AC 2010-1250: A PRE-ENGINEERING PROGRAM TO MOTIVATE HIGH SCHOOL STUDENTS TOWARDS ENGINEERING

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A Pre-Engineering Program to Motivate High School Students Towards Engineering

Abstract

A pre-engineering program has been developed by The University of Michigan-Flint for high school students in the Lapper County Intermediate School District (LCISD) to motivate students' towards engineering or other STEM disciplines during their undergraduate study. A cohort of approximately twenty students from five different high schools was enrolled in four different engineering and computer science courses. These courses, offered at Lapeer Technology Center, provided a classroom environment similar to high school, using instructional materials relating students' prior knowledge of science and math that are relevant in engineering education.

A survey questionnaire was used to evaluate students' backgrounds in science and mathematics, perception and motivation towards engineering, and whether the pre-engineering program motivated them towards engineering or other STEM disciplines. Classroom observation and changes in participation were also made during the courses, to evaluate the level of motivation. The number of students from the first year pre-engineering cohort that pursued engineering or STEM undergraduate education is also presented in this paper demonstrating the impact of the program.

Introduction

To sustain technological leadership in the competitive global economic environment, significant improvements in K-12 outreach must be made to attract and motivate more students toward engineering and science education. The United States has been at the forefront of innovation in the past century. As the advent of technologies is bringing the world closer, United states is facing exponentially increasing level of challenge in the global platform, where emerging economies are shaping the future global leadership. To this end, we need to nurture the youth of this nation to ensure that the rate of technological innovation increases at a phenomenal pace, more so than it was in the past few decades.

Innovation and creativity in development of future technological breakthrough requires the motivation of current high school students to focus more towards science and technology. A number of pre-engineering programs have been developed across the nation during the past few decades to encourage students to consider engineering and science as career choices. Although the programs showed an increased level of interest towards STEM disciplines, those initiatives are less than adequate as we are still seeing declines in enrollment in STEM disciplines. To address the projected critical shortage of future scientists and engineers in the USA, a pre-engineering program was developed at University of Michigan-Flint in collaboration with a local rural school district for a limited number of high school students. This program was designed to encourage high school students to consider engineering as their chosen field of study. A unique feature of the program is the level of mentoring provided to the students by the engineering professor and senior undergraduate engineering students. Weekly tutoring sessions were also conducted by the engineering professor and senior engineering student, in addition to the content delivery of the classes. Students were also encouraged to use online discussion board to

discuss about different topics and assignments asynchronously where the professor also participated on a regular basis. These unique activities may have a positive influence in increasing the level of motivation of the students.

To assess the level of interest and need, the development process for this pre-engineering program involved input from high school principals, students and parents. Four different courses were carefully selected and offered during the first and second year of the program. Two courses offered during fall semester were introduction to engineering and introduction to computer programming. The other two courses offered in winter semester were computer aided design and computer programming in C++. These courses were taught by experienced faculty from the University of Michigan-Flint at the Lapeer Education and Technology Center to ensure the students would not perceive an environment different from their regular classrooms.

Initial classroom discussion revealed that more than half of the students demonstrated low level of interest towards engineering or any other STEM education in spite of their higher grades in high school science and math courses although the selection process that required interest towards engineering. The primary reason identified by the students was a lack of awareness: of the admission process at a university; of career opportunities; and lack of understanding of the professional work environment.

The pre-engineering courses were designed using problem-based and activity-based learning with examples and illustrations. The students were encouraged and required to use their prior knowledge of high school math and science courses to provide a smooth transition to complex topics. The course materials included review of high school algebra, geometry, and physics. This enabled students to learn new materials with an understanding of how it relates to their prior knowledge and thereby minimize the undue complexities perceived by other engineering students. This results in a higher level of knowledge, understanding and motivation towards the overall learning process. Assessments were conducted to evaluate their prior knowledge and level of awareness of engineering education at a university, career opportunities and motivation. The changes in students' interest and level of motivation towards engineering education were monitored throughout the year.

