Underrepresented and International Student Success and Confidence in a Small, Lab-based CAD Class

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Abstract

In this digest, we explore confidence and success of different demographic groups in a lab- based CAD course. We hypothesize that students with lower spatial visualization ability, who typically struggle in traditional engineering graphics courses, benefit from the relaxed time constraints and frequent instructor interaction of this lab-based class. Our analysis showed that initial spatial visualization test scores were not a good predictor of course grades. Women and international students, both groups with low average spatial visualization ability, had different outcomes: on average, domestic women had higher grades than their domestic male counterparts, while international male students had lower grades than their domestic counterparts. International, domestic minority, and domestic female students reported lower confidence on a survey compared with their counterparts. While the lab-based format appears to help female students' grades, more work is needed to ensure equal benefit for international students and to encourage confidence in all students.

Introduction

The population of students graduating with undergraduate engineering degrees in the US has become more diverse in recent years. From 2010 to 2017, the percentage of bachelor's degrees awarded to female, underrepresented minority (URM), and international students increased from 18% to 21%, 13% to 19%, and 6% to 10%, respectively (Yoder, 2017). Northern Arizona University serves a diverse population, with URM students representing 28% of all undergraduates (Northern Arizona University, 2015). International student enrollment is also increasing (5% of all NAU undergraduates in 2015), with most international students in engineering coming from the Middle East. It is increasingly important to confirm that all students, regardless of demographics, can succeed in engineering classes. Previous studies identified a correlation between grades and spatial visualization ability in 2D engineering graphics classes (Gimmestad, 1989;

Hsi, Linn, & Bell, 1997) and, to a lesser extent, CAD classes (Hamlin, Boersma, & Sorby, 2006; Branoff & Dobelis, 2012; Budinoff & McMains, 2018). This correlation can disadvantage females and students from certain ethnic groups and countries, such as the Middle East, who tend to have lower spatial visualization ability (Segil et al., 2016; Sorby & Veurink, 2012; Sorby, Cubero, Pasha-Zaidi, & Karki, 2015).

This digest focuses on a lab-based class, with one weekly 1.5-hour session where the instructor demos examples in SOLIDWORKS while students duplicate instructor actions on their own PC, and a second weekly 1.5-hour session where students work independently on assignments. Class exams (weighted at 35% of the overall course grade) have lenient time constraints, with most students finishing early. Homework and a project are weighted highly (40% and 15% respectively). Average class size is 22 students.

Most assignments focused on interpreting engineering drawings and modeling 3D objects, which requires spatial visualization ability. Maeda and Yoon (2013) found that the magnitude of the gender difference in scores on a common spatial visualization test, the Purdue Spatial Visualization Test: Rotations (PSVT:R), is lessened by extending the testing time. Similarly, Hsi, Linn, and Bell (1997) identified gender differences for scores on class exams with time restrictions but not for homework and projects, which had more relaxed time restrictions. Because of these findings, we hypothesized that the lenient time restrictions of all class assignments would reduce gender differences in course grades. We were also interested in exploring course outcomes for URM and international students. Groups with low visualization ability could benefit from the small class size, as small classes may be associated with larger gains in spatial visualization skills than large lecture classes (Leopold, Górska, & Sorby, 2001).

In addition to class grades, we sought to explore student confidence. Kelly (2017) found that males have higher engineering graphics self-efficacy than females, and Towle et al. (2005) found a correlation between PSVT:R scores and spatial visualization self-efficacy. There is little research on engineering graphics self-efficacy for URM or international students.

Methods

The 30-question PSVT:R was administered on paper in 20 minutes during the first week of the semester. The Wilcoxon rank-sum test was used to evaluate differences in medians of PSVT:R scores and course grades with a significance level of $\alpha=.05$. This study includes only male international students to preserve the anonymity of the few female international students.

To gauge student confidence, we administered an optional survey, based on that of

Hamlin, Boersma, and Sorby (2006), with questions related to student perceptions about a SOLIDWORKS homework assignment. An "average perception" was calculated by averaging scores for questions related to confidence (e.g. "how did you feel when you started work on this assignment?"). More details are available in Budinoff and McMains (2018). The survey also asked students for demographic information and how long it took them to complete the assignment. The PSVT:R was re-administered within a week of completion of the assignment.

