both CAD instruction and technical drawing in developing and enhancing spatial abilities as reported in earlier studies. The latter finding is especially robust among one institution's female students. This result motivates further research into the specific contributions of technical drawing activities to the development and enhancement of spatial abilities in general in females. The re-investigation of "old school" interventions may be of particular interest to P-12 engineering educators working with constrained resources.**

Index Terms – educational interventions, gender issues in engineering education, P-12 engineering education, spatial abilities.

INTRODUCTION

Spatial abilities have long been acknowledged as critical to success in engineering studies [1] – [2]. They are also widely acknowledged to be gender-differentiated, although there are indications that other factors, such as socioeconomic status and development of working memory, may be involved [3] – [4]. Research identifying these other factors affecting skill levels further indicates that an underlying factor may be the level of access to and use of agents shown to improve spatial abilities such as video games and Legos, thus demonstrating the trainable nature of these abilities. The finding of trainability holds even for the skill for which the largest performance gender gap exists, mental rotation.

Development of and performance with respect to spatial abilities are important topics in gender studies in engineering because facility with these abilities is critical to success in disciplines in which female students are grossly underrepresented – and, not incidentally, the disciplines in which the great majority of undergraduate engineering degrees are awarded: civil engineering, electrical and computer engineering, mechanical engineering, and computer science (within engineering). In Academic Year (AY) 2007, females earned only 13.6% of the bachelor degrees awarded in these majors, which account for 69% of all bachelor's degrees in engineering overall [5]. The identification and implementation of educational interventions to improve a student's level of spatial abilities may therefore be an important factor in the retention of females and other students from underrepresented populations in undergraduate engineering studies, especially in programs of study in which facility with these abilities are important.

In this work in progress, we present results from preliminary research into the efficacy of various teaching/learning methods on the development and enhancement of students' spatial abilities and discuss directions for further work. We acknowledge that spatial abilities are critical to success in many fields (*cf.* [6], [7]); however, our focus will be on identifying effective interventions for females in engineering and technology studies.

SPATIAL ABILITIES: A BRIEF OVERVIEW

"Spatial abilities" are a collection of cognitive, perceptual, and visualization abilities skills. While lists may differ, substantial agreement exists that spatial abilities involve [8, p. 115]:

- the ability to visualize mental rotation of objects
- the ability to understand how objects appear in different positions
- the skill to conceptualize how objects relate to each other in space
- three-dimensional (3D) understanding
  - The traditional focus was on the understanding and manipulation of 2D space (*cf.* [7])

Sorby discusses the difference between "spatial abilities" and "spatial skills." Technically, the former refers to innate abilities and the latter to learned abilities; however, the two terms are often used interchangeably [9].

METHODOLOGY

We developed a brief online survey to elicit student opinions on the courses they believed to be most effective in

978-1-4244-6262-9/10/$26.00 ©2010 IEEE

the development and enhancement of their spatial abilities. The survey was administered to fourth-year mechanical engineering students (n = 25) at the University of Virginia (UVa), and to students in two majors – technology / pre-engineering education (T/PE Ed; n = 18) and dual education / math/science/technology (M/S/T; n = 50) – at the College of New Jersey (TCNJ) during the Spring 2010 semester. Basic demographic information was also elicited. There were different survey versions for UVa and TCNJ since school-specific information, such as course numbers, is extensively used.

Preliminary Results and Future Work

The courses having the highest self-reported impact on the development and enhancement of student spatial abilities are reported in Tables I and II, below. The survey results affirm the efficacy of both CAD instruction and technical drawing in developing and enhancing spatial abilities as reported by earlier studies. No differences in responses can be attributed to any demographic category. We also list probable interventions, identified from course descriptions, to investigate in the tables.

TST 161, Creative Design, is one course whose content and methods we will investigate further. It is a required course for the three populations we're interested in studying – undergraduate engineering students, T/PE Ed students, and M/S/T majors – thereby providing us with opportunities for robust samples. Once the course's most effective interventions are identified, we will develop research plans to develop more precise measurements of effectiveness. We anticipate using a mixed methods approach.