This program was compared with other similar programs and initiatives at universities across the country, those being used to encourage students towards engineering and science curriculums. The success criteria of this program was measured by not only encouraging more students to consider engineering as a career choice, but also by encouraging them towards other programs in other STEM disciplines. Another measure of success is the increased awareness about engineering education to students in rural communities by presenting the opportunities offered by the engineering profession.

Background

In a recent summit on K-16+ engineering education, during his keynote speech Charles M. Vest, President of National Academy of Engineering presented data that were not only disappointing, but perhaps shocking, and urged immediate attention by all stakeholders, such as educators, parents, government and businesses[1]. Vest's data in Table 1 clearly demonstrates our declining

number of graduates compared to other three leading nations. In 2003, the fraction of college graduates with an engineering degree was 20% in Asia, 12% in Europe and 4% in USA.

Table 1: Engineering Graduates in Four Different Nations[1]

Country	Engineering graduate in 1980 (approximate)	Engineering Graduate in 2007	Percent change
China	75,000	250,000	+233%
India	75,000	225,000	+200%
USA	75,000	60,000	-20%
Japan	75,000	100,000	+33%

Technology courses are offered in almost every high school, with pre-engineering programs offered at more than 500 schools with a goal that such program may attract more students towards STEM discipline. Other programs begin even earlier in the K-12 education system to expose students to the STEM disciplines. A number of these were examined in the planning phase of the Lapeer Pre Engineering program that revealed that most of the currently offered programs emphasized on content delivery resulting less than desired level of success. A number of similar programs are briefly summarized in the following section.

The "Mission Science" program of University Of Southern California for elementary school students[2] was designed to stimulate natural curiosity of children and develop enthusiasm about science and technology through "hands-on" activities, demonstrations and projects. A month long residential summer program for high school student, Discover Engineering introduces students to various engineering disciplines as well as field trips to manufacturing and engineering organizations.

Project Lead The Way (PLTW) is a not-for-profit organization that works with public schools, the private sector, and higher education to increase the quantity and quality of engineers and engineering technologists by providing middle school and high school students with engaging pre-engineering education. The program's focus is to promote and support a standardized, pre-engineering curriculum in K-12 schools that is both stimulating and motivating. And while PLTW curriculum prepares students to enter into a college-level engineering degree program, it simultaneously builds their enthusiasm for the subject matter.

Introducing these topics during high school will attract more students to engineering and will allow students to better determine if engineering is their career choice, thus reducing the attrition rate in college-level engineering programs[3]. The PLTW classes are modeled after introductory engineering courses taught at the university level. The limited success of the program may be partially due to the lack of formal engineering education and work experience, of the high school teachers in the PLTW program. Another factor may be lack of familiarity about different engineering discipline, career opportunities. These components are necessary to build motivation in the student.

To increase awareness in science and engineering education, the University of West Florida engineering department, in conjunction with a local northwest Florida high school, initiated in a

high school engineering program. Primary issues encountered in the program included staffing, enrollment, finance, curriculum and deployment of instruction materials. Unique solutions and methods were applied to make the program a success[4].

Clarkson University involved graduate STEM students into local schools to develop and disseminate more rigorous STEM curricula, integrated and aligned with state and local academic content standards and expected by postsecondary STEM disciplines[5] .

The University of Akron offered a six-week summer residential program to improve the running of outreach programs to underrepresented high-school students[6] that provided a series of career workshops and tutorial programs.

The American Institute of Aeronautics and Astronautics (AIAA) pre-college outreach program offers annual workshop jointly with Joint Propulsion Conference and a second workshop called Education Alley[7]. These programs are aimed at direct outreach to local students providing fun, interesting and educational events that promotes STEM.

Valencia Community College offers a more specialized Associate degree in pre-engineering to increase recruitment of local high school students who are interested toward engineering education. The program assisted high school students to bridge the gap between high school and a four-year institution to motivate students to continue their engineering education with support from government and local industries [8].

The Bagley College of Engineering at Mississippi State University admitted students expressing interest in engineering who do not meet the criteria as undecided majors with a pre-engineering concentration[9] where they work towards meeting the requirement for admission to the engineering.

