Paper ID #28534

A comparison of spatial ability in first-year and graduating students in a 4-year engineering degree program (WIP)

Dr. Maxine Fontaine, Stevens Institute of Technology (School of Engineering and Science)

Maxine Fontaine is a Teaching Assistant Professor in Mechanical Engineering at Stevens Institute of Technology. She received her Ph.D. in 2010 from Aalborg University in Aalborg, Denmark. Maxine has a background in the biomechanics of human movement, and she currently teaches several undergraduate courses in engineering mechanics. Her research interests are focused on improving engineering pedagogy and increasing diversity in engineering.

A comparison of spatial ability in first-year and graduating students in a 4-year engineering degree program (WIP)

Introduction

Spatial ability has been identified as a key indicator of success in an engineering degree program [1, 2]. Students who have low spatial ability are more likely to drop out of engineering. It is well-established that women are disproportionally affected with lower spatial ability [3-8]. However, spatial skills can be improved significantly with focused practice [9]. Sorby's "Developing Spatial Thinking" curriculum is one of the most widely used for spatial skills courses [10].

For these reasons, we have recently implemented a first-year program aimed at identifying and helping students with low spatial ability at Stevens Institute of Technology. Spatial ability of all first-year engineering students is assessed by the Purdue Spatial Visualization Test: Rotations (PSVT:R) as a part of our engineering graphics course [11]. Students who score below 60% are encouraged to attend evening spatial skills workshops. Generally, students who complete a short 4-week spatial skills workshop see a significant increase in test score, pre- vs. post-workshop.

But are these immediate gains in spatial skills retained? Do spatial skills continue to improve over the course of the engineering degree program? In this study, we compare the PSVT:R scores of first-year and graduating (senior) engineering students.

Methods

All first-year engineering students were required to take the PSVT:R as a part of their engineering graphics course. The test was offered as an extra credit assignment for all graduating engineering students enrolled in senior design course section under the Mechanical and Civil Engineering departments. A total of 299 freshmen and 56 seniors participated in the study in fall 2017. A total of 412 freshmen and 171 seniors participated in the study in fall 2018.

The PSVT:R consists of 30 questions, and students were given 30 minutes to complete the test. Pass rates were calculated based on a passing test score of 60% (18 out of 30). First-year students who scored below 60% were encouraged to attend a spatial skills workshop and retake the test at the end of the semester. Most first-year students who did not initially pass the test chose to re-take the test at the end of the semester, whether they attended the workshop or not. Graduating seniors were only offered one opportunity to take the test during the semester.

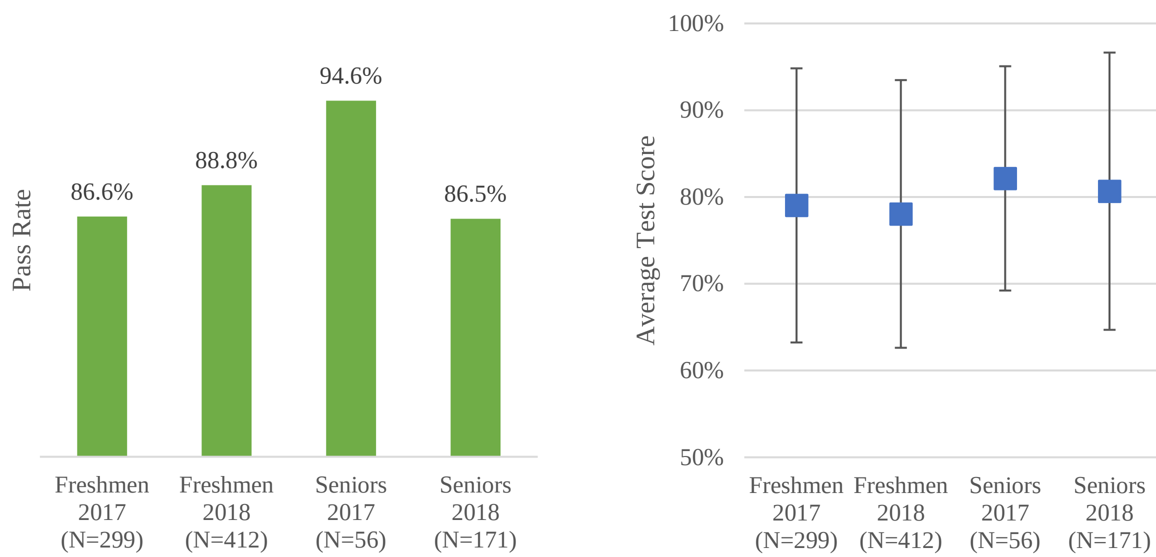
Results

Participant data by year and by gender are summarized in **Table 1**. For all four classes, the percentage of female engineering students was similar, ranging from 27% to 29%.

