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Performance in Introductory Engineering Graphics Courses as an Indicator of Future Success in a Mechanical Engineering Technology Program (WIP)

Dr. Nancy E. Study, Pennsylvania State University, Behrend College

Dr. Nancy E. Study is an Associate Teaching Professor in the School of Engineering at Penn State Behrend where she teaches courses in engineering graphics and rapid prototyping, and is the coordinator of the rapid prototyping lab. Her research interests include visualization, haptics, curriculum development, assessment, and graphics standards.

Dr. Steven Nozaki, Pennsylvania State University, Behrend College

Ph.D. Engineering Education - The Ohio State University

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Introduction

The Mechanical Engineering Technology (MET) program at Penn State Behrend requires two engineering graphics courses as part of the first-year curricula. Students in the first of these courses, EGT 120, take a standardized visualization test, the Purdue Spatial Visualization Test: Visualization of Rotations (PSVTR) [1] as part of ordinary classroom practice. Faculty in the program have begun working on longitudinal assessment of student success in the program, and previous work [2] has compared the students' scores on the PSVTR as first-year students and as seniors.

In continuation of the ongoing work, and in part to assess if the graphics courses should be included in the entrance to major (ETM) requirements, this paper includes data on the PSVTR scores of first-year students, along with their grades in the engineering graphics courses, their grades in the currently required ETM courses, and overall GPA. This is to assess if there is a relationship between visualization ability, performance in the graphics courses, and success in the major. This is a precursor to potentially including the graphics courses as part of ETM requirements.

To be eligible for ETM, an MET student at Behrend must have a minimum of a 2.0 cumulative GPA, and a grade of C or higher in an introductory physics course and a calculus course. Although multiple courses in the major require an earned grade of C or above, no major courses are currently used as ETM requirements. If the data discovered in this paper indicate a significant relationship between performance on the PSVTR and grades in the graphics courses and success in the MET major, changes to the ETM may be considered.

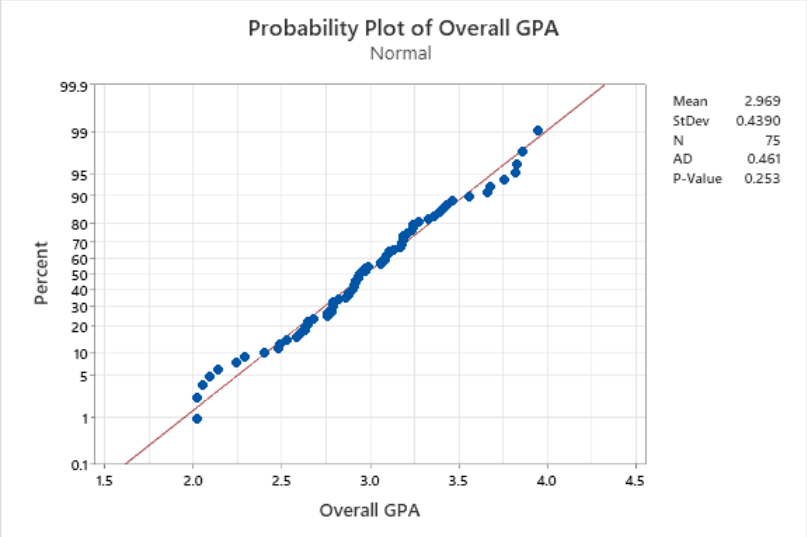
Research Hypotheses

The authors acknowledge that there exists concern in engineering education research over whether a student's GPA is an appropriate and accurate measure of their success. However, the GPA is a requirement for entrance to major considered at Behrend and many other institutions. While a student's assessed performance on any standardized measure of a topic or content may be different from their graded performance in a related course, the use of the GPA is a requirement by the administration at Behrend and departments cannot enroll or deny a student based on non-GPA data. Therefore, GPA is being analyzed along with performance on the PSVTR assessment. In this study, the EGT courses are taught by different faculty using the same course outline, topics, and similar assignments and exams. The mathematics and physics courses are taught by multiple faculty, and there are three different mathematics courses and two physics courses that meet current ETM requirements.