The pre-engineering program at the Hampton University was established in order to achieve two goals. The first was to allow students experiencing deficiencies in basic math to spend one year taking preparatory courses needed to enter engineering program. The second objective was to increase the retention rate. Data collected over a period of six years showed that a large number of electrical engineering students who went through the pre-engineering program graduated at the top of their class[10] .

Louisiana Tech University's five-week summer Freshman Enrichment Program (Frap) was developed to increase number of STEM graduates prepared to successfully enter the workforce[11]. Enrichment topics include study skills, time management and career decision making that prepares students to become successful in engineering classes.

The College of Engineering (COE) at Southern Illinois University, Carbondale (SIUC) developed an engaging and informative learning model by incorporating math into introductory engineering courses to stimulate interest toward application of mathematical principles in engineering problem solving[12].

Faculty in the engineering, mathematics and physics departments at the Auburn University launched an experimental pre-engineering program. The 2-year program consisted of a team-taught sequence of mathematics, engineering, and physics courses that have been integrated so as to enable pre-engineering students to grasp the interrelatedness of the concepts in each of these domains. The program unified mathematics, engineering, physics, and computer technology in an enhanced academic atmosphere that included small group interactions, mentoring, supervision, and remediation[13].

The Bowling Green State University developed AIMS, a four year undergraduate program that consists of a 5-week Summer Bridge Program, a freshman-sophomore phase and a junior-senior phase ending in graduation. Its Summer Bridge Program is aimed at providing a pre-college experience to the high school graduates accepted in the program and enhances the preparedness to succeed. The freshman-sophomore phase builds the foundations for retention of students within the STEM areas[14]. The junior-senior phase completes graduation requirements and prepares students to readily compete for jobs within the STEM disciplines.

Another two-year pre-engineering program at University of Wisconsin-Marathon County (UWMC) offers core engineering courses, after which the student may transfer into one of the engineering programs at various universities. The curriculum of the pre-engineering program encompassed necessary courses students need, regardless of which specific major or university they transfer[15]. This program is somewhat similar to the Lapeer Pre-Engineering Program presented in this paper.

Lapeer Pre-Engineering Program

To motivate high school students for future engineering or STEM education, a collaborative program was developed by University of Michigan-Flint and Lapeer County Intermediate School District's Education and Technology Center. This particular school district was chosen because of its proximity and higher need for the program, as rural school districts on average have weaker science and mathematics programs. The collaboration with the University of Michigan-Flint could make a greater contribution to those served by the LCISD. A series of four introductory engineering and computer science courses were offered by University of Michigan-Flint faculty. Selected senior students from six public high schools in LCISD were enrolled in the pre-engineering program. The selection process and criteria includes completion of or enrolled in pre-calculus, physics with overall grade point average of more than 3.0 and interest towards engineering education. A cohort of 17 students was enrolled during the first year followed by 23 students during second year. Four different courses were offered: two courses were during the fall semester and two courses were during the winter semester with total number of eleven credit hours of coursework. The unique features of this program includes problem-based, activity-based instruction using prior knowledge of science and math, strong mentorship, motivation, tutoring by engineering professor and undergraduate engineering students to increase students' level of motivation. Figure 1 below shows the integrative approach using students' preconception on science and math in the course materials along with strong motivation and mentorship to promote engineering and STEM education.

