The Development of a Pre-Engineering Program for First-Year Students

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Developing a Pre-Engineering Program for First Year Students

Abstract

The University of Maine offers a Pre-Engineering Program for incoming freshmen. This program is designed to allow otherwise under-qualified students who wish to follow an academic path in engineering to come to the University. The University's Admissions Office enrolls these students in the College of Liberal Arts and Sciences (CLAS). They are assigned a CLAS academic advisor and are put in courses that follow traditional engineering pre-requisites and humanities electives. Students are also placed in remedial courses to improve study skills for the rigors of University level academics. CLAS advisors monitor these students progress for the first year of the student's education to see whether the individual student can academically perform within the College of Engineering. The first semester, first year engineering course in this program is called GEE 103 Introduction to Pre-Engineering. This course gives students an overview of the varied types of engineering disciplines offered at the University and exposes them to the applied practices of these disciplines.

This is a work in progress paper that describes the Pre-Engineering program at the University of Maine with specific focus on the GEE 103 course. It describes the results of the successes of the program in the past 5 years for 2014-2018 and looks at the retention rates as students are mainstreamed into the traditional engineering curricula offered at the University of Maine.

introduction

Engineers have a vital role in modern society. They are the developers and innovators of the products, services, and overall environment in which we live. As consumers, we seek improved and reliable services. We want innovative, environmentally neutral, and sustainable products. We expect a reliable and safe infrastructure to continue our daily living standard. Engineers are needed to keep us at the living standard that we enjoy and expect.

As we enter into the 21st Century, the demand for more engineers in the United States is increasing. According to projections from the U.S. Department of Labor, "engineering occupations will add 178,300 jobs in the 2008-2018 period at a growth of 10.3% [1]." The Bureau of Labor Statistics (BLS) projects that the number of Science and Engineering jobs will grow by 853,600 between 2016 and 2026, a growth rate (1.1% CAGR) that is somewhat faster than that of the overall workforce (0.7%). In addition, BLS projects that 4.179 million scientists and engineers will be needed due to labor force exits and occupational transfers (referred to collectively as occupational separations). BLS projects the total number of openings in S & E (science and engineering) due to growth, labor force exits, and occupational transfers between 2016 and 2026 to be 6.033 million, including 1.265 million in the engineering occupations [2]."

Although there is a strong demand for engineers in the U.S., there has been a decline in the graduation rate of engineers with a consistently stagnant number of engineers being

graduated from U.S.Universities. “Only 4% of all U.S. graduating college students graduate with an engineering degree. Since 1966, all awarded university degrees have grown by 220% while those receiving engineering degrees have grown only by half that amount increasing from 33,000 to 70,000 degrees per year. The number has been pretty constant at 70,000 since the 1980s [3].” Several statistics in a literature review show that of students entering college, 10% enter as engineering students. By the time of graduation, half of those entering engineering students either withdraw or change majors. Many find that they are not prepared for the rigor of engineering study or find the courses to be too difficult.

Charles M. Vest of the National Academy of Engineering reinforced the need for more engineers in his remarks at the 2011 NAE Annual Meeting. He gave four reasons for the need as follows:

1. U.S. industry, including the national security industry, is facing a wave of retirements in the coming years.
2. It is not crystal clear that we will forever be able to fill the engineering gap with the best and brightest from other countries.
3. Many high-tech companies report that they cannot find qualified U.S. citizens to fill critically important engineering and technology jobs, including in manufacturing; but most important of all,
4. We need a new generation of brilliant engineers, researchers, and entrepreneurs to create a vibrant future, just as preceding generations did. [3]

The declining enrollment in engineering education in the U.S. poses challenges for the future of U.S. engineering programs. In just the State of Maine, the need for engineers is growing faster than our University can graduate them. Statistics show that Maine has had a 15% engineering job growth between 2005 and 2015 that added 810 positions. Currently, 27% of the State’s engineering workforce is older than 55 and within retirement age. Dr. Dana Humphrey, the Dean of the UMaine College of Engineering, has projected a need of 1750 engineers in the next decade [4]. The current UMaine rate of graduation does not meet the projected need.

