Aptitude, Effort, and Achievement in an Introductory Engineering Design Graphics Class

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Abstract

We investigate the relationships between spatial ability, time spent on homework, lecture clicker participation, and grades in an introductory engineering graphics class. Out of mental rotation test performance, hours spent on homework, and lecture attendance/participation, the first was found to have the most effect on a student's total course score.

Introduction

Data was collected from the Fall 2015 offering of the introductory freshman graphics class, Visualization for Design, at Berkeley with final enrollment of 137 students. The 2-unit course meets for a one-hour lecture and a two-hour lab each week.

Previous research has shown a correlation between spatial ability and performance in science and engineering classes (Carter, LaRussa, & Bodner, 1987; Gimmestad, 1989). Gimmestad (1989) found that a student's score on the Purdue Spatial Visualization Test: Rotations (Vandenberg & Kuse, 1978) was the best predictor of performance for an engineering graphics course, with a higher correlation than previous experience with shop training or a solid geometry class. Sorby and others at Michigan Tech have used the PSVT:R to identify "low visualizers" in order to provide those students with extra training (Sorby & Baartmans, 2000). In keeping with these previous studies, we measured the students initial ability using the PSVT:R.

The authors are not aware of previous research regarding effort or participation as a predictor of outcomes for engineering design courses. For this course offering, students were asked each week to report the hours they spent on the homework and lab assignment, which varied widely. Lecture participation with clickers was also tracked. This data was studied to determine the relative effect of students' spatial ability, homework effort, and lecture participation on their total score in the course.

Methodology

Spatial ability was measured with the PSVT:R, administered using pencil and paper during lab the first week of instruction. Students who scored less than 20 out of 30 correct on the aptitude test were encouraged to complete four sets of extra practice exercises over the course of the semester for an extra unit of credit. Seven students signed up for this extra unit, five of whom were female.

Effort was measured from self-reports of hours worked. Students filled out an online form each week in which they reported the estimated time they had spent on the homework and lab assignment during the preceding week, as well as whether they had received assistance with the homework and/or if they had assisted other students. (It is unclear if students who did the extra practice exercises included the time for those exercises in their self-reports.) Lecture participation credit was awarded if the student used their classroom response system "i-clicker" to answer all but one of the multiple choice questions posed during lecture.

These three variables (spatial ability, effort, and participation) were compared with course performance, as measured by the uncurved total course score (out of 100 points). Using MATLAB, the linear least squares regression line was found in order to examine the relationship between each of the three explanatory variables and course performance. The coefficient of determination, R^2, of each regression was also found.

The mean scores of different groups were calculated and compared using the MATLAB implementation of the Wilcoxon signed-rank test (chosen because the data was not normally distributed). The significance level was set to 0.05 throughout the analysis.

Results

The PSVT:R results for the course are summarized in Table 1. Women averaged 14% lower on the test than their male colleagues, but only 4% lower on total course score. Both differences were found to be statistically significant.

Table 1. Total course scores and PSVT:R scores for male and female students

	Female students (*n*=35)	Male students (*n*=102)
	Mean (Standard deviation)	Mean (Standard deviation)
PSVT:R score	21.9 (4.8)	25.4 (4.4)
Total course score	78.4 (8.6)	81.8 (7.8)

The R^2 value was found to be only 0.316 for the regression of PSVT:R scores for all students versus total course scores. A scatter plot of this data is shown Figure 1 with the corresponding regression line.

