A Proposed Model Curriculum for Pre-Engineering Degree Programs

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Abstract – **The Pre-Engineering associate degree program is a specifically designed curriculum for high school graduates and college freshmen to prepare them for transferring into a four-year university engineering discipline for a bachelor degree. Therefore, the Pre-Engineering program not only increases transfer opportunities for students, but also advances in engineering education to impart the basic skills in science, engineering and mathematics for tomorrow's engineers. In order to provide a better Pre-Engineering curriculum, this paper addressed the importance of Pre-Engineering programs, reviewed a variety of Pre-Engineering programs at high school and college level in the United States. Moreover, a major investigation was conducted on Pre-Engineering curriculums of various colleges and universities. By means of electronic website search, 70 Pre-Engineering curriculums were randomly found, and then printed out to collect data. Based on comparing and analysis, a Pre-Engineering Associate Degree model curriculum with a total of 68 credits for 20 courses has been developed in this study to enhance engineering education in facing today's challenge. As a result of the study, this proposed model curriculum may work and be deliverable for an individual institution with necessary adjustment to accommodate some core and selective courses.**

Index Terms – Degree programs, Model curriculum, Pre-Engineering, Tomorrow's engineers

INTRODUCTION

After the industrial revolution took place in England in the mid-eighteenth century, some engineering schools were established in France, Germany and Britain. The first American engineering school was the U.S. Military Academy at West Point, New York, established in 1802 [1]. Today in the US there are hundreds of engineering schools offering a variety in engineering disciplines and degree programs.

Advances in technology fuel the economic growth of United States and the industrialized nations. However, the shortage of employees with adequate science, mathematics and engineering skills at all levels, created a major impediment to continued national economic growth. Increasingly, new jobs in many fields require an array of mathematical, scientific, technical and engineering skills. Therefore, raising the level of skills of all Americans is vital, because many societal issues have become grounded in mathematical and scientific principles [2].

To train tomorrow's engineers is a significant task for engineering community in facing the challenge in the 21st century [3, 4]. The Pre-Engineering programs have been developed in secondary education for years. PLTW (Project Lead The Way) is a good example of Pre-Engineering program for public high schools. Currently, more than 300 schools in 26 states offer PLTW courses taught by trained teachers. The Pre-Engineering curriculums sponsored by PLTW provide training in design, digital electronics and computer integrated manufacturing [5].

Another example for the secondary education is DAPCEP (Detroit Area Pre-College Engineering Program), operating for 23 years in the state of Michigan. Hill [6] reported that, "About 80 percent of DAPCEP's high school graduates attended universities and colleges across the country. And more than 56 percent of those who attended college pursue degrees in mathematics and science - way above the national of 23.5 percent, according to the National Science Foundation."

To connect the secondary education and increase transferring opportunities for engineering education, many institutions of higher education offer Pre-Engineering degree programs for high school graduates. At the college level, the Pre-Engineering associate degree is a special degree program of study designed to prepare students for transferring into a four-year university in engineering disciplines beyond their two-year associate degrees. The course offerings include general education, introduction of engineering, and transfer requirements. Upon successful completion of the program, the students with an associate degree in Pre-Engineering will be academically prepared to start a third year of study at their chosen universities to pursue a Bachelor of Science in engineering major. A variety of engineering disciplines include aerospace, agricultural and biological, architectural and construction, chemical, civil, computer, electrical and electronic, environmental, industrial, material, mechanical, nuclear, general engineering, and other engineering fields. The Pre-Engineering programs are available in both two-year and four-year institutions.

In addition, Pre-Engineering programs have strengthened technical education. Why? Scarella et al. [7] explained in their report: "Pre-Engineering education has a direct correlation to technology education", and "technology education has provided both the career exploration and skill development for students to enter the engineering profession." The second reason is that "across this nation, there is a serious shortage of engineers and engineering technologists." "Another important factor for career and

technical educators is that engineering provides advanced career path for technology education students." For example, the South Carolina Advanced Technological Center of Excellence (SCATCE) has developed a Pre-Engineering technology program, known as "Technology Gateway" in the technical college system in South Carolina [8, 9].

On the other hand, as a part of transferring curriculums, the Pre-Engineering programs have increased transferring opportunities in higher education. Transferring is one of the key issues in higher education and has been for a long time. "The pressure on colleges and universities to adopt standard formulas for transferring credits has grown in recent years along with the number of transferring students. More than half of students graduating from four-year public institutions began their undergraduate studies at another institution, according to the Association of American Colleges and Universities. In addition to traditional 'vertical' transfer from two-year to four-year institutions, colleges and universities face increasing numbers of 'horizontal' transfers between institutions of the same kind, transfers from online or corporate education programs into traditional universities, and transfers from foreign to U.S. institutions." [10]

Specifically, Bradbum and Hurst's study [11] indicated that quite a good transfer rate for community college students who expect to earn a bachelor's degree or higher at a four-year college or university was thirty-six percent [9]. Duan [12] addressed that transferring from two-year institutions into four-year institutions is a good option for students. They could start their engineering training at a two-year program, then finish two more years of training at a university and become engineers in their chosen career. Obviously, attention was paid to the pre-engineering studies in engineering education.

