Importance of Spatial Training for Pre-Calculus Students

A. J. Hamlin and N. L. Veurink
Department of Engineering Fundamentals
Michigan Technological University

Sheryl A. Sorby
Department of Mechanical and Aerospace Engineering
The Ohio State University

Abstract

A spatial visualization training course has been offered at Michigan Technological University in various forms since 1993. Several studies (Sorby and Veurink, 2010; Veurink and Sorby, 2011) have suggested that not only do students with weak spatial skills that take the spatial training course do better than students with weak spatial skills that did not take the course, but they also do better in their math and graphics courses than students who have marginally developed spatial skills. In this study, grades for first-year engineering, math, and science courses are compared for students that scored 60% or below on the PSVT:R and were required to take a spatial training course to students that scored between 60% and 70% on the PSVT:R and did not take a spatial training course.

Introduction

Spatial visualization skills are crucial to many careers and in particular to STEM fields. A course, in various forms, to develop spatial visualization skills has been offered to engineering students at Michigan Technological University since 1993. Due to the positive impact of this course on student success and retention, beginning in the fall of 2009 this course was required for all engineering students that score 18 out of 30 (60%) or below on the Purdue Spatial Visualization Test: Rotations (PSVT:R) (Guay, 1977) taken during orientation.

The longitudinal study conducted by Veurink and Sorby (2011) found students that marginally passed the PSVT:R (score of 19-21 out of 30) had lower rates of retention, lower grades in their first year engineering, math, and science courses, and a higher rate of unsatisfactory completion of these courses than those students that scored 60% or below on the PSVT:R and that took the spatial visualization course. In their study, Veurink and Sorby examined grades for students who scored 21 (70%) or below on the PSVT:R during orientation of the following years: 1996-1998, 2000-2002, and 2009-2010. At the time this study was conducted the students that matriculated in the fall of 2010 had not yet completed their first year of classes. As 1.5 years have passed since this study was conducted, these students and students that matriculated in the fall of 2011 have had a chance to complete one or more years of course work. This study evaluates the 2009-2011 students to see if the students that scored 60% or below on the PSVT:R continue to outperform those that marginally passed the PSVT:R.

Method

In this study grades in first-year engineering, math, and science courses were examined for all engineering students that took the PSVT:R during orientation in the fall of 2009-2011 and either marginally passed or failed the test (n=648). Grades earned on the first attempt of a course were compared for students that were required to take the spatial training course (scored 18 or below on the PSVT:R, n=306) to those students that marginally passed (score 19-21, n=342). Students that did not successfully complete the spatial training course were excluded from this analysis (n=15).

Results and Discussion

Table 1 compares the average grades for introductory engineering, math, and science courses typically taken by engineering students, as well as overall GPA for students in the Experimental Group (EG) – those required to take the spatial training course – and those that marginally passed the PSVT:R. The significance of difference between groups is determined using an unpaired t-test. The one-tailed probability values are reported in Table 1. The average grades for those students in the experimental group are higher than the average grades for those students that marginally passed for most of the courses. The exceptions to this are Physics I (consistent with Veurink and Sorby, 2011), ENG1102 (not included in Veurink and Sorby, 2011) and Computer Science I (inconsistent with Veurink and Sorby, 2011) where the marginally passing group has a higher average grade than the experimental group. The difference in Computer Science I findings could be due to the lower number of students in the Veurink and Sorby (2011) study (n = 36) than in this study (n=56).

The results of this study suggest that the spatial training is especially important for those students that are not calculus ready, as indicated by the statistically significant differences in the average grades in the classes these students take their first semester (ENG1101a and Pre-Calculus). Students that begin their math sequence in Pre-Calculus take two semesters to complete ENG1101 – Engineering Analysis and Problem Solving. These students take Engineering Analysis (referred to here as ENG1101a) concurrently with Pre-Calculus and Engineering Problem Solving (referred to here as ENG1101b) concurrently with Calculus I. While Veurink and Sorby (2011) found the average grades for ENG1101a and Pre-Calculus were higher for the experimental group, the differences were not statistically significant. Additionally, Veurink and Sorby (2011) found the differences in grades to be statistically significant for ENG1101b (p=0.005), however, the difference is no longer statistically significant (p=0.204).

