Developing Competencies For Engineering Foundations Courses

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Abstract

Pre-college Minority Engineering Program has been designed to motivate and prepare minority middle and high school students for careers in science and engineering. The Program, called "Tex-PREP," is an aggressive, pro active outreach system that introduces a joint curriculum between science, math and technology to help students become successful in their future careers. Our goal within this program is to provide a summer workshop that attracts students to science and engineering. The workshop has been conducted at the University of Texas at Brownsville after developing vital competencies to help students become successful engineers in the future. This paper discusses the competencies that have been practiced through a developed course called "Foundation for Engineers." The course has been offered as part of the Tex-PREP program that is funded by NSF. The course targets students from 8^{th} to 11^{th} grades. The students in this stage always have lots of confusion about their choices of being an engineer, a lawyer, or any other professional in the future. Therefore, the strategies of teaching this course went through many stages. First, providing awareness of practical life of all kind of engineers and answering all puzzles in the students' mind about engineering. Second, setting competencies that can help students to master problem solving as well as basic skill enrichment. Third, developing the course activities and materials that practice all competencies. This strategy was the key to increased enrollment in engineering. A Final Exam at the end of the course proved that the new strategy is the most effective way to influence student commitment and positive attitude toward engineering.

1. Introduction

Tex-PREP is identified as the **Tex**as **P**re-F**r**eshmen **E**ngineering **P**rogram which offers an academically intense seven weeks program that stresses the development of abstract reasoning skills, and problem solving skills as well as awareness of career opportunities in science, mathematics, engineering and technology (SMET). This program is designed to provide educational enrichment for high-ability middle and secondary school students who are in the confusion stage about their future careers. At the conclusion of the program the participants will have a clear understanding of the opportunities available to them. The University of Texas at Brownsville and Texas Southmost College (UTB/TSC) offers courses that improve the retention, success rate and graduation rate of students in middle and high schools, as well as courses for college credit for advanced students. The main emphasis of the program is to recruit students from economically disadvantaged families who have strong desire to succeed in SMET, but are held back because of the need to work and help the family, especially during summer.

It primarily targets students who desire to pursue careers in mathematics, science, engineering technology, medical and computer science opportunities and may have limited opportunities and financial resources. The goals of the program include: (1) providing academic preparation for students in an area of their choice in either credit or enrichment core courses; (2) providing students with career development experiences; (3) increasing the retention rate of program participants as they progress in their pre-college and college courses; and (4) increasing the number of competently prepared minority and female students to pursue careers in SMET.

2. Objectives

Within this program a new course "**Foundations of Engineering**" was developed to attract students to the engineering program. The new course addressed three fundamental needs for the students: (1) awareness of future engineering careers and guidance through educational video tapes; (2) strong academic foundation in engineering and technology through developed laboratory-based courses; and (3) skills building targeting students' creativity and learning abilities to help them understand the value and power of post secondary education and SMET careers. These three fundamental needs were important to satisfy students' feelings of the interrelationship between engineering and physical sciences and the importance of continuing onto post secondary education.

The course introduces basic brainstorming processes that improve mathematical skills of the students and teach them how to use these skills in engineering analysis such as measurement techniques. The course covers important technological concepts and experimental issues (including a number of laboratory sessions) that elevate students' skills and provide them with hands-on experience in dealing with experimental measurements and instrumentation. The developed material for this course is specifically designed to challenge students' intellectual curiosity with open-ended problems using many ways for implementing numerical skills. It is easy enough to collect a massive amount of data through measurement, but the key is the validation of these data. Invalid data will lead to a faulty theory and then be verified by other erroneous experiments. The questions represent the basic and systematic queries that have to be answered satisfactorily before data analysis, e.g.: are the data worth analyzing? are the data valid? what accuracy can be expected? what is the repeatability (precision) of the data? etc.

Additionally, important basic mathematical concepts and methods needed by engineers and scientists as well as mathematicians who are interested in the applications of their field is provided. Topics in this course begin with a clear statement of pertinent definitions followed by principles and theories and continue with illustrative and other descriptive materials. Examples of the things provided in this course are:

1. Step-by-step procedure that answers dozens of mathematical questions as well as measurements and analyses from the lowest to the highest level of complexity.
2. Problems solving procedure that walks the students through course materials and provides check points that can help avoiding the wrong direction of thinking.
3. Thinking improvement through an actual measurement that can verify a physical law.
4. A scheme that pinpoints some of the important exercises that could serve as good tools for the open mind thinking.
5. A team work concept where students learn how to work in groups, as well as individuals.

