Predicting and Preventing Perception Problems in Freshmen Engineers

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Abstract

The Virginia Military Institute (VMI) engineering division has conducted a survey of all entering engineering students to understand their perceptions of engineering. The survey includes a quantitative part that measures the student's confidence in various skill sets and their commitment to successfully finishing an engineering degree. In addition, there is a qualitative component that requests why they chose engineering, their future plans, and their biggest fears in an engineering program. The results revealed the students with confidence in math, problem solving, and science based laboratory courses have more confidence in their ability to succeed in engineering. The biggest academic fears were math preparedness and overall workload. At the same time, the students chose engineering because of math and are confident that they can succeed academically. The implications include the need to emphasize numerous topics during recruitment, in introductory engineering courses and throughout the curriculum.

Keywords

Retention, Introduction to Engineering, Engineering Perceptions

Introduction

The Virginia Military Institute (VMI) is a four-year undergraduate university offering ABET-accredited engineering programs in electrical, mechanical, and civil engineering. Most first–year students are 18 years old and enter the university directly from high school or after one to two years at a community college. All students are admitted based on the major they declare upon application to the university. Each August, the new class of engineering students starts taking courses within their department that includes an introduction to their respective field of engineering. The departments' curriculums are designed to help prepare the students in their field of study through a variety of courses and extra-curricular activities.

In recent years, the perceptions of the students as they enter college have been a concern. The respective departments know what they are attempting to teach the students and know what failures they are trying to prevent both academically and in their future careers. However, an important part of preventing future problems is knowing their preconceived ideas and perceptions. An investigation was undertaken to identify common perceptions of incoming engineering students and their relation to success in engineering. Then efforts are made to amend the curriculum and activities to help the students become better engineers.

Survey Results

To obtain a snapshot of the perception of incoming engineering students, a series of survey questionnaires similar to those used in the previous study[1] were distributed to freshmen during the first week of class in 2018. One hundred and four completed surveys of the 177 surveys administered were collected for a response rate of 59% with margin of error of 6% at the confidence level of 95%. Several studies[2, 3, 4, 5] reported their survey response rate as acceptable at approximately 25% and the response rate of this study exceed the acceptable rate suggested by other researchers[6, 7]. The majority (66%) of the students came from Virginia and plan to commission in the armed forces upon graduation (71%). In the 2018 freshman class, 37% were enrolled in civil & environmental engineering, 19% in electrical engineering, and 44% in mechanical engineering. Every student was entering the engineering department for the first time and almost every student had graduated from high school the previous year.

Overall, the analysis of survey results answered the four research questions as follows:

Research Question (RQ) 1: Is there a significant relationship between success in engineering and S1, S2, S3, S4, and S5 (see Table 1)?
RQ 2: What perceptions/factors are more important to success in engineering?
RQ 3: What are students' biggest academic concern or fear?
RQ 4: Why did students choose an engineering major?

Following the demographic and general perception questions, the students were asked to rate their responses to six statements in a six-level Likert-type scale as summarized in Table 1. The intention of these statements was to address the students' perception of confidence in certain areas.

Table 1. Statements to Address Students' Perception of Confidence

	I am confident in my ability to…	Likert-type Scale
S1	Succeed at completing high-level math using quantitative reasoning. (Math Level)	1 (Strongly Disagree) ~ 6 (Strongly Agree)
S2	Solve open-ended problems using abstract reasoning. (Problem Solving)	
S3	Succeed in required science and lab-based courses. (Lab Course)	
S4	Communicate effectively in writing. (Communication in Writing)	
S5	Work effectively as part of a team. (Teamwork)	
S6	Succeed in my engineering courses.	

In this study, the relationship among students' perception of success in engineering (Question S6) was compared to their confidence in other abilities (Questions S1-S5). The term 'success in

engineering' was not explicitly defined in the survey, but is implied to mean 'passes all the required courses and graduates with an engineering degree from VMI'.

To examine the relationship between success in engineering and the other factors (Math Level, Problem Solving, Lab Course, Communication in Writing, and Teamwork) and their relative importance to success in engineering, a multiple regression analysis was performed. The results, summarized in Table 2, indicated that the model explained 44.9 % of the variance ($R^2 = 0.449$) and the model was a significant predictor of success in engineering, $F(5, 95) = 15.47$, $p < 0.001$. As can be seen in Table 2, S1, S2, and S3 scales had significant positive regression weights, indicating students with higher confidence in completing high level math using quantitative reasoning, solve open-ended problems using abstract reasoning, and success in required science and lab-based courses were expected to have high confidence in success in engineering. Among these three variables, it turned out that solving open-ended problems using abstract reasoning ($\beta = 0.407$) was the most important factor among the examined variables to success in engineering followed by confidence in high-level math ($\beta = 0.212$) and science and lab course ($\beta = 0.201$).