Table 1: Average grades in first year engineering, math, and science courses for students marginally passing the PSVT:R and the experimental group.

	Marginally Passed PSVT:R	EG	p
ENG1101 Eng. Analysis & Problem Solving	2.48 (s=0.962, n=223)	2.50 (s=0.950, n=183)	0.414
ENG1101a Eng. Analysis	2.16 (s=1.149, n=92)	2.46 (s=0.979, n=99)	0.028*
ENG1101b Eng. Problem Solving	2.66 (s=0.849, n=57)	2.83 (s=0.815, n=70)	0.126
ENG1102 Eng. Modeling & Design	2.78 (s=0.884, n=211)	2.73 (s=0.901, n=182)	0.303
Pre-Calculus	2.02 (s=1.191, n=96)	2.38 (s=1.179, n=97)	0.017*
Calculus I	2.40 (s=1.324, n=224)	2.50 (s=1.337, n=208)	0.233
Calculus II	2.23 (s=1.372, n=152)	2.35 (s=1.253, n=135)	0.225
Chemistry I	2.44 (s=1.055, n=189)	2.53 (s=0.935, n=165)	0.211
Physics I	2.65 (s=1.114, n=214)	2.35 (s=1.202, n=188)	0.005*
Computer Science I	2.56 (s=1.261, n=32)	2.52 (s=1.186, n=24)	0.283
Overall GPA	2.71 (s=1.381, n=339)	2.80 (s=0.684, n=291)	0.145

*Significant at 0.05

The percentage of students that do not successfully complete a course in their first attempt is shown in Table 2. Courses with a grade of a D, F, or W are considered to be an unsuccessful completion of a course. At Michigan Tech a W is given when a student drops a course after the third week of the semester. The significance of the difference between the proportions is determined using the Z Test. The one-tailed probability values are reported in Table 2. For most of the courses the percent of DFW grades for the experimental group are lower than or nearly equal to those of the marginally passing group, with the exception of Physics and Computer Science. Again, the spatial training seems most important for the Pre-Calculus students. The difference between the EG and the marginally passing group is larger for Pre-Calculus and Physics in this study than the difference found by Veurink and Sorby (2011), while the differences for Calculus, Chemistry, and Computer Science are smaller.

Table 2: Comparison of the percentages of D, F, and W grades between the experimental and marginally passing PSVT:R groups.

	EG	Marginally Passed PSVT:R	p
ENG1101	n=190	n=223	
	14.2% (27)	13.2% (30)	0.384
ENG1101a	n=100	n=93	
	15.0% (15)	30.0% (26)	0.014*
ENG1101b	n=71	n=59	
	8.5% (6)	10.2% (6)	0.368
ENG1102	n=182	n=211	
	6.0% (11)	5.7% (12)	0.440
Pre-Calculus	n=99	n=99	
	20.2% (20)	31.3% (31)	0.037*
Calculus I	n=212	n=227	
	20.3% (43)	21.6% (49)	0.369
Calculus II	n=135	n=152	
	22.1% (31)	28.2% (44)	0.116
Chemistry I	n=167	n=190	
	11.4% (19)	12.6% (24)	0.358
Physics I	n=188	n=214	
	18.6% (35)	12.4% (27)	0.043*
Computer Science I	n=42	n=44	
	28.6% (12)	25.0% (11)	0.283

*Significant at 0.05

In this study, the impact of spatial training on the Pre-Calculus students is examined further. The average grades for Pre-Calculus only students in the marginally passing group and those in the experimental group are shown in Table 3 along with their significance of difference. As shown, the students in the experimental group had better average grades in Engineering, Calculus, and Chemistry,

with the differences in Calculus II and Chemistry being statistically significant. The average grades in Physics are nearly equal with the marginally passing group having a slightly higher average. The average overall GPA for the experimental group was higher than the marginally passing group.

Table 3: Average grades of Pre-Calculus students in first year math and science courses for students marginally passing the PSVT:R and the experimental group.