Table 1. Summary of participant data by year and by gender

Year	Male	Female	Non-Binary	Total
Freshmen 2017	213	86	0	299
Freshmen 2018	289	120	3	412
Seniors 2017	41	15	0	56
Seniors 2018	122	49	0	171

Test results over the two-year study are shown below in **Figure 1**. Figure 1a shows that 94.6% of all seniors and 86.6% of all freshman initially passed the test in 2017. Similarly, 86.5% of all seniors and 88.8% of all freshman initially passed the test in 2018. Overall pass rates for seniors were not significantly higher than those of freshmen. This would seem to indicate that graduating students have a similar level of spatial ability as incoming students. However, considering average test scores, seniors slightly outperformed freshmen in both years, as seen in Figure 1b. The average test scores among the freshmen classes were 79.0±15.8% and 78.0±15.4%, slightly lower than those of the senior classes, 82.1±12.9% and 80.7±16.0%.



(a) (b)

Figure 1. (a) Pass rates of seniors and **initial** pass rates of freshmen in fall 2017 and fall 2018. (b) Average test scores of seniors and **initial** average test scores of freshmen in 2017 and 2018.

Incoming students were offered the chance to take the test again during the semester, in addition to the opportunity to attend a spatial skills workshop. In 2017, 60 out of 72 freshmen who did not initially pass opted to retake the test, and 82 out of 104 freshmen in 2018. Initial test scores were replaced with the re-take test scores, and new pass rates were calculated for the freshmen class, shown below in **Figure 2**. Pass rates for the seniors remain unchanged.

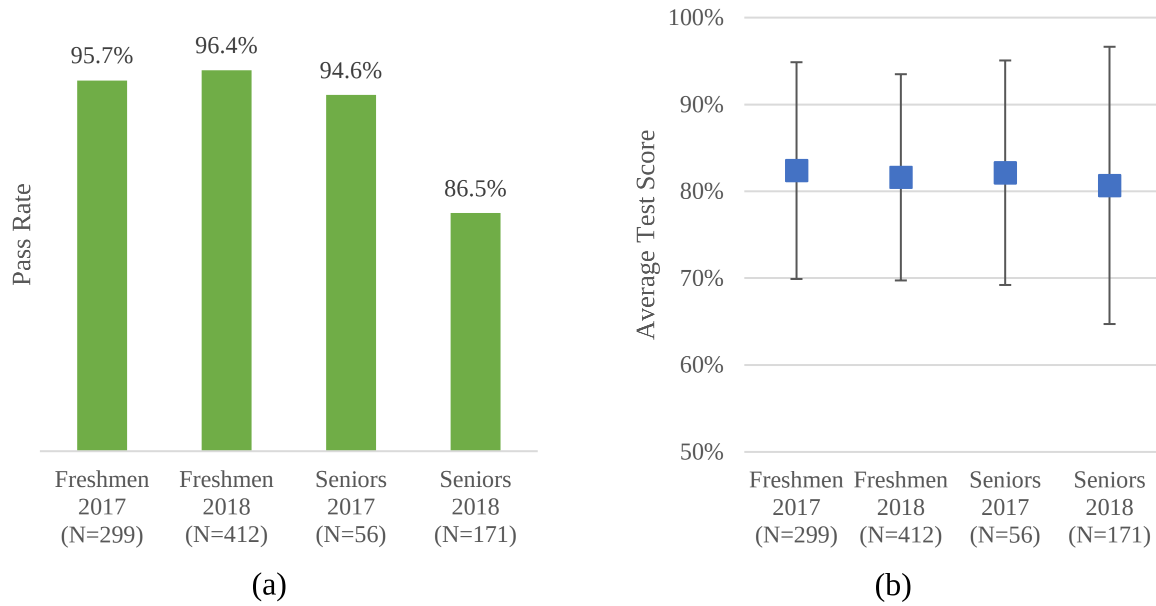


Figure 2. (a) Pass rates of seniors and **final** pass rates of freshmen in fall 2017 and fall 2018. (b) Average test scores of seniors and **final** average test scores of freshmen in 2017 and 2018.