Acknowledgment

I am grateful to Larry Richards, Professor of Mechanical and Aerospace Engineering at the University of Virginia, for his mentorship and support, and for administering the survey discussed here in MAE 468, Creativity and New Product Development II. I also appreciate the contributions of the undergraduates through survey participation.

References

[1] Findley, W.G., "Using Tests to Select Engineers," *Proceedings of the IRE* 39(11), 1951, pp. 1364 – 1367.

[2] Sorby, S.A.; Drummer, T.; Hungwe, K.; Parolini, L.; and Molzan, R., "Preparing for Engineering Studies: Improving the 3-D Spatial Skills of K-12 Students," *Proceedings* of the 9th International Conference on Engineering Education (2006), pp. T3E-6 – T3E10.

[3] Levine, S.C.; Vasilyeva, M.; Lourenco, S.F.; Newcombe, N.S.; and Huttenlocher, J., "Socioeconomic Status Modifies the Sex Difference in Spatial Skill," *Psychological Science* 16(11), 2005, pp. 841 – 845.

[4] Kaufman, S.B., "Sex Differences in Mental Rotation and Spatial Visualization Ability: Can They be Accounted for by Differences in Working Memory Capacity?," *Intelligence* 35(3), May – June 2007, pp. 211 – 223.

[5] Gibbons, M.T., "The Year in Numbers," *2007 Profiles of Engineering and Engineering Technology Colleges*, Washington, DC: The American Society for Engineering Education, 2007.

[6] Stavridou, F. and Kakana, D., "Graphic Abilities in Relation to Mathematical and Scientific Ability in Adolescents," *Educational Research* 50(1), March 2008, pp. 75 – 93.

[7] Olkun, S., "Making Connections: Improving Spatial Abilities with Engineering Drawing Activities," *International Journal of Mathematics Teaching and Learning*, April 2003, pp. 1 – 10.

[8] Sutton, K. and Williams, A., "Developing a Discipline-Based Measure of Visualization," *UniServe Science Proceedings*, 2008, pp. 115 – 120.

[9] Sorby, S.A., "Developing 3-D Spatial Visualization Skills," *Engineering Design Graphics Journal* 63(2), Spring 1999, pp. 21 – 32.

Author Information

Susan K. Donohue, Assistant Professor, Department of Technological Studies, School of Engineering, The College of New Jersey, Ewing, NJ, 609.771.2798, sdonohue@tcnj.edu.

TABLE I
UVa Mechanical Engineering Courses Identified Contributing to the Development of Spatial Abilities (Spring 2010)

Course Name	% Students Selecting	Probable Intervention(s)
MAE 4710 Mechatronics	32%	design focus
MAE 2320 Dynamics	36%	3D and rotational modeling
ENGR 1620 Introduction to Engineering	36%	design focus
MAE 2310 Strength of Materials	40%	diagram creation and analysis, modeling
MAE 2300 Statics	44%	diagram creation and analysis, modeling
MAE 3710 Mechanical Systems Modeling	48%	modeling and simulation
MAE 2000 Introduction to Mechanical Engineering (Mechanics Familiarity Lab)	60%	engineering graphics, engineering drawing, CAD, and solid modeling

TABLE II
TCNJ Technological Studies Courses Identified as Contributing to the Development of Spatial Abilities (Spring 2010)

Course Name	% T/PE Ed Students Selecting	% M/S/T Students Selecting	Probable Intervention(s)
ETE 111 Engineering Design	67%	18%	design focus, CAD, modeling
ETE 261 Multimedia Design	28%	36%	2D modeling, design focus, graphics
ETE 271 Structures and Mechanics	33%	38%	3D modeling, design focus, diagram creation and analysis
TST 161 Creative Design	50%	64%	2D and 3D modeling, design focus, technical drawing