Results

International and female students had lower PSVT:R scores, as summarized in Table 1, confirming results presented Segil et al. (2016) and Sorby and Veurink (2012). Differences in scores between domestic men versus domestic women, and domestic students versus international students were statistically significant (*ps*<.001).

Table 1. Gender and demographic differences in average PSVT:R scores.

Group	Score (out of 30)
Domestic men (*n*=184)	23.3 (SD=4.48)
Domestic women (*n*=43)	19.3 (SD=5.36)
International men (*n*=61)	13.5 (SD=6.09)

Average course grades are not presented because about half of the grade data was only available as ordinal data (A, B, C, etc.). The difference in course grades between international men and domestic men was statistically significant (*p*=.005), but the difference between domestic women and domestic men was not statistically significant (*p*=.108). This could be due to the larger difference in PSVT:R scores between international and domestic men, or a different factor, such as women benefitting from the relaxed time constraints. A comparison of grade distributions (Figure 1) shows that domestic females who are low visualizers, scoring less than 20 on the PSVT:R, perform similarly to students who scored 20 or higher (difference in grades is not statistically significant, *p*=.153), whereas domestic and international male low visualizers have significantly lower grades than students scoring 20 or higher (*p*=.009 and *p*=.010, respectively).

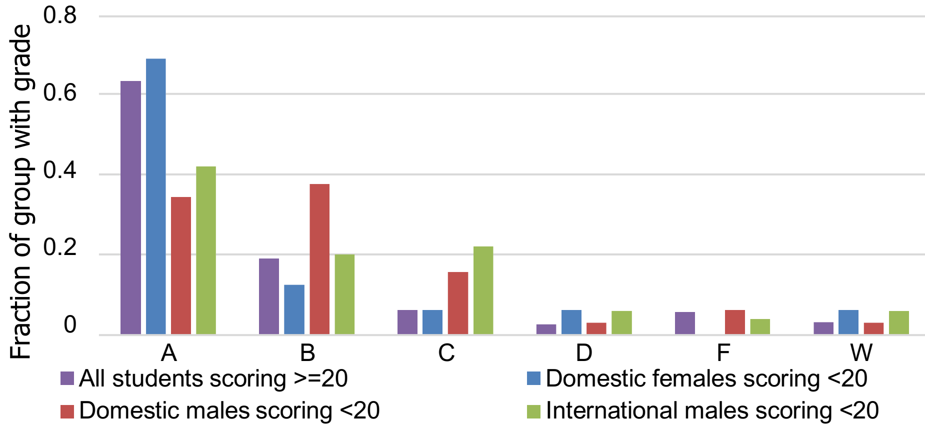

Figure 1. The percentage of female low visualizers earning an A is approximately double that observed for domestic male and international male low visualizers.

We also analyzed survey results to understand differences in confidence between demographic groups. Because the survey was optional, our sample size is small, which limits us to qualitative comparisons between groups. As summarized in Table 2, while most groups reported similar completion times, URM students reported higher difficulty than white students, and domestic women reported higher difficulty than domestic men (difficulty is measured as a higher average perception). International students reported both substantially higher completion times and difficulty. Domestic women reported higher completion time than domestic men. PSVT:R scores are correlated with average perception (Budinoff & McMains, 2018), so it is not surprising that groups with lower PSVT:R scores reported more difficulty. However, some groups feel more confident, even if they require a similar amount of time to complete the assignment.

Table 2. Perception of difficulty and time required to complete an assignment.

Group	**PSVT:R score at time of survey**	**Average perception (out of 5)**	**Average time (out of 5)**
White (all genders) (*n*=17)	23.9 (SD=4.82)	2.36 (SD=0.65)	3.53 (SD=0.88)
URM (all genders) (*n*=7)	21.8 (SD=6.07)	2.70 (SD=1.02)	3.50 (SD=0.46)
International men (*n*=4)	16.3 (SD=3.70)	3.46 (SD=0.62)	3.75 (SD=0.43)
Domestic women (all ethnicities) (*n*=9)	23.2 (SD=3.92)	2.58 (SD=0.69)	3.53 (SD=0.84)
Domestic men (all ethnicities) (*n*=16)	23.9 (SD=6.00)	2.39 (SD=0.76)	3.47 (SD=0.76)