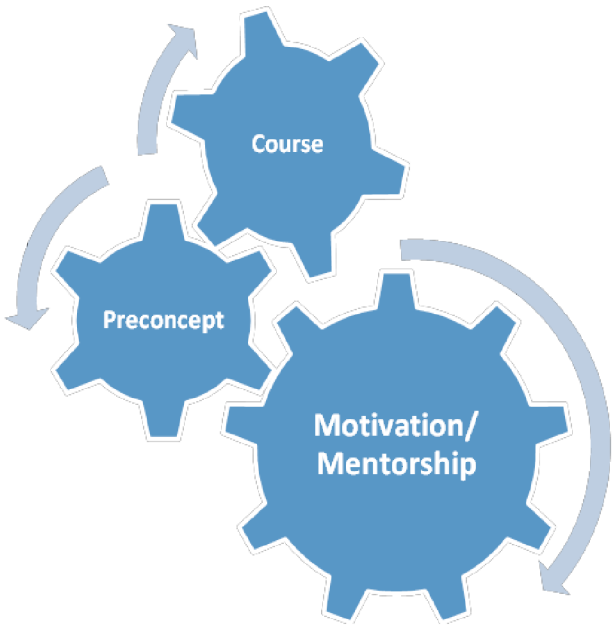

Figure 1: Integrative approach used in Lapeer Pre-Engineering Program

Hypothesis

The hypotheses being investigated regarding the Pre-Engineering Program are as follows:

1. Students with a strong mathematics and science background are more interested in Engineering than those without
2. Students with a strong mathematics and science background are more motivated for Engineering Education than those without.
3. High School students are knowledgeable about admission to Engineering Program.
4. High school students are aware of the Engineering Profession.
5. The Pre-Engineering Program motivated students towards pursuing Engineering Education.

Survey Methodology

Student surveys were used to gather information about students to test the above hypotheses. A follow-up survey questionnaire was used after the first year of the program to evaluate the impact of the program on the student's actual choice of their undergraduate major. Student's feedback from the weekly survey questionnaire was also used to monitor and improve their level of interest and motivation towards engineering education. The results of the survey questionnaire for entire year were also used to determine whether any changes in the program may be necessary to achieve the desired learning outcome of the program.

Although responding to the survey was not mandatory, 38 out of 40 students responded during a two year period, for a response rate of 95%. Students were asked to complete 26 questions about their background and interest in mathematics and science: grade point; interest and motivation towards engineering education; awareness of admission requirement in engineering programs;

knowledge about current and future trends in the engineering profession. The survey responses were coded onto a five point Likert scale; Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree. The survey questions were carefully designed so that each group of questions may address each of the five hypotheses in an effective way. The survey instrument was refined after receiving feedback from a group of similar students with the preliminary survey questionnaire. This step was critical and necessary to validate the survey instrument.

Statistical Procedure

The first hypothesis, which states that students with a strong mathematics and science background are interested in engineering, is related to the survey questions 'My high school Math has relevance in daily life' and 'I had my highest individual grades in Math and Science.' In a similar way, the other four hypotheses are related to certain survey questions. Attempt was made to ensure that the sample is representative of the population and with a sample size of 38, it appears to be sufficient for this analysis (n.>30). The survey data was analyzed using the statistical analysis program SPSS (Statistical Product and Service Solutions, formally Statistical Package for the Social Sciences) technology[16]. Among various statistical analysis techniques, correlation analysis was chosen because it will provide the most useful information for testing our hypothesis enabling us to better understand the relationship among different variables.

Analysis of results

To analyze the data, the dependent and independent variables were selected in such a manner that they address the hypothesis questions in an effective way. The dependant variables used in the analysis were interest in engineering, motivation, admission knowledge and future profession. The independent variables were grade level, GPA, gender, and students with a mathematics and science background. A number of analyses were performed and the results of these are presented in the following section.

Results

Hypothesis One was tested to determine the correlation between the students' background in science and mathematics and their level of interest towards engineering education. The analysis was performed using background in math and science as predictor and interest in engineering as dependant variable. The analysis results are presented in Table 2. A moderate correlation of 0.333 was observed with a p-value of 0.10 showing that students with a science and mathematics background are somewhat interested in engineering.