Table 2. Summary Results of the Regression Analysis

Variable	Multiple Regression Weights		
	B	SE B	β
S1 (Math Level)	0.171	0.067	0.212*
S2 (Problem Solving)	0.320	0.071	0.407**
S3 (Lab Course)	0.187	0.087	0.201*
S4 (Communication in Writing)	0.011	0.063	0.014
S5 (Teamwork)	0.089	0.100	0.073
R^2		0.449	
F		15.47**	

* $p < 0.05$, ** $p < 0.001$,

In addition to the quantitative questions, several qualitative questions were asked of the incoming students to provide insight into responses for RQ2 through RQ4. The survey questions included:

1) What are your plans following your graduation from VMI?
2) What is your biggest academic concern or fear?
3) Why did you chose an engineering major?

The questions were open-ended essay questions that resulted in student responses that varied in length from a few words to numerous sentence responses. Over 90% of the students filled in some form of response for each question. The responses were all categorized by content to determine patterns in the responses.

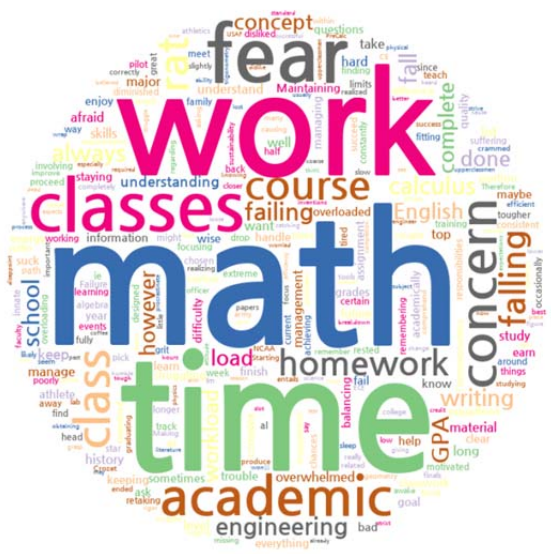
For the first question, the responses were organized based on what they plan on doing after graduation. Every response was categorized as military, non-military, further education, and undecided. Many gave multiple answers in multiple categories and most were undecided

whether to pursue a military or engineering career (or both). Approximately 7% did not respond or gave no specific plan. Almost 79% were planning on or considering some form of military assignment upon graduation. About 38% saw themselves entering the engineering workforce at some point in their career. Less than 5% planned on going to graduate or professional school upon graduation.

The second question was what is their biggest academic fear or concern. These responses were categorized into the subject matter, time management, grade point average, VMI specific fears, and other. A specific academic subject or perceived rigor of college academic expectations was a concern for over 42% of the students. The biggest fear in this category was math (18%). Time management, which included falling behind, doing homework, course load, and getting rest, was a concern for about 54% of the students. Achieving a low grade point average was a concern for 14% of the students, which included loosing scholarships, failing the program, and getting a lower average than expected. Considering the students were in the middle of a 10-day training period that introduced them to military life at VMI, about 12% had VMI specific concerns that were not directly academic, but could affect their academic results. Essentially, outside factors such as military training and athletics were a concern for just a small number of students.

The responses to the third question were categorized based on what influenced them to choose engineering as a major. Four categories were used to divide the influence: A person, the subject matter, the military, and economics. Surprisingly, less than 13% said a person influenced them to pick engineering whether it was a family member, friend, counselor, or admissions officer. The biggest influence was from the subject matter (about 80%). This included their preference for using math and science, solving problems and overcoming challenges, and designing and building things. These incoming students perceived that engineering was something they wanted to do and would likely enjoy. Over 10% were influenced by the military because of scholarships available and possible job assignments for engineers. About 29% were interested in engineering because of the job security and money making potential. Interestingly, only about 8% chose engineering because they could benefit or help society.

An alternate way of analyzing the qualitative response is to view a word cloud. Figure 1 shows the results for RQ3 and RQ4. Similar to the previous study, students were concerned about their workload, time management and math preparedness the most. In addition, the results revealed that students choose an engineering major because they like math as well as enjoying building things. In other words, math is students' gateway to the engineering and at the same time, it is one of their biggest fears in engineering school.



a) RQ 3: What are students' biggest academic concern or fear?

b) RQ 4: Why did students choose an Engineering major?

Figure 1. Visualizing Text Analysis Results with Word Clouds for a) RQ3 and b) RQ4.

Preventive Efforts (May be?)

The results of the survey have driven an analysis of the VMI CEE Department's current and possible future policies for teaching and advising of civil engineering students when they arrive at VMI. This includes two topics in particular: math preparation and introduction to civil engineering fundamentals.

Math Preparation:

Although students surveyed entering VMI have confidence in math and their ability to succeed in engineering. The problem is that roughly 40% of incoming freshman do not pass the math placement test after two attempts. In addition, lack of student success in VMI's pre-calculus and calculus courses is a significant factor in attrition in VMI's CEE department.