This work in progress paper discusses one of the ways that our University is using to increase undergraduate interest in engineering through a first-year pre-engineering program. It will specifically look at the criteria for admission and retention in the program. It then will look at the Course GEE 103 the Introduction to Pre-Engineering to correlate data for predicting success for the student.

definition of pre-engineering

A general literature review reveals that there are three general definitions of pre-engineering programs as relates to college training of engineers. First, there are pre-engineering programs developed through STEM education and partnering at the secondary school level. The literature shows several successful programs that introduce engineering and offer college credit math, science, and general education courses. These courses transition motivated academic students to engineering programs within universities such that students

may enter at second year levels. Another form of this type of program allows students to enter pre-engineering programs at community colleges that transition or "bridge" students later into traditional university engineering programs. Many of these academic paths follow 2 + 3 formats from the community college into a baccalaureate degree at a four-year engineering program. Second, there are pre-engineering programs offered at universities that admit students who want to be in engineering but lack the demonstrated academic credentials to meet the engineering academic admission standards. Literature review shows that academic success is linked to secondary education GPA and SAT or ACT scores. Literature review also suggests student success in engineering can be based on student demographics. These programs focus on students from primarily low income, under-represented ethnic backgrounds, and gender. These academic programs are somewhat remedial intended to improve student academic performance for success. Third, there are pre-engineering programs developed to improve student awareness as to the types of engineering professions available through career exploration. These academic programs give students exposure to different disciplines such that they can decide what course of study is of interest. All of the information on STEM, remedial academic recovery, and exploration form a general definition of pre-engineering.

University of Maine pre-engineering program

The University of Maine is a seven campus statewide public land grant institution. The College of Engineering is established at the flagship campus in Orono. A sister campus in Portland offers some of the engineering disciplines. The Orono campus is categorized through the Carnegie Classification as a medium sized four year research university. It is considered rural with residential offerings servicing both in-state and out of state students. In regards to the general definition of pre-engineering programs, the one created at the University of Maine is a hybrid of the three generalized programs found through literature search. The University of Maine has a remedial program for under-qualified students. These students are not necessarily from urban areas nor do they necessarily meet the target populations related to income, ethnic background, or gender. They have weaker identified academic skill sets. The student in the University of Maine program also has limited knowledge of the engineering profession and is undecided to particular disciplines for study.

At the University of Maine, the admission standard into the College of Engineering is somewhat more rigorous than in other colleges at the University. With the very distinct disciplines defined in the College of Engineering, there is no one area to provide academic supports or exploration into these varied disciplines. Because of the growing need for undergraduate engineers, the University of Maine created a pre-engineering program in 2014. In cooperation with the College of Liberal Arts, the College of Engineering formed a pre-engineering program. This pre-engineering program allows students not meeting academic standards for admission into the College of Engineering but meeting overall University of Maine admission standards to begin courses that can lead to admission to the College of Engineering. Students need to demonstrate an acceptable academic record within the first year of study and apply to the engineering program of interest. Because the pre-engineering program is administered through the College of Liberal Arts, a pre-engineering student is not considered an engineering student upon admission to the University.

Table 1 shows the difference in admission requirements between a generally admitted student to the University of Maine and a student admitted to the College of Engineering [5]:

High School Course	General Admission	Engineering	Engineering Technology
English	4	4	4
Algebra 1 and 2	2	2	2
Geometry	1	1	1
History/Social Sciences	2	2	2
Senior Math	1	Pre-Calculus	Trigonometry
Chemistry w/lab	2 sciences either of these	1	Suggested
Physics w/lab		1	1

Table 1- Minimum academic courses required for Admission into the University of Maine

Under the general admission requirements, students don't need either a calculus or trigonometry math course and aren't required to take an analytical science. A pre-engineering student can be admitted without taking the fundamental analytical courses required for a traditional engineering student. Consequently, these types of courses are introduced at the college level to many pre-engineering students who have difficulty understanding these courses. They often need remedial preparation.

In addition to the course work, the minimum general SAT and ACT scores are for Engineering SAT 1180 and ACT 24; for General Admission SAT 1050 and ACT 21. (These are anecdotal minimums) Composite standards for admitted students are reported at the 25th percentile at 1130 and at the 75th percentile at 1310. Other items such as high school GPA and application essay enter the consideration for admission. The consideration for acceptance into the College of Engineering or the Pre-Engineering program rests in the individual student's prior coursework in math and science and SAT percentile [6].