	Marginally Passed PSVT:R	EG	p
ENG1102	2.57 (s=0.904, n=35)	2.61 (s=0.815, n=38)	0.471
Calculus I	2.05 (s=1.29, n=74)	2.20 (s=1.33, n=81)	0.230
Calculus II	1.36 (s=1.30, n=37)	2.03 (s=1.20, n=40)	0.012*
Chemistry I	2.10 (s=1.028, n=57)	2.39 (s=0.869, n=57)	0.054*
Physics I	1.99 (s=1.21, n=35)	1.91 (s=1.16, n=39)	0.393
Overall GPA	2.51 (s=2.26, n=92)	2.67 (s=0.715, n=99)	0.267

*Significant at 0.05

A preparatory chemistry course may also contribute to the statistically significant difference in Chemistry I grades for these Pre-Calculus students. At Michigan Tech, students placed into Pre-Calculus are automatically placed into Preparatory Chemistry, a three-credit course designed for students who have not had high school Chemistry. Based on their high school math and chemistry background, students may elect to take Chemistry I rather than take Preparatory Chemistry followed by Chemistry I. A larger fraction of the EG Pre-Calculus students opted to take Preparatory Chemistry (41.7%) than the Pre-Calculus students in the marginally passing group (35.1%).

Other interventions that may impact student success and retention include their participation in living/learning communities and mentoring programs, and their use of available campus resources, including learning centers. All interventions are available for all students. Michigan Tech requires all first-year students to live in one of the residence halls on campus. Students may opt to live in one of the following Living/Learning Communities: Computer Science, First-year Experience, Forest Resources & Environmental Science, Global Village, Leadership, Summit (Healthy Living), Visual & Performing Arts, or Women in Engineering. Students opting to live in one of these communities are required to take a one-credit course designed to help students develop strategies for creating academic, professional, and personal success. Students participating in the mentoring program on campus, meet with a mentor once a week for five weeks, meet with program staff several times a semester, agree to use campus learning centers, and take a one-credit course that explores ways to be a more effective student. The number of students participating in living communities and mentoring programs for the

students in this study are shown in Table 4. Approximately 25% of the students in this study participated in a living/learning community; with a larger fraction of Pre-Calculus students chose to participate in a living/learning community. It does not appear that the living/learning communities are contributing to the difference in average grades, as one would expect that the group with the larger fraction of students participating (Marginally Passing) would have earn higher grades. This is the opposite of what was observed, students in the EG tended to outperform those in the Marginal Passing Group.

Table 4: Number of students opting to participate in a living/learning community and/or mentoring program.

	EG	EG (Pre-Calc)	Marginally Passing	Marginally Passing (Pre-Calc)
Living/Learning Community	20.9% (n=63)	32% (n=27)	26.9% (n=87)	45.5% (n=35)
Mentoring Program	4.3% (n=13)	8.3% (n=7)	2.7% (n=9)	6.5% (n=5)

Conclusions

This study expands the work of Veurink and Sorby (2011) to include additional first-year courses (ENG1102 and Calc II), an additional year of students (Fall 2011), and time for all the students in the study (from matriculation Fall 2009-Fall 2011 through Spring 2012) to complete their first-year courses. Similar to earlier findings, students that scored 18 or below on the PSVT:R and received spatial training, the experimental group, tend to have higher grades in their engineering, math, and chemistry courses and a lower failure rate in these courses than those students that marginally passed the PSVT:R (scored 19-21). However, some of these differences are smaller in this study than the earlier study (average grades: ENG1101b, Calc I, Chemistry I, and Physics I; failure rate: Calc I, Chemistry I, Physics I, and Computer Science I). The differences in average grades are larger in this study for Pre-Calculus and ENG1101a, and the difference in failure rates is larger for Pre-Calculus compared to the earlier study. This difference suggests that the spatial training may be especially important for students that begin their math sequence in Pre-Calculus.

These findings are significant as the students in the experimental group initially have weaker spatial skills than those students in the marginally passing group that they outperform. This suggests that those students in the marginally passing group may benefit from spatial skills training.

References

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