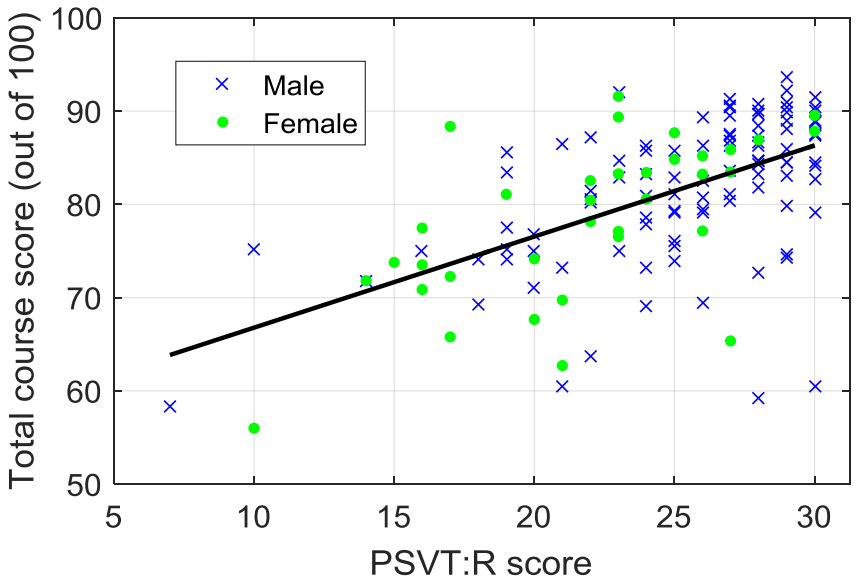

Figure 1. PSVT:R test score vs. course performance for male and female students (R^2=0.316).

The amount of time students spent on homework varied widely and had no statistically significant correlation with that student's homework grade for that week. However, there were interesting trends relating the total scores, PSVT:R scores, and total hours. As seen in Figure 2, all of the students who scored 90 and above in the course had a PSVT:R score above 20. Most of the students who spent more than 60 hours on the class scored below a 26 on the PSVT:R.

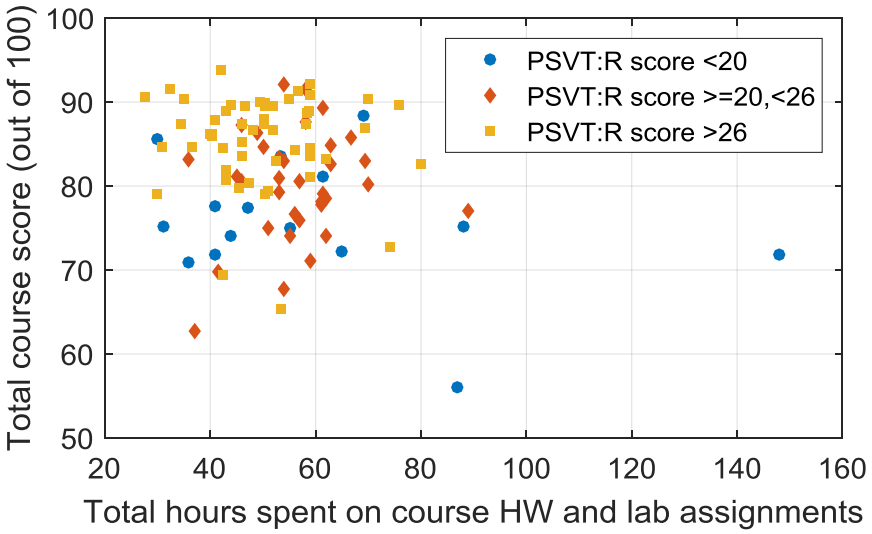

Figure 2. PSVT:R test score compared with course performance and effort.

Figure 2 excludes students who did not submit their time spent on all of the homework assignments (i.e. for every week); 104 of 137 students submitted all summaries. There were no statistically significant differences in the self-reported hours between male and female students.

Table 2. Summary statistics of total course scores and total effort for students with high, medium, and low PSVT:R scores (only students who reported all hours)

	PSVT:R Score		
	Less than 20 points (*n*=15)	Between 20 and 25 points (*n*=34)	More than 25 points (*n*=55)
	Mean (Standard deviation)	Mean (Standard deviation)	Mean (Standard deviation)
Total course score	75.7 (7.6)	80.1 (6.6)	85.6 (5.5)
Total hours spent on assignments	59.8 (30.4)	56.3 (10.0)	49.9 (11.3)

Table 3 provides a breakdown of the results of the students who scored less than 20 on the PSVT:R by those who did and did not elect to complete the optional extra assignments. The students who participated in the extra practice had slightly higher averages on exams and the

course as a whole, but the sample size of both groups is relatively small and analysis does not indicate that the differences between the groups are statistically significant.