By the end of the semester, pass rates for freshmen (95.7% and 96.4%) exceeded those of seniors (94.6% and 86.5%), as shown in Figure 2a. Average test scores of freshmen (82.4±12.5% and 81.6±11.9%) and seniors (82.1±12.9% and 80.7±16.0%) also became quite comparable, seen in Figure 2b. The spatial ability of the freshmen class appears well-matched with that of the senior class by the end of their first semester. This also raises the question as to whether spatial ability reaches a peak during the first semester, following focused practice in either the spatial skills workshop or the engineering graphics course itself. It should also be noted that the spatial skills program was launched only recently, so the seniors participating in this study had no such intervention when they were freshmen.

The overall pass rates presented above can be further separated into pass rates by gender. In Figure 3, pass rates of seniors are compared to *initial* pass rates of freshmen. A clear disparity between the spatial ability of male and female students is apparent in all four classes. While these gender differences are unsurprising among the incoming engineering students, the large gender gap in graduating engineering students was unexpected. This seems to indicate that our female engineering students persisted in engineering, despite having lower spatial ability than their male counterparts.

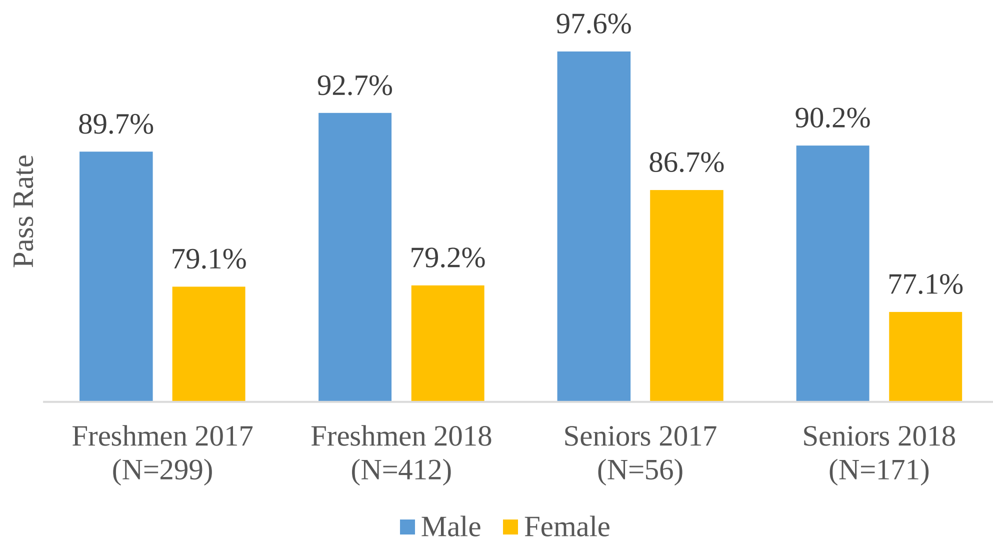


Figure 3. Pass rates of seniors and **initial** pass rates of freshmen in 2017 and 2018, by gender.

In Figure 4, pass rates of seniors are now compared to *final* pass rates of freshmen. Among the freshman classes, the disparity between spatial ability of male and female students has nearly disappeared. This speaks to the success of the spatial skills workshop and graphics course in improving the spatial ability of all students, especially female students.

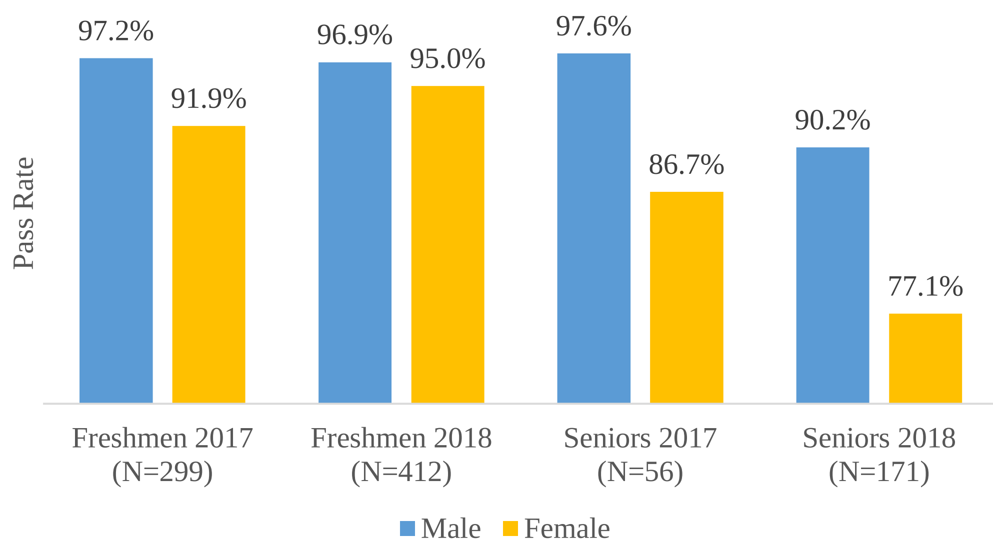


Figure 4. Pass rates of seniors and **final** pass rates of freshmen in 2017 and 2018, by gender.