Current Policy: Students are required to take a math placement test in the summer prior to registering for courses in the fall and have to solve at least 21 out 30 (70%) problems correctly to enroll in calculus. Students who do not pass the test have three options:

1) Students may take a re-test, typically before August
2) Students may enroll in a pre-calculus course during the Summer Transition Program
3) Students may enroll in a pre-calculus course for the fall semester

The pre-calculus course is a "pass-fail" three credit hour course in which students must achieve a 75% in the course to pass. The credit hours for the course do not count towards degree requirements. Students who enroll and successfully pass the course in the fall are still behind one semester in regards to math sequence. As a result, students have to alter their sequence of required/elective courses until the necessary calculus pre-requisites are passed.

Future Policy: The current policy of allowing students two attempts to pass the math placement test and a third chance by passing a pre-calculus course provides ample opportunities for students to be ready for calculus. However, VMI does not provide review material to assist with math placement test preparation. A proposed option would be to provide students review material to assist in preparing for the test. In addition, the CEE department wants to increase efforts in emphasizing the importance of the math placement test to all perspective students who visit the school during scheduled "open house" events. Students attending VMI's Summer Transition Program would also be encouraged to take pre-calculus in the summer to increase the probability of being calculus ready for the fall semester and staying on schedule in regards to the math sequence.

Introduction to Civil Engineering Fundamentals:

Current Policy: To introduce the sub-disciplines of civil engineering, the current practice of the VMI CEE Department is to teach two civil engineering fundamental courses, namely CE 109 (CE Fundamentals I) and CE 110 (CE Fundamental II), in the fall and spring semesters, respectively. These two courses include in class lecture and field/lab work for concrete, hydraulics, water and waste water, foundations, transportation, construction management, steel lab (Pasco Truss lab), trebuchet (Engineering in Military), and demolition. Students often have to attend invited professional engineers' lectures. Additionally, these two courses also teach technical drawing and AutoCAD©. Overall, students obtain a very good overview about the diversity and sub-disciplines of civil engineering. While they really enjoy the hands on experiences from different sub-disciplines, previous years' records show a significant portion of them struggle with the lessons involving math exercise.

Future Policy: A proposed option is to incorporate additional relevant pre-calculus math exercises in the CE109 course and calculus-based math exercises in the CE110 course. During lecture periods, continue to reinforce the many opportunities and various career paths available in civil engineering.

Conclusion

The following conclusions may be drawn from the analysis of the survey results from the incoming VMI freshman students:

1) The student survey is useful to identify trends and expose gaps between initial perceptions and academic realities.
2) Students that enter with confidence in math, problem solving, and science-based laboratory courses have more confidence in their ability to succeed in engineering.
3) A small percentage of students want to pursue graduate school. Further investigations are required to identify the actual reason(s) for this outcome.
4) Math, academic rigor, and time management issues continue to be the biggest academic concerns of incoming students.
5) The vast majority of students are genuinely interested and excited about becoming an engineer.
6) The VMI CEE Department is reviewing the introduction to engineering courses and math sequence and considering the implications of both to future engineers.

7) Further tailoring of the student survey would generate additional data for prediction and prevention efforts. For example, additional questions asking to reason their choices about their plan after graduation could also reveal the possible reasons why only a small percentage of students are interested in graduate school. As always, efforts to increase the survey response rate would also be implemented.

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Jai Kyoung earned his Ph.D. in Civil and Environmental Engineering at Cornell University. His research topics include computational and experimental approaches to infrastructure sustainability. He teaches geotechnical engineering and foundation design as an Assistant Professor at the VMI. At the same time, he is expanding his research topics in multidisciplinary areas including big data analysis for condition assessment of underground infrastructure system.

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Matthew earned his Bachelors and Masters degrees in Civil Engineering from Missouri S&T and then worked as a bridge designer at the Missouri Department of Transportation. He earned his Ph.D. in Civil Engineering at Virginia Tech and worked at the Turner-Fairbank Highway Research Center on concrete bridge research. He is currently an Associate Professor at the VMI teaching engineering mechanics and structural engineering courses and enjoys working with the students on bridge related research projects and with the ASCE student chapter.

Paul Ackerman

Paul earned his Bachelors in Civil & Environmental Engineering from VMI in 1993, M.S.C.E. from West Virginia University in 1995, and a Ph.D. in Civil Engineering from Virginia Tech in 2014. He is a registered professional engineer with over 20 years of design and consulting experience. As an Assistant Professor at the VMI, he teaches surveying, project management, and senior capstone courses at VMI and is an alumnus of VMI's pre-calculus program.

Thomas Timmes

Thomas is a 1992 graduate of the VMI who spent over 25 years working as an environmental engineer in the U.S. Army Medical Service Corps. He earned his M.S.E. from Johns Hopkins University and his Ph.D. at Penn State University. As an Associate Professor at the VMI, he teaches the environmental engineering courses and enjoys working with students on research projects in the environmental engineering laboratory.

Charles Newhouse

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