In comparison, first year students in the College of Engineering have higher mean SAT scores than those in the Explorations program at our University for the period of 2014 to the present. This is summarized in Table 2 [7]:

Year	Engineering			Explorations (Pre-Engineering)		
	Verbal	Math	Total	Verbal	Math	Total
2014	614	642	1256	563	561	1113
2015	616	644	1260	550	545	1095
2016	612	635	1247	554	543	1097
2017	612	631	1243	546	538	1084
2018	614	635	1250	541	530	1072

Table 2- Comparison of Average SAT Scores of Entering 1st Students in Engineering as Opposed to Explorations

The weighted average mean SAT Engineering score is 1251 and the weighted average mean SAT Explorations score is 1092. The mean SAT Engineering score is 14.6% higher than that of the Explorations score. The mean SAT Explorations score is slightly above the minimum SAT score allowed for University admission and below the 25th percentile score of 1130.

The growth rate of the pre-engineering program for the period of 2009 to the present is greater than the general growth rate of the College of Engineering. Though the raw number of students is different, the trend shows the greater growth. The College of Engineering growth rate is 2.5% while that of the pre-engineering program is 14.4%. [7] (It is noted that the pre-engineering program data starts at 2014 and is normalized for the period to represent a growth rate for comparison)

Application yield rate is another interesting area of comparison between the College of Engineering and the pre-engineering program. This information is summarized as Table 3 [7]:

Year	Engineering			Explorations (Pre-Engineering)		
	Accepted Applications	Acceptance Rate %	Yield %	Accepted Applications	Acceptance Rate %	Yield %
2014	1380	77	29	1324	84	22
2015	1394	75	27	1296	82	19
2016	1466	72	28	1344	84	20
2017	1483	69	27	2376	95	17
2018	1516	72	29	2151	95	17

Table 3- Acceptance and Yield Rates of 1st Year Students in Engineering versus Explorations

From the data, Engineering accepts 73% of the applications for admission to the College of Engineering and yields 28% of the students admitted. The Explorations program accepts 88% of the applications for admission to the Explorations program and yields 19%. [7] (It is noted that the pre-engineering information is not differentiated from the data available from the Explorations program. The actual yield rate may be different)

First year student retention rate is another comparison point between Engineering and Pre-Engineering. There are additional statistics available for First year student retention rate for the University of Maine as a whole. This information is summarized as Table 4 [7]:

Year	Engineering %	Explorations (Pre-Engineering) %	University as a whole %
2014	82	73	76
2015	86	70	76
2016	83	65	75
2017	87	65	78

Table 4 – Retention Rate of Engineering, Explorations, and University as a Whole

Engineering has the highest average retention rate in this period at 85%, followed by the University at 76%, and Explorations at 68%. (It is noted that the pre-engineering information is not differentiated from the data available from the Explorations program. Retention rates may be different.)

Information from first year dropout rates can be compared across Engineering, Explorations, and University as a whole. This information is summarized as Table 5 [7]:

Year	Engineering %		Explorations %		University %	
	Suspend	Withdraw	Suspend	Withdraw	Suspend	Withdraw
2014	6	13	6	21	6	18
2015	7	7	5	25	6	18
2016	6	11	9	25	6	18
2017	5	9	12	23	6	16

Table 5- Suspensions of 1st Year Students. Engineering vs. Explorations vs. University as a Whole

Suspension rates across the three areas of consideration are consistent with Engineering and the University at around 6%; however, Explorations shows a slight increase at 8%. Withdrawals are higher with Engineering at 10%, the University at 18%, and Explorations at 23.5%. [7] (It is noted that the pre-engineering information is not extracted from the data available from the Explorations program. Withdrawals and suspensions may be different.)

pre-engineering program structure

Students that enter the Pre-Engineering program generally take a first semester course load of 15 credit hours. Each student is assigned an academic advisor within the Explorations program of the College of Liberal Arts. Students take a 50 minute per week seminar with their respective advisor titled FYS 100. In this seminar, advisors instruct students in college preparedness and offer one on one meetings with individual students to monitor student progress. FYS 100 introduces students to time management skills and varied academic resources available across the University campus. Each student at the University of Maine is required to take a math placement exam upon entering their first year. In Pre-Engineering, depending on the results of an individual's exam, individual students are placed in either pre-calculus or trigonometry classes. If exam results are lower, students may be in algebra or remedial math courses. Based on the student's math ability, students with higher math placements are entered into lab sciences of either Chemistry or Physics. Students with lower math placements are entered into general education electives and other social science courses appropriate to individual engineering disciplines of interest to the student. All students in Pre-Engineering also take a 1 credit hour Introduction to Pre-Engineering class designated as GEE 103. The Pre-Engineering program was originally instituted to provide a gap year for a student entering the University of Maine to take academic courses to prove their ability to succeed within a traditional engineering program. Students would need to pass math through pre-calculus at a C or better and to have at least an overall GPA of 2.0 to enter either the School of Engineering Technology or an overall GPA 2.5 to enter College of Engineering programs. Because of limited resources with the growing Engineering program at the

University, the College of Engineering instituted an internal application process in 2017. Pre-Engineering students had to fill out an application for the Engineering program of interest and submit it after first semester grades for consideration to be in an engineering program in their second year. Currently, there are students who now have entered a second year in the Pre-Engineering program as they try to pass math courses at a C level to meet the transfer requirement to an Engineering program.