Table 2: Correlation of Interest in Engineering and Mathematics, Science Background

		Interest in Engineering	Math and Science Background
Pearson Correlation	Interest in Engineering	1.000	0.333
	Math and Science Background		1.000
p-value	Interest in Engineering	-	0.10
	Math and Science Background		-
Number of observations		38	38

Hypothesis Two was tested to determine whether the students with a higher math and science background are more motivated to pursue engineering education or engineering as a career choice. Similar to the previous analysis, background in math and science was used as a predictor with motivation as the dependant variable. The result of this analysis is presented in Table 3. A weak correlation coefficient of 0.160 was observed with a p-value of 0.138 showing that there is almost no relationship between students with a strong science and math background and their level of motivation towards engineering. In other words students with a strong science and math background may or may not prefer engineering for their career as their motivation level may be low. Motivation level may be influenced by interest or vice-versa and therefore hypothesis one and two both show similar results.

Table 3: Correlation of Motivation and Mathematics, Science Background

		Motivation for Engineering	Math and Science Background
Pearson Correlation	Motivation for Engineering	1.000	0.160
	Math and Science Background		1.000
p-value	Motivation for Engineering	-	0.138
	Math and Science Background		-
Number of observations		38	38

The third and fourth hypotheses about high school students' knowledge towards admission requirements and awareness of engineering profession process was tested to evaluate the level of preparedness of the students to pursue engineering education at an institution of higher education. This correlation analysis was performed using admission knowledge as the dependant variable. The independent variables or predictors used were math and science background, gender, high school grade level, and enrollment in Lapeer Pre-Engineering Program. Students were also asked to respond about the source from where they have received the information that provided the knowledge about the admission process. No significant correlation was observed between the independent and dependant variables suggesting that students have poor knowledge about the admission process. Among all the independent variables used in the analysis, the largest correlation coefficient observed for gender and math and science background implying that female students with a math and science background appear to be more knowledgeable about the admission requirements in engineering programs and are more aware of the engineering profession.

Table 4: Correlation of Admission Process Knowledge with Other Variables

		Admission Knowledge	Grade Level	GPA	Gender	Pre-Engineering Program	Math and Science Background
Pearson Correlation	Admission Knowledge	1.000	-.075 (0.306)	.110 (0.228)	**.255** (0.040*)	.085 (0.282)	**.242** (0.049*)
	Grade		1.000	**-.496** (0.00**)	.092 (0.267)	.085 (0.284)	.109 (0.230)
	GPA			1.000	**.320** (0.013*)	.119 (0.211)	**-.252** (0.042*)
	Gender				1.000	**.242** (0.049)	.015 (0.458)
	Pre-Engineering Program					1.000	.135 (0.181)
	Math and Science Background						1.000

(p-value) * p-value < 0.05, ** p-value <0.01, *** p-value < 0.001

The last hypothesis evaluated whether the pre-engineering program motivated students to pursue engineering education or select engineering as a career choice. The analysis was performed using motivation as a dependent variable with math and science background, gender, grade level, GPA and pre-engineering program as the independent variables. The Pearson correlation coefficients and p-values are presented in Table 5. The correlation coefficients are weak for all independent variables except the pre-engineering program for which the correlation coefficient is 0.61 suggesting a moderately strong correlation. This strong correlation supports the hypothesis and therefore it can be accepted. The pre-engineering program motivated students towards pursuing engineering education and selection of engineering as their future profession.

Table 5: Correlation of Motivation Towards Engineering Education and profession

		Motivation	Grade Level	GPA	Gender	Pre-Engineering Program	Math and Science Background
Pearson Correlation	Motivation	1.00	0.06 (0.338)	0.13 (0.181)	0.22 (0.062)	**0.61** (0.001***)	0.16 (0.138)
	Grade		1.00	-0.50 (0.00**)	0.09 (0.267)	0.08 (0.284)	0.11 (0.230)
	GPA			1.00	0.32 (0.013*)	0.12 (0.211)	**-0.25** (0.042*)
	Gender				1.00	0.24 (0.049*)	0.02 (0.458)
	Pre Engineering Program					1.00	0.13 (0.181)
	Math and Science Background						1.00

(p-value) * p-value < 0.05, ** p-value <0.01, *** p-value < 0.001

The effect of Lapeer pre-engineering program on their decision about engineering and other STEM education is presented in Table 6. Before enrollment in the program 16 out of 38 students

expressed their interest towards engineering compared to 23 students interested in engineering. The number of students become more interested changed from 42% to 61% that may be considered as significant contribution. After completion of the program, 24 students were enrolled in undergraduate engineering program at different universities compared to initial 16 students interested in engineering showing a 50% increase in the interest level. Another major impact was the number of undecided student number decreased from 9 to 3 as this program was able to motivate the undecided students to choose either engineering or other STEM discipline as their undergraduate major and future career.