The purpose of this study is to enhance engineering education in terms of Pre-Engineering curriculum development. The researcher investigated a variety of Pre-Engineering programs in post-secondary education in the US, figured out the classifications of the degrees and curriculums, then analyzed and compared the offerings, and finally proposed an associate degree model curriculum for Pre-Engineering programs.

METHODOLOGY

In addition to the literature search, review of the Pre-Engineering programs on the Internet is a primary approach for this study. It was found through the electronic search that hundreds of colleges and universities offer Pre-Engineering degree programs in the US. The GOOGLE search engine was used for this study [13]. For example, on a computer using "pre-engineering" as a key word for GOOGLE search, about 497,000 items could be immediately received in 0.12 seconds; but, using "pre-engineering degree programs" as key words, about 213,000 items could be received also in 0.12 seconds.

In the search process, only 70 institutions offering Pre-Engineering degree programs were randomly chosen; they were the both two-year and four-year institutions. All the 70 institutions' published Pre-Engineering curriculums were printed out and collected for references in this study. These institutions included two-year technical colleges, two-year community colleges, four-year public state universities and colleges, and four-year private universities and colleges. Based on an analysis and comparing all the data, the researcher indicated curriculum and degree classifications, and then developed a curriculum for associate's degree Pre-Engineering programs.

FINDINGS

Several significant findings have emerged in this study. First, the classification of Pre-Engineering programs in American higher education were figured out. Table 1 provides a summery of classification for Pre-Engineering degree programs. There are five types of Pre-Engineering degrees; three of them are associate degrees: AS (Associate of Science), AA (Associate of Arts) and APE (Associate of Pre-Engineering), requiring 60-70 credits to award a degree. These three associate degrees may be offered in both two-year and four-year institutions. However, most associate degrees are offered in two-year colleges.

TABLE 1
TYPES OF PRE-ENGINEERING DEGREE PROGRAMS IN THE U.S.

#	PROGRAM TYPE	DEGREE	CREDITS	YRS.
1	Associate	AS (Associate of Science)	60-70	2
2	Associate	AA (Associate of Arts)	60-70	2
3	Associate	APE (Associates of Pre-Engineering)	60-70	2
4	*3-2 Pre-Engineering	towards a Bachelor	>70 for first 3 yrs.	5
5	**2-2 Pre-Engineering	towards a Bachelor	>60 for first 2 yrs.	4

Notes:
*3 years in Liberal Arts School, 2 years in Engineering School, 2 degrees (BA, BS) could be awarded.
**2 years of Liberal Arts, Science and Math courses; 2 years of engineering courses, BS is awarded.

In the category of four-year institutions, there are two options for students to earn an engineering degree in 4 to 5 years. The first option is a 3-2 Pre-Engineering program towards a Bachelor's degree in an engineering discipline within 5 years (BA or BS). This option requires 3 years of study in a liberal arts school, and then 2 years of study in an engineering school. For the first 3 years of study, more than 70 credits could be achieved.

Another option is a 2-2 Pre-Engineering program. This option requires 2 years of liberal arts. science and

mathematics courses plus another two years of study of engineering courses, a Bachelor of Science in an engineering discipline could be awarded.

Among these 70 randomly selected Pre-Engineering programs, there are community colleges, technical colleges, public state universities, and private universities. Table 2 provides 8 good examples of institution-settings with institution's name, location, classification, title of degrees offered, required credits, and individual institution's website [14-21]. Three community colleges offer AS, AA and APE, respectively; a state technical community college offers an AS; they are listed in Table 2. In addition, two state universities, one independent university, and one four-year independent college are also listed in Table 2.

TABLE 2
SAMPLES OF PRE-ENGINEERING DEGREE PROGRAMS

#	COLLEGE	TYPE	DEGREE	CREDITS
1	Red Rock Community College Colorado	2 yr. Community College	AS	60
2	Lake Sumter Community College Florida	2 yr. Community College	AA	60-62
3	Chattanooga State Technical Community College Tennessee	2 yr. Tech. Community College	AS	60
4	Salt Lake Community College Utah	2 yr. Community College	APE	63-69
5	Missouri Southern State University Missouri	4 yr. Public University	AS	65-66
6	Weber State University Utah	4 yr. Public University	APE	> 60 >20 in residence
7	Illinois Wesleyan University Illinois	4 yr. Private University	3/2 for a BA or BS	Dual Degree Program
8	Hillsdale College Michigan	4 yr. Private College	2/2 for a BS 3/2 for BA and BS (2 degree program)	2 years of liberal arts 2 years of engineering 3 years at Hillsdale

It is obvious that all the Pre-Engineering programs require course studies in the following areas: mathematics, natural and physical science, English composition/oral communication, computer competence, humanities, behavioral/social science, and introduction to engineering. The required course credits vary from college to college, university to university. In general, 60-70 credits are required to achieve an associate Pre-Engineering degree during a period of two years.

A PROPOSED MODEL CURRICULUM

Based on an analysis and comparing the data from these 70 randomly selected Pre-Engineering programs, the researcher proposed a model curriculum containing 68 credits for 20 courses. Table 3 shows the breakdown of a total of 20 courses with credits.