GEE 103 introduction to pre-engineering

To create a liaison to the College of Engineering, a College of Engineering faculty member teaches GEE 103 as an extra course. This course is set up as a one credit hour pass-fail survey course. It meets once a week to give students an overview of the many facets of Engineering. Depending on their backgrounds, many students that attend the class know which Engineering discipline is of interest to them, yet many others do not know. Because the program has had an annual growth rate of 14%, the class is now offered in two sections to accommodate the size of the class and to allow the varied first year courses that the pre-engineering students take in their first year, first semester under the Explorations program.

The course is offered in the fall semester and meets for 12-13 weeks depending upon the weekly class meeting time and relation to varied university holidays in the fall semester. Typical breakdown is shown in Figure 1 as follows:

Week	Topic	Description
1	Introduction	Description of Course, College of Engineering presentation on how one can progress to Engineering
2	University Career Fair	Career Center Personnel come in and discuss the College wide engineering/construction job fair held in October. Students are assigned resumes
3	Tutor Program	Tutor staff come in and discuss the tutor process and how students can get tutor assistance on math and physics or chemistry classes
4	Research Methods	The Engineering Librarian discusses all the electronic resources that students have to search topics
5	School of Engineering Technology	The Director of the School of Engineering Technology comes in to discuss the differences of SET vs. College of Engineering and the possibilities.
6	Career Fair	Students attend the Career fair on their own and are required to report on three booths they visited.
7	Self- Guided Field Trips to University Engineering Centers	Students are divided into 4 cohorts and take tours of 4 engineering centers on campus during their regularly scheduled class period. The instructor attends random locations. These centers include a manufacturing center (mechanical engineering), structures center (civil engineering), paper laboratory (chemical engineering), and steam heat plant (applied mechanical engineering)
8		
9		
10		

11	Power Utility Engineer	A guest speaker from a power utility speaks about power to the class (electrical engineering)
12	GPS/Survey	A construction engineer comes in to discuss how GPS is used on equipment and CAD modeling (civil engineering, construction engineering, surveying, and computer automation)

Figure 1-Typical Engineering Discipline and Topic Breakdown in GEE 103 in a Typical Semester

Students are required to attend all activities and are asked to report on selected discussion topics, the field trips, and the career fair. A Blackboard format is used to collect written work. Students are allowed to submit typed paper copies during class. The written assignments are only gauged at a couple of paragraphs to cover the major highlights of observation or discussion. These assignments are not meant to be detailed documents, but rather complete notes to provide evidence that a student understood the topic. The resume is meant to be a working start to a professional document that will change as the student gathers experience through their academic and working journey in college. Each item is graded at 10 points. Attendance is graded as to whether a student is present. The total written points and attendance points are added. Attendance is weighted such that it is 60% and the written is 40%. The grades are then figured on 100 points. Greater than 60% is considered a pass, lower is a fail. Based on the simple matrix score, the pass-fail rates for the GEE 103 class is presented in Table 6 [8]:

Year	Number Students	Number Pass	Number Fail	% Failed
2014	75	66	9	12
2015	66	58	8	12
2016	68	46	22	32
2017	139	126	13	9.3
2018	79	68	18	22.8

Table 6- Failure Rate of 1st Year Students in GEE 103

Failure reflects students that do not pass in assignments and who have frequent absences from class. The lack of commitment in such a survey class shows general lack of effort since the performance criteria is relatively low.

discussion and future study

The development of a Pre-Engineering program at the University of Maine began in 2014 to give academically under-prepared students interested in engineering an opportunity to enter engineering study through another entry point. Many of these students don't have the academic skill set to satisfy the entry requirements to enter the College of Engineering but

meet the general requirements for admission to the University of Maine. These students are accepted into the University of Maine and are conditionally accepted for engineering. However, individual students need to prove themselves academically before full acceptance in the College of Engineering. Individual students must take a lab science and pre-calculus class along with pre-requisite classes during their first semester. They need to receive passing grades above a C to be considered for admission into the College of Engineering. On a case by case basis after the first semester, students apply to the respective engineering discipline department of interest for full acceptance into the college.