Table 6: Effect of Pre-Engineering Program on Selection of Undergraduate Major

	Before Pre-Engineering Program	After Pre Engineering Program	Undergraduate Major
Interested in Engineering	16	23	
Interested in other STEM discipline	13	8	
Undecided	9	7	
Engineering major			24
STEM Major			11
Undecided			3

Conclusion

A pre engineering program was developed by University of Michigan-Flint and Lapeer County School District to motivate high school students towards engineering and STEM disciplines. Study was conducted to evaluate whether any significant correlation exists between students academic background and their interest towards engineering education or engineering profession as a whole. Another area of the study was to evaluate whether a pre-engineering program offered at a location similar to a high school setting has any significant impact on students' level of motivation towards engineering education. A set of 26 survey questions was used for this study and the data was analyzed using Pearson correlations analysis with SPSS statistical analysis software. A significant correlation was observed between admission knowledge and math and science background (p-value 0.049) was observed as shown in Table 4, inferring that students with a strong math and science background also possess more knowledge about admission requirements and processes in engineering programs offered by universities. Table 5 shows a strong correlation between motivation and pre-engineering program (Pearson correlation 0.61, $p = 0.001$). This strong correlation shows that the pre-engineering program was able to motivate students towards engineering education. Due to the small sample size, the study may not be able to detect other correlations. By extending this study with larger sample size and multiple classes, correlations can be observed.

The significant change in motivating students who were not initially interested in engineering education and undecided students are presented in Table 6. The main factors for this change may be due to a passionate professor and senior undergraduate engineering student roles as mentors during the program. It was observed that effective use of preconception of science and math in the courses offered along with strong mentorship and motivation resulted higher level of success in motivating students. Programs similar to Lapeer Pre-Engineering Program can be offered by other engineering programs to motivate more students towards engineering and

STEM discipline to address the critical need of technologically competent professional in the USA.

The limitations of this study include selection process used in recruitment of high school students with higher GPA, math and science background, interest towards engineering. Other limitations include sample size and one year duration of the study. A multi-year study may reveal more interesting observations. Some of the questions in the survey may be subjective to the dependant variables that may influence the analysis results. The study conducted for one year may not be conclusive and should be extended for multiple years to determine the effect of different variables on motivation to high school students. Another study may be conducted among high school students who are not motivated to study engineering with lower math and science skills.

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Appendix: Survey Questionnaire

No	Questions
1	My high school Math has relevance in daily life.
2	My Science courses have relevance to daily life.
3	There is a relation between Math's and Science.
4	Math and Science are interesting to me.
5	I had highest individual grade in Math and science
6	Math and Science provide good opportunity to improve overall grade.
7	Applied real life problem in Math and Science is interesting.
8	Course material kept me interested to pursue Math and Science.
9	Teachers and their unique style kept me interested to pursue Math and Science.
10	Good Math and Science background is important for study of engineering
11	I am very familiar with admission requirement in Engineering from high school.
12	I heard about admission requirement in print, video or online media.
13	I heard about admission requirement through family member
14	I have good knowledge about different fields of Engineering.
15	Engineers must work in field, factory or similar environment
16	Job outlook for engineers is better than other profession.
17	Engineering jobs are now globalized due to global economy
18	Engineering requires more global skill than any other profession.
19	The Pre-Engineering Program helped me decide about Engineering Education.
20	This program helped me decide about different engineering program
21	I would pursue Engineering Education even without this Program.
22	I am strongly motivated to be an Engineer.
23	My parents/family motivated me to become an engineer
24	I was passionate about engineering since childhood
25	My high school/middle school teacher motivated me
26	I need more information to decide about engineering education