Discussion and Future Work

Results from the past two years provide only a few data points, so no conclusive remarks can yet be made at this time. However, it is interesting to note that the spatial ability of freshmen is not vastly different than that of seniors. This confirms that fact that spatial ability is a good predictor of success in engineering, and early identification of students with low spatial ability is crucial.

In the current study, the spatial ability results for graduating students may not be entirely reliable for two reasons: (1) Not all seniors chose to participate in the study, and (2) Seniors may not have put forth their best effort on the test.

Without a complete survey of all graduating engineering students, the section of students who did complete the test may not be entirely representative of the entire graduating class, e.g. if students with low spatial ability opted not to take the test at all. While the spatial skills test was a part of the course grade for the freshmen classes, seniors were offered extra credit for simply completing the test. In future years, we plan to further incentivize the seniors to put forward their best effort by presenting the activity as a friendly competition between the freshmen and senior classes. We also plan to reach out to students beyond just the Mechanical and Civil Engineering departments.

Lastly, all four data points consisted of different populations of students. We plan to complete a longitudinal study with one-to-one tracking of students to yield more reliable results. Additionally, the two senior classes did not have the benefit of a spatial skills intervention in their first year, whereas the two freshmen classes did. Gender differences in spatial ability are quite apparent the graduating students. It will be interesting to see whether this gap closes with future classes of students who had access to the workshop and improved their skills in the first semester.

In summary, future work includes a longitudinal study where the same set of students can be tracked over the course of their engineering degree program. This will allow us to make more definitive conclusions about whether immediate gains in spatial skills are retained and whether spatial ability continues to improve over the course of a four-year engineering program. We could then also investigate whether higher spatial ability correlates to a higher overall GPA at the time of graduation.

References

1. S. Sorby, "Educational Research in Developing 3-D Spatial Skills for Engineering Students," *International Journal of Science Education*, vol. 31, no. 3, pp. 459-480, 2009.
2. J. Wai, D. Lubinski, and C. P. Benbow, "Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance," *Journal of Educational Psychology*, vol. 101, no. 4, pp. 817-835, 2009.
3. M. B. Casey, E. Pezaris, E., and R. L. Nuttall, "Spatial ability as a predictor of math achievement: the importance of sex and handedness patterns," *Neuropsychologia,* vol. 30, pp. 35-40, 1992.
4. D. Halpern, D., "Sex differences in cognitive abilities, Third Edition," Mahwah, NJ: Lawrence Erlbaum Associates, 2000.
5. D. Voyer, S. Voyer, and M. Bryden, "Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables," *Psychological Bulletin,* vol. 117, pp. 250-270, 1995.
6. N. E. Study, "Assessing and improving the below average visualization abilities of a group of minority engineering and technology students," *Journal of Women and Minorities in Science and Engineering*, vol. 12, no. 4, pp. 363-374, 2006.
7. S. C. Levine, M. Vasilyeva, S. F. Lourenco, N. S. Newcombe, and J. Huttenlocher, "Socioeconomic status modifies the sex difference in spatial skill," *Psychological Science*, vol. 16, no. 11, pp. 841-845, 2005.
8. J. L. Segil, J. F. Sullivan, B. A. Myers, D. T. Reamon and M. H. Forbes, "Analysis of multi-modal spatial visualization workshop intervention across gender, nationality, and other engineering student demographics," in *2016 IEEE Frontiers in Education Conference (FIE), Erie, PA, USA, 2016*, pp. 1-5.
9. S. A. Sorby and A. F. Wysocki, *Introduction to 3D Spatial Visualization: An Active Approach*. New York, NY: Thomson Delmar Learning, 2003.
10. "Spatial Visualization Skills (SVS): Learn More," ENGAGE Engineering. [Online]. Available: https://www.engageengineering.org/spatial/whyitworks/learnmore. [Accessed: Aug. 27, 2017].
11. R. B. Guay, *Purdue Spatial Visualization Test: Rotations*. West Lafayette, IN: Purdue Research Foundation, 1976.