# A Five-Year Engineering Program at the University of Southern Indiana

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**Abstract** – In 2002 the University of Southern Indiana started a new engineering program leading to a Bachelor of Science in Engineering degree. In addition to a standard 4-year program, a 5-year program was developed to accommodate students who show interest and potential in engineering, but are not ready for calculus their first semester. Two first-year courses were developed for these students. The main goals of these courses are to provide these students with (1) the skills they will need to compete with their peers in the 4-year program, (2) immediate contact with the engineering faculty and students, and (3) an introduction to the rigor and commitment required to successfully complete an engineering program. The first course focuses on the principles of problem solving, while the second course focuses on the application of problem solving. The learning objectives of these courses, direct measures, indirect measures, and retention rates are presented.

*Keywords:* freshmen, engineering, pre-calculus.

## INTRODUCTION

The University of Southern Indiana (USI) started civil, electrical and mechanical engineering technology programs in 1975. These programs were accredited in 1980, and had helped to serve the needs of the region for over twenty years. However, due to changes in states professional licensing requirements, ABET requirements, and the changing needs of the regional employers, it became clear that a bachelor of science in engineering at a public university was needed. An internal study was done in May 2000, which recommended phasing out the three engineering technology degree programs (electrical, civil, and mechanical) and starting an engineering program [1]. In May 2002 the Indiana Commission for Higher Education approved degree-granting authority for the USI to offer the Bachelor of Science in Engineering (BSE) degree. The University began offering this program starting in 2002 and had its first graduating class last May. All students take 30 credits of engineering core. At the end of their sophomore year, students meet with an engineering faculty advisor to select 30 credits of engineering electives, emphasizing in electrical, civil, or mechanical engineering. Further details about the program can be found on its website [2].

Starting a new engineering program provides wonderful opportunities for curriculum development. One problem area addressed in the 2000 self-study was that a significant population of the engineering technology students entered the program without the necessary mathematics and science background [1]. Although these students were advised by engineering technology faculty, they were not enrolled in engineering courses their first year. This was identified as a reason that more than half of the incoming freshman left engineering after the first year. It was anticipated that this problem could worsen since the mathematics and science requirements are more rigorous in the

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upcoming engineering program. One engineering program in the United States indicated that a reason for low success among the pre-calculus engineering student population is that they "lack early exposure to engineering and, therefore, lack socialization within their declared engineering programs" [3].

To address the aforementioned problem, the University of Southern Indiana decided to implement a 5-year engineering program for these pre-calculus students in addition to the traditional 4-year program. This 5-year program was developed to accommodate students who show interest and potential in engineering, but are not ready for calculus their first semester. Two new courses were developed for these students to take their freshman year. The main goals of these courses are to provide these students with (1) the skills they will need to compete with their peers in the 4-year program, (2) immediate contact with the engineering faculty and students, and (3) an idea of the rigor and commitment of an engineering program.

It is important to note that students entering in the 5-year program must place at the college algebra level. Students who place lower are designated as "pre-engineering" students and must complete the necessary math courses before they can begin the 5-year program.

## OVERVIEW OF THE FIRST TWO YEARS

The recommended plan of study for students in the five-year engineering program is shown in Figure 1. Physics 101 is an algebra based physics course that focuses on concepts, and is strongly recommended for students who did not take physics in high school. In order to enter the five-year program, the students must achieve a math placement level of either MATH 118 (College Algebra & Trig) or MATH 111 (College Algebra). If the later, then they must also take an additional math course their second semester before they can begin their calculus courses. If the students test into Calculus I (MATH 230) then they can start the traditional four-year program. If they test lower than MATH 111 (such as MATH 100 – Intermediate Algebra), then those students are classified as "pre-engineering" students at USI until they can take MATH 118.

ENGR 101 – Engineering Orientation - is a seminar class that all first year engineering students are required to take, whether they are in the 4-year program, 5-year program, or pre-engineering program. In this way all first year students intent on pursuing engineering get some exposure to the study and careers in engineering. Reference 4 describes the details on the ENGR 101 course.

Two engineering courses – ENGR 103 and ENGR 104 - have been developed solely for the five-year students to take during their freshman year. These courses are described in the following section. The five-year program also has the added benefit of providing a reduced load. These students take 12-15 credits per semester, as compared to their peers in the four-year program who take 16-18 credits per semester. This should provide the five-year students more time to study per course than their peers in the four-year program.

The five-year students who are on track will take chemistry, statics, and thermodynamics during fall semester of their third year. The last three years for the five-year student plan is very similar (with the exception of a reduced credit load) to the last three years for the student in the four-year plan [2, 4].

| Fall Semester – First Year | Spring Semester – First Year |
|---|---|
| ENGR 101 – Engineering Orientation<br>ENGR 103 –Principles of Problem Solving<br>MATH 118 – College Algebra & Trig<br>PHYS 101 – Introduction to Physics<br>OR General Education course<br>ENG 101 – Rhetoric & Composition I<br>PED 186 – Physical education health class | ENGR 104 – Applied Problem Solving<br>MATH 230– Calculus I<br>CMST 101 – Introduction to Public Speaking<br>PED 1XX – Physical education activity class<br>General Education Course |
| **Fall Semester – Second Year** | **Spring Semester – Second Year** |
| ENGR 107 – Introduction to Engineering<br>MATH 330 – Calculus II<br>PHYS 205 – Intermediate Physics I<br>ENG 201 – Rhetoric & Composition I | ENGR 108 – Introduction to Design<br>PHYS 206 – Intermediate Physics II<br>MATH 335 – Calculus III<br>Ethics/Philosophy General Education Course |

**Figure 1: Plan of study for the first two years in the *five-year engineering program* at the University of Southern Indiana.**

## COURSE DESCRIPTIONS AND OBJECTIVES FOR THE PRE-CALCULUS ENGINEERING COURSES

Two engineering courses unique to the five-year program are described.