- Hypothesis 1 – there is no significant relationship between performance on the PSVTR and overall GPA
- Hypothesis 2 – there is no significant relationship between performance on the PSVTR and EGT 120 course performance
- Hypothesis 3 – there is no significant relationship between performance on the PSVTR and performance in math courses
- Hypothesis 4 – there is no significant relationship between performance on the PSVTR and performance in physics courses
- Hypothesis 5 – there is no significant relationship between performance in EGT courses and overall GPA
- Hypothesis 6 – there is no significant relationship between performance in math courses and overall GPA
- Hypothesis 7 – there is no significant relationship between performance in physics courses and overall GPA

Results

All statistics in this paper were calculated using Minitab. The students' GPAs in this study were nearly normally distributed as indicated by the probability plot below.



The mean PSVTR score of 23.89 with a standard deviation of 3.92 is in the range expected for first-year students in engineering graphics courses [3], [4], [5].

PSVTR Descriptive Statistics

Variable	Mean	SE Mean	StDev	Minimum	Median	Maximum
PSVTR	23.89	0.45	3.92	11	25	30

Hypothesis 1, when comparing performance on the PSVTR to the overall GPA of students who had obtained entrance to major (ETM), an analysis of variance was significant with a P value of 0.01, and the hypothesis is rejected.

ANOVA Overall GPA vs PSVTR

Source	DF	SS	MS	F	P
Regression	1	1.16	1.16	6.46	0.01
Error	73	13.10	0.18		
Total	74	14.26			

Hypothesis 2, when comparing performance on the PSVTR and EGT 120 course performance, the analysis of variance had a P value of 0.00 and the hypothesis is rejected.

ANOVA PSVTR vs EGT 120 Grade

Source	DF	SS	MS	F	P
Regression	1	179.06	179.06	13.64	0.000
Error	73	958.08	13.12		
Total	74	1137.15			

Hypothesis 3, for performance on the PSVTR compared to performance in math courses, the results were not significant, and the hypothesis is accepted.

ANOVA PSVTR vs MATH Grade

Source	DF	SS	MS	F	P
Regression	1	10.38	10.38	0.67	0.41
Error	73	1126.77	15.44		
Total	74	1137.15			

Hypothesis 4, there was not a significant relationship between performance on the PSVTR and performance in physics at the 90% confidence level, and the hypothesis is accepted.

ANOVA PSVTR vs PHYS Grade

Source	DF	SS	MS	F	P
Regression	1	39.37	39.37	2.62	0.11
Error	73	1097.78	15.04		
Total	74	1137.15			

Hypothesis 5, there were significant relationships between performance in both EGT courses and overall GPA at P 0.00 values. The hypothesis is rejected.

ANOVA Overall GPA vs EGT 120 Grade

Source	DF	SS	MS	F	P
Regression	1	4.24	4.24	30.90	0.00
Error	73	10.02	0.14		
Total	74	14.26			

ANOVA Overall GPA vs EGT 121 Grade

Source	DF	SS	MS	F	P
Regression	1	4.07	4.07	29.16	0.00
Error	73	10.19	0.14		
Total	74	14.26			

Hypothesis 6, there was a significant relationship between performance in math courses and overall GPA at P 0.00. The hypothesis is rejected.

ANOVA Overall GPA vs MATH Grade

Source	DF	SS	MS	F	P
Regression	1	2.18	2.18	13.19	0.00
Error	73	12.08	0.17		
Total	74	14.26			

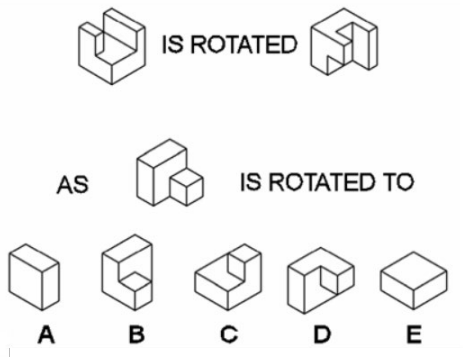
Hypothesis 7, there was a significant relationship between performance in physics courses and overall GPA at P 0.00. The hypothesis is rejected.

ANOVA Overall GPA vs PHYS Grade

Source	DF	SS	MS	F	P
Regression	1	7.49	7.49	80.88	0.00
Error	73	6.76	0.09		
Total	74	14.26			

Discussion

The Purdue Spatial Visualization Test: Visualization of Rotations (PSVTR) is a timed 20-minute test consisting of 30 items of varying difficulty. There are four types of items; one requiring rotation of 90° about one axis, another requiring rotation of 180° about one axis, one requiring rotation of 90° about two axes, and one requiring rotation of 90° about one axis and 180° about another axis [1]. This test is widely used in engineering graphics to assess visualization ability.