TABLE 3
PRE ENGINEERING CURRICULUM FOR ASSOCIATE DEGREE

CATEGORY	CREDIT HOURS
MATHEMATICS	**15**
College Algebra	4
College Calculus I	4
College Calculus II	4
Differential Equations	3
NATURAL & PHYSICAL SCIENCE	**16**
College Chemistry	4
College Physics I	4
College Physics II	4
Introductory Biology	4
COMPOSITION/ORAL COMMUNICATION	**9**
Fundamentals of Public Speaking	3
English Composition	3
Technical Writing	3
COMPUTER COMPETENCE	**3**
Computer Fundamental for Technology	3
HUMANITIES	**6**
Introduction to Philosophy	3
Introduction to Ethics	3
BEHAVIORAL/SOCIAL SCIENCES	**6**
Principles of Macroeconomics	3
Introduction to Psychology	3
INTRODUCTION TO ENGINEERING	**13**
Technical Graphics	3
CAD Fundamentals	3
Introduction to Engineering and Technology	3
Engineering Mechanics	4
	Total: 68

For Mathematics, 4 courses are listed for a total of 15 credits: College Algebra, College Calculus I, College Calculus II, and Differential Equations.

For Natural and Physical Science, 4 courses are required to reach a total of 16 credits: College Chemistry, College Physics I, College Physics II, and Introductory Biology. Three courses are required for a total of 9 of credits in English Composition/Oral Communication:

Fundamentals of Public Speaking. English Composition and Technical Writing.

Only one course in Computer Competence is required: Computer Fundamental for Technology with 3 credits. Humanities require 2 courses for 6 credits: Introduction to Philosophy, and Introduction to Ethics.

Similarly, Behavioral/Social Science also requires a course for 6 credits: Principle of Macroeconomics, and Introduction to Psychology.

Finally, 4 courses are in the area of Introduction to Engineering: Technical Graphics, CAD Fundamentals, Introduction to Engineering and Technology, and Engineering Mechanics. A total of 13 credits are required.

In summary, a total 68 credits for 20 courses are required to accomplish an associate Pre-Engineering degree. All the details are shown in Table 3.

What would be a good plan within a two year period to accomplish an associate Pre-Engineering degree? A suggested study plan is shown in Table 4.

TABLE 4
SUGGESTED STUDY PLAN FOR PRE-ENGINEERING ASSOCIATE DEGREE

FRESHMAN YEAR		SOPHOMORE YEAR	
First Semester		**First Semester**	
College Algebra	4	College Calculus II	4
College Chemistry	4	College Physics I	4
English Composition	3	Introduction to Psychology	3
Engineering Graphics	3	Introduction to Philosophy	3
Computer Fundamentals for Technology	3	Introduction to Engineering and Technology	3
	17		**17**
Second Semester		**Second Semester**	
College Calculus I	4	Differential Equations	3
Introductory Biology	4	College Physics II	4
Fundamentals of Public Speaking	3	Principals of Macroeconomics	3
Technical Writing	3	Introduction to Ethics	3
CAD Fundamentals	3	Engineering Mechanics	4
	17		**17**
		Total: 68	

In order to achieve a two-year Pre-Engineering degree within a period of two years as full-time student, the students have to take 5 courses each semester not including summer tem; on average, 17 credits is assigned for each semester.

Clearly, as a result of this study, the proposed model curriculum provides some guidelines and directions as a template for a variety of Pre-Engineering degree offerings. Individual institutions may make necessary adjustments for a specific degree curriculum to meet student needs and community demands.

CONCLUSION

This paper addressed the importance of Pre-Engineering programs, reviewed a variety of Pre-Engineering programs at high schools and at college level in the United States. The following conclusions may be made:

1 The Pre-Engineering degree program in higher education is a specifically designed curriculum for high school graduates and college freshmen to prepare them for transfer into a four-year university engineering discipline for a bachelor's degree. How do we train tomorrow's engineers better? Pre-Engineering degree program is one of college effective offerings. The program not only increases transfer opportunities for students, but also advances in engineering education to impart the basic skills in science, engineering and mathematics for tomorrow's engineers. Pre-Engineering degree programs are offered by hundreds of colleges and universities in the US. This could benefit engineering education and meet societal needs.

2 In this study, only seventy published Pre-Engineering curriculums were randomly chosen and collected for research. As a result of this study, a proposed model curriculum was developed. The model curriculum may work and be deliverable for an individual institution with necessary adjustment to accommodate some course changes. Also, it may be considered as a template to boost training for tomorrow's engineers.

3 A systematic study in Pre-Engineering programs was made in this paper. As a preliminary program of engineering, Pre-Engineering program is significantly important towards engineering education. A better curriculum can attract more students in. Hopefully, more young high school graduates who are interested in science, engineering and mathematics, may start their college studies with a Pre-Engineering program; then transfer into an engineering discipline; and finally become tomorrow's engineers. Clearly, this move would advance engineering education. Most importantly, an increased number of tomorrow's engineers would definitely boost the economical growth in facing today's challenge.

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