**ENGR 103 – Principles of Problem Solving**

This is a 3-credit course that has two hours of lecture and two hours of recitation/laboratory per week. This course introduces problem-solving methods using geometry, trigonometry, force vectors, curve-fitting, and unit conversion. Math 118 (College Algebra & Trig) is the co-requisite for this course. The textbook required is in reference 5.

The course objective for ENGR 103 is for student to learn a problem solving method consisting of logical, step-by-step, organized solutions in fundamental areas of math, physics and engineering. ENGR 103 has evolved since first taught in 2002, and each instructor who teaches it is allowed a certain amount of academic freedom. During spring semester 2005, twenty-two Course Learning Objectives (CLOs) or Course Outcomes were identified and evaluated. Seven of these course learning objectives are discussed in this paper. They are:

1. list organized steps of a problem solving method,
2. identify the known and unknown variables in complex problems,
3. select the correct trigonometry principles to solve a problem,
4. obtain straight line function (y = mx + b) coefficients,
5. construct hand drawn semilog graphs,

6. obtain exponential function (y = K $e^{mx}$) coefficients,

7. participate as a group member and/or leader in a study group.

**ENGR 104 – Applied Problem Solving**

This is a 3-credit course that has two hours of lecture and two hours of computer laboratory per week. This course introduces computer problem solving methods using flowcharts and computer programming. ENGR 103 and Math 118 (College Algebra & Trig) are the pre-requisite for this course. The textbook are required include the same text fro ENGR 103 [5] plus a new text for using Microsoft Excel [6].

The course objective for ENGR 103 is for student to learn how to organize a problem for logical, step-by-step, organized solutions using common engineering software, and to graph these solutions. ENGR 103 has evolved since first taught in 2002, and each instructor who teaches it is allowed a certain amount of academic freedom. During spring semester 2006, ten Course Learning Objectives (CLOs, i.e., Course Outcomes) were identified and evaluated. Five of these course learning objectives are discussed in this paper. They are:

1. prepare documented problem solutions within the software application Excel and TK Solver,

2. construct flowcharts and algorithms,

3. write and debug software using Visual Basic for Applications (VBA) within Excel,

4. determine the sequential, selective and repetitive steps of a computer program,

5. participate as a group member and/or leader in a study or laboratory group.

## EVALUATION FOR THE PRE-CALCULUS ENGINEERING COURSES

The CLOs for each course were measured directly by evaluating students' work, and indirectly from a student survey at the end of the semester. Results of those measures provide feedback as to which Course Learning Objectives are being met, which need more attention, and which ones should be added, removed, or changed. In addition, retention statistics are presented.

**Direct Measures**

Each CLO was evaluated for each student on a 1-5 scale according to a metric created by the instructor. Description of each metric for each CLO and the average score for one recent class are shown in Table I for ENGR 103 and Table II for ENGR 104. The goal was a class average of 3.0/5.0 or higher. From these measures, more attention is needed for CLOs 1, 2, 3, and 6 for ENGR 103; and CLOs 1 and 5 for ENGR 104.

**Table I: Direct Measures for ENGR 103 from Fall Semester 2005.**

| Course Learning Objective | 5 | 4 | 3 | 2 | 1 | Average Score of Class |
|---|---|---|---|---|---|---|
| | Exemplary | Very Good | Proficient | Adequate | Poor | |
| 1. List organized steps of a problem solving method. | Does this on all work, without being asked. | Checks answer to see if it makes physical sense. | Draws good sketches and diagrams and presents in organized, neat manner. | Uses Given, Find Relationship, Solution and verifies answer and units. | Does not show written work, or is sloppy and hard to follow. | **2.5** |
| 2. Identify the known and unknown variables in complex problems. | Converts unlike units to same before starting. | Lists all variable units in sketch. | Has all variables shown in the sketch. | Has all variables listed. | Leaves out key variables. | **2.0** |
| 3. Select the correct trigonometry principals to solve a problem. | Does this on all work, without being asked. | Checks answer to see if it makes physical sense. | Can solve force vector problems using the law of sine, etc. Converts radians to degrees. | Uses sine, cosine, tangent (and inverse) to find side or angle or a triangle. | Demonstrates no knowledge of trig functions. | **2.0** |
| 4. Obtain straight line function (y = mx + b). | Does this on all work, without being asked. | Graphs are clearly labeled. Tabular data are checked against formula calculation. | Draws good graphs (with straight edge) in neat manner. | Draws good linear graphs in neat manner, and calculates *m* and *b*. | Does not show