Table 3. Comparison of course scores of students who elected to complete extra assignments and those who scored <20 but did not complete extra assignments

		PSVT:R score	Midterm exam score	Final exam score	Total course score
	Percent female (%)	Mean (Standard deviation)	Mean (Standard deviation)	Mean (Standard deviation)	Mean (Standard deviation)
Extra practice (*n*=7)	71.4	17.6 (1.4)	85.3 (8.6)	60.1 (8.5)	75.7 (6.4)
No extra practice (*n*=14)	35.7	15.1 (3.8)	84.0 (10.4)	55.7 (13.0)	72.9 (8.4)

No statistically significant correlation was found between attendance in lecture (as measured by clicker participation) and total course score, as seen in Figure 3.

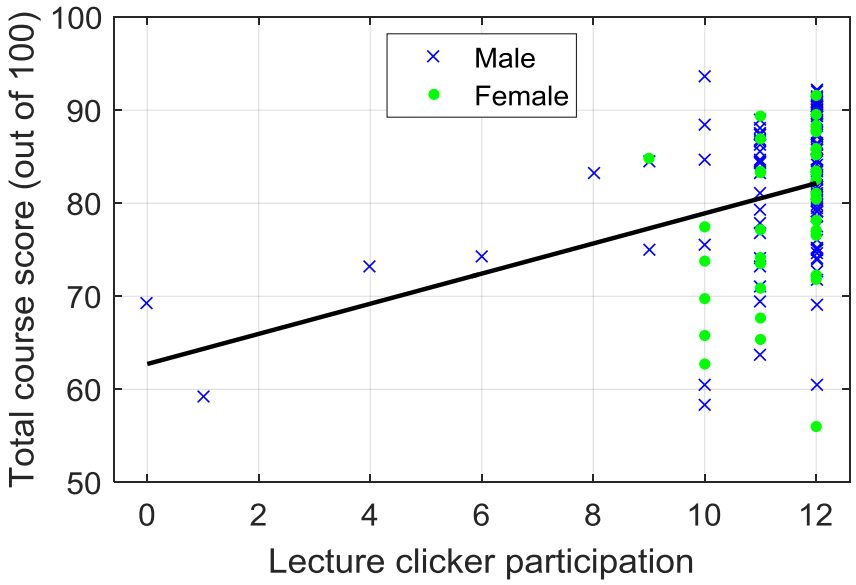

Figure 3. Lecture attendance vs. course performance (R^2 =0.120).

Conclusion

Our findings support the previously identified correlation between PSVT:R score and engineering graphics course performance (Carter et al., 1987; Gimmestad, 1989; Sorby & Baartmans, 2000). The PSVT:R scores also showed statistically significant differences for male and female students, as seen in previous studies (Maeda & Yoon, 2013).

A correlation was not identified between overall course performance and total reported hours spent on course homework and lab assignments. However, when the data was grouped for students with similar PSVT:R scores, students with lower PSVT:R scores tended to spend more time on homework, with several students in the lowest scoring group spending over 80 hours compared with a course average of 54 hours. In future work, the system of self-reporting could be improved to clarify exactly what activities the students should include (limitations include that no surveys were conducted for time spent studying for exams or working on the final project, and time spent on extra practice exercises was not mentioned in the instructions).

There were slight improvement in the outcomes of "low visualizer" students who elected to complete extra assignments compared to those who did not, although the statistical significance of the difference was limited by the small sample size. It is worth noting that these students elected to participate in extra assignments rather than being randomly selected. More research is warranted to further evaluate this intervention.

References

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