Discussion and Conclusion

Our analysis indicates that this course especially enables women to succeed but the reason is unclear. The high percentage of female low visualizer who earned an A or B could be a result of the course's relaxed time constraints. Previous studies indicate that measured gender differences in spatial ability scores decrease with relaxed time constraints, but this has not been shown for other demographic factors like nationality. Further study is needed to determine if the differences in spatial visualization between nationality or ethnicity groups is affected by time constraints. Small class size, frequent instructor interaction, and hands-on nature of the class might also have supported better outcomes for females, although it is unclear why females would especially benefit from these factors.

There was a statistically significant difference in the grades of international students and domestic students, likely due in part to lower visualization ability, the effect of which wasn't diminished with the relaxed time constraints. Domestic and international male low visualizers struggled in the class, despite the relaxed time constraints. Further, international, URM, and female students all reported lower confidence than white students and domestic males. It is unclear how social factors affect confidence and self-efficacy. This digest highlights the need to study how student success varies with different class formats and pedagogy strategies, and to better understand the interaction between social factors, visualization ability, and student success.

References

Branoff, T. J., & Dobelis, M. (2012). The relationship between spatial visualization ability and students' ability to model 3d objects from engineering assembly drawings. *Engineering Design Graphics Journal, 76*(3), 37–43.

Budinoff, H. & McMains, S. (2018). *Relationships between Spatial Visualization Ability and Student Outcomes in a 3D Modeling Course*. Proceedings of the 72nd ASEE EDGD MidYear Conference, Montego Bay, Jamaica.

Gimmestad, B. J. (1989). *Gender differences in spatial visualization and predictors of success in an engineering design course.* Proceedings of the National Conference on Women in Mathematics and the Sciences, St. Cloud, MN, 133-136.

Hamlin, A., Boersma, N., & Sorby, S. (2006). *Do Spatial Abilities Impact the Learning of 3-D Solid Modeling Software?* Proceedings of the 2006 ASEE Annual Conference, Chicago, IL.

Hsi, S., Linn, M. C., & Bell, J. E. (1997). The role of spatial reasoning in engineering and the design of spatial instruction. *Journal of Engineering Education*, *86*(2), 151-158.

Kelly, D.P. (2017). *Measurements of self-efficacy in engineering graphics students: An examination of factors impacting student outcomes in an introductory engineering graphics course* (Doctoral dissertation). Retrieved from https://repository.lib.ncsu.edu/handle/1840.20/34580

Leopold, C., Górska, R. A., & Sorby, S. A. (2001). International experiences in developing the spatial visualization abilities of engineering students. Journal for Geometry and Graphics, 5(1), 81-91.

Maeda, Y., and Yoon, S.Y. (2013). A meta-analysis on gender differences in mental rotation ability measured by the Purdue spatial visualization tests: Visualization of rotations (PSVT: R). Educational Psychology Review, 25(1), 69-94.

Northern Arizona University. (2015). Fact Book. Retrieved from https://nau.edu/institutional- research/fact-book/

Segil, J. L., Sullivan, J. F., Myers, B. A., Reamon, D. T., & Forbes, M. H. (2016). Analysis of multi-modal spatial visualization workshop intervention across gender, nationality, and other engineering student demographics. Proceedings of the 2005 Frontiers in Education Conference, Erie, PA.

Sorby, S. A., & Veurink, N. (2012). Spatial skills among minority and international engineering students. Proceedings of the 2012 ASEE Annual Conference, San Antonio, TX

Sorby, S. A., Cubero, S., Pasha-Zaidi, N., & Karki, H. (2014). Spatial skills of engineering students in the United Arab Emirates. Proceedings of the Engineering Leaders Conference 2014, Doha, Qatar.

Towle, E., Mann, J., Kinsey, B., O'Brien, E. J., Bauer, C. F., & Champoux, R. (2005). Assessing the self efficacy and spatial ability of engineering students from multiple disciplines. Proceedings of the 2005 Frontiers in Education Conference, Indianapolis, IN.

Yoder, B. L. (2017). Engineering by the Numbers. Retrieved from https://www.asee.org/papers- and-publications/publications/college-profiles