3. Developing the required competencies

To provide students with skill building through workshops, it is important to define what we need to foresee in our students upon graduation from high school. This can be represented by developing a number of competencies that deal with basic practical engineering life [1]. Examples of competency fields (e.g., technical, physical laws, etc.) and competency objectives are listed below:

1.	Technical	Create and modify free hand sketches for electrical diagrams.
2.	Technical	Read and interpret engineering drawings wiring diagrams.
3.	Technical	Apply Ohm's and Kirchhoff's laws to the analysis of simple electric circuits.
4.	Technical	Construct a DC circuit from wiring diagrams and predict and measure the currents through and voltages across the circuit elements and the power used by the circuit.
5.	Technical	Demonstrate knowledge of electrical power sources and their characteristics.
6.	Technical	Demonstrate knowledge of electric safety devices such as switches, fuses, proper grounding techniques.
7.	Technical	Use digital meters to measure electrical and electronic parameters.
8.	Technical	Evaluate & analyze data obtained from measurements.
9.	Technical	Record and present data for evaluation and analysis.
10.	Technical	Use appropriate measurements procedures and techniques to determine unknown variables.
11.	Technical	Use Micrometer, Vernier caliper, Force gage, Thermocouple and many more devices to measure physical quantities.
12.	Technical	Assemble and disassemble electrical components (resistors, transistors, etc.)
13.	Physical science	Demonstrate a knowledge of the definitions of fundamental physical quantities such as length, time, mass, charge.
14.	Physical science	Predict and calculate the power consumed by simple electric circuit.
15.	Math	Collect, organize and describe data from real world situations.
16.	English	Classify information into related groups, analyze data to discover or present similarities and differences, and highlight specific details.
17.	English	Report chronological events accurately.
18.	Creativity	Build electric circuits for two-ways light.
19.	Ethical behavior	Create ethical code for students.

4. The Process of Teaching

Ideally, conveying the instructor's interest in the material to be learned to students is the best stimulus to learning rather than such external goals as grades or later competitive advantages. The first object of any act of learning [2] over and beyond the pleasure it may give, is that it should serve students in the future. Theodore R. Sizer [6] indicated that mastery of the fundamental ideas of a field involves not only the grasping of general principles, but also the development of an attitude toward

learning inquiry, toward guessing and hunches, and toward the possibility of solving problems on one's own. Unless detail is placed into a structured pattern, it is rapidly forgotten. Learning a subject seems to involve three almost simultaneous processes. First, there is acquisition of new information - often information that runs counter to or is a replacement for what the person has previously known. A second aspect of learning may be called transformation - the process of manipulating knowledge to make it fit new tasks. A third aspect of learning is evaluation - checking whether the way we have manipulated information is adequate to the task. Designing the course materials with all the competencies in mind as well as the three-teaching processes was a tedious task. Keeping in mind that our audiences involve 8 th to 11th grade students, material developed for our "Foundations of Engineering" course has included the following:

1. Teaching aids. Providing films, audio-visual aids and other devices (e.g., devices that may have short-run effect of catching attention). It is important to note that overuse of these devices and aids may produce a passive person waiting. Therefore our intention was to include this means not on a regular basis in our class.

2. Students' motivation. Motivating our students by reducing or removing components of learning environment that lead to failure or fear as confusion about their understanding, and plan activities to allow learners to meet esteem needs.

3. Teaching Flexibility and adaptability. Change style and content of the learning activity by making students' reaction and involvement essential parts of the learning process (e.g., problem solving, and team work to maximize students' involvement and participation).

4. Classroom assessment. To monitor the teaching process, we devised a mechanism to check how well the students are learning at all time. Through classroom assessment (questions, answers, discussions, group assignments, surveys, etc.), we can get to understand and promote learning, and reduce students' confusion by declaring all hard points with more examples. Classroom assessment is an approach designed to help us to find out what students are learning in the classroom and how well they are learning it.

5. Teaching Strategy and Outcome

Before teaching the course materials and workshops, it was important to set up a strategy that should be integrated in the classroom teaching.

1. Discussing the ethical code for students, and the way to implement it in the classroom.
2. memorizing students names, to overcome the walls between the faculty and students.
3. Learning the background of the students.
4. Giving more thoughts and time to friendly relationship between the faculty and students.
5. Open more office hours to integrate the effort in class with the required levels of learning.
6. Concentrate on learning as well as teaching through experiments and theories.
7. Workout the trivial mistakes that can cause catastrophes.
8. Direct step-by-step ways of thinking through problems.
9. Encourage ALL students to pursue the engineering field.

Teaching our Foundations of Engineering course with the above strategy, competencies and the three-prcesses teaching methodology has been a new experience. To evaluate this new experience, we conducted a survey at the end of the course. The results of the surveys revealed the following:

1. Increased students' enrollment in the College of Math, Science and Technology by 20%.
2. A strong scholastic foundations and devoted career awareness in science and engineering.
3. Provide students with skill building through workshops.
4. Improved professional communication and team working skills.
5. Enhanced students' creativity and ability for problems solving.
6. Improved laboratory testing skills and Hands-on experiences.
7. Prepared competitive students who, because of their research training and enhanced curriculum, are well prepared for SMET careers.

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