The Pre-Engineering program is administered through the College of Liberal Studies as part of the Explorations program. Explorations is a guided program for students who are looking at possible disciplines of study. As such, students have individual guidance from academic counselors who help them discern careers. Pre-Engineering students have dedicated guidance that they would not be able to get within the College of Engineering. These students are given academic supports as needed to demonstrate that they are capable of meeting the requirements established for the College of Engineering.

In preparing this paper, data was collected through the University of Maine's Office of Institutional Research. In researching data specific to the Pre-Engineering program, I found that the data is not differentiated from that collected on the Explorations Program. As such, information presented for SAT means, application yield rates, first year retention, and suspensions/withdrawals may be somewhat irregular. The overall trends shown are accurate in comparing the larger cohort of the Explorations Program to the College of Engineering. In the same regard, the actual failure rates of students in the GEE 103 class are similar to the overall failure rate of students within the Explorations program. The lower admission standard allowed for students entering Pre-Engineering seems to be reflected in the ultimate drop out and failure rates of the larger Explorations cohort. Results of the graded failure rate for the GEE 103 class are parallel to the reported failure and retention rates of the First Year students in the Explorations program. From observation, Pre-Engineering students tend to have a lower academic skill set and it is reflected in the non-attendance and not passing in of written assignments. Engineering requires attention to detail and production to a final solution. At the beginning stage of one's professional development, these skill sets are important. Not producing assignments in GEE 103 may be an indicator of the type of student that some of the pre-engineering students will be if entering the engineering program. They will undoubtedly fail. The data shows that Engineering students have a higher first year retention rate and lower suspension rate than the Pre-Engineering students. This could reflect a different engagement level formed from association with a distinct program of study. It could also reflect the weaker academic preparation that is reflected in SAT scores and other markers used in the Admissions process. There is a 15% difference in the SAT mean score between the accepted Engineering student and the students accepted into Explorations/pre-engineering. Does this provide a significant indication for performance?

Future investigation needs to be conducted to see if the Pre-Engineering Program is effective. Does the program yield viable undergraduate students for the College of Engineering? In order to investigate this premise, the data at the Office of Institutional Research needs to be explored as to what is currently collected and is viable to sort. Several questions should be

addressed to determine effectiveness.

1. What is the number of pre-engineering students admitted at various ranges of traditional markers such at SAT scores? Are pre-engineering students interested in engineering closer to engineering scores for accepted engineering students?
2. Do students that drop out of engineering have lower markers than their peers or are they similar to pre-engineering students?
3. What are the numbers of pre-engineering students that transition within a semester? What is the time frame for the average transition?
4. What field of engineering study do pre-engineering students most likely enter? What do they want to enter?
5. What is the reason for pre-engineering drop-out?
6. In comparison to traditional engineering students, what are the average math and analytical lab scores for pre-engineering students?
7. What are the typical demographics of pre-engineering students? Are they first generation college students? Are they non-traditional ages? What is their socio-economic background?
8. Other than math/science areas, how do pre-engineering students perform in other courses such as English and the humanities?

In addition to general information that may be available through the Office of Institutional Research, various surveys should be conducted to track a cohort of students through to graduation. This instrument should be administered prior to beginning the pre-engineering program, during the first year of study and through subsequent years to graduation. The survey should track courses of study, individual course performance, and overall development through the student's time at the University.

A pre-engineering is an alternative way to allow under-prepared students who are interested in engineering an opportunity to enter engineering study. To determine the effectiveness of the pre-engineering program at the University of Maine, better data collection will be required. Current data collected for the Explorations program needs to be divided into pre-engineering, explorations, and foundations. The information on pre-engineering students needs to be better quantified as to where pre-engineering students transition to after entering the pre-engineering program. What is the drop-out rate? Are there specific disciplines that pre-engineering students enter? What is the ultimate successful graduation rate?

The GEE 103 course should be developed to better gauge success in the pre-engineering program. Class exercises need to be more frequent with better accountability from students to reflect academic expectations in an introductory engineering course. Though these exercises will not have academic rigor, they should be better structured to substantiate success and failure rates. Further work will need to be done to develop a working protocol to predict success for students in pre-engineering.

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