The topics covered in EGT 120 include multiview projection, auxiliary and section views, isometric views, assembly drawings, detail drawings, and dimensioning standards. Work is done both with hand sketching and CAD using Creo. EGT 121 implements both sketching and CAD work and covers the topics of ANSI standards, geometric dimensioning and tolerancing, sectioned assemblies, working drawings, fasteners, weld and finish symbols, advanced layouts, and bill of materials.

The extremely significant relationship between PSVTR scores and grades in the engineering graphics courses was expected based on the amount of 3D visualization required by assignments

and exams in the courses. Although there have been multiple studies indicating a positive relationship between visualization abilities and success across STEM courses [6], [7], [8], there was no significant relationship between success in math and physics courses and visualization ability as measured by the PSVTR for this small data set. A possible explanation is that the comparisons were not to a single math or physics course because there are multiple courses offered at Behrend that meet ETM requirements. Also, there is currently no data available on whether assignments requiring the specific use of 3D visualization are incorporated as part of classwork, homework, or exams in these courses. For students who repeated a course, only the final earned grade was used in calculations. Another possibility to consider is that the previous studies noted above have primarily been on subjects enrolled in traditional engineering programs. All the subjects in this study are enrolled in an engineering technology program, which requires more practical and applied work in lab courses, and more engineering graphics courses, than do typical engineering programs.

Because grades in EGT 120 and 121 are quite highly correlated, a multiple regression model was run that removed EGT 120. The R-squared was not significantly different, therefore only the EGT 121 grade will be used in the future for analyses because both courses are required for students majoring in MET at Behrend.

When considering the use of math and physics as ETM requirements, they both showed significant correlations with GPA. That said, the R-squared value for goodness of fit was much higher for physics, 51.91% adjusted, than 14.15% adjusted for math. The R-squared value for EGT 121 was higher than math but lower than physics, with a value of 27.56% adjusted indicating that the EGT 121 grade may be a better predictor of success in the major than the math grade.

Model Summary
GPA vs Physics Grade

S	R-sq	R-sq(adj)
0.30	52.56%	51.91%

Model Summary
GPA vs Math Grade

S	R-sq	R-sq(adj)
0.41	15.31%	14.15%

Model Summary
GPA vs EGT 121 Grade

S	R-sq	R-sq(adj)
0.37	28.54%	27.56%

As noted in previous work [2], knowledge of certain topics in mathematics is necessary for many engineering technology courses including, statics, dynamics, heat transfer, and so on. At Behrend, there is a small but still significant portion of first-year students who do not have the opportunity to take higher level math in high school, and/or who do not test into Calculus I when beginning their studies. This can delay their entry into the major, even if mathematics is not a prerequisite to certain courses, because enrolling in the mathematics courses can take precedence in course scheduling over enrolling in major courses. Of the students for whom we have complete data, 20 of the 75 had to retake their entrance to major mathematics course. Eight had to retake their physics course.

Out of curiosity, because physics was a good predictor of student success, the interaction between passing physics with a C or above the first time and having to retake physics was assessed, but it was found to be not significant. However, it seemed to indicate if a grade higher

than C was earned, but it was on a retake, it was not as good an indicator for future GPA than if a higher grade was earned in the course on a first attempt.

Many of the courses in the MET major at Behrend require the use of 3D visualization skills, including the two EGT courses used in this study, an advanced CAD course, two FEA courses, a production design lab that requires the creation of technical drawings and the machining of parts, and a technical elective in rapid prototyping that incorporates surface modeling and the building of physical models for data acquisition. The significant positive relationship between the PSVTR score and the overall student GPA indicates we should look further than just math and physics for the ETM requirements to assess if there are better ways to ensure that students who are accepted to the major are not only adequately prepared, but that those who may initially struggle with their mathematics are not unnecessarily excluded from attempting the major of their choice.

The findings are being discussed at the departmental level as the program considers revising its entrance to major requirements. Specifically, the program is considering optimizing its ETM requirements to more closely align them with predictors that have been demonstrated to be statistically significant indicators of student success. Of significant note is that since spatial skills can be developed through training [6], inclusion of such development at an appropriate time in the program has the possibility of improving program success rates both as measured by degree completion and outcome achievement. Such an approach is suggested as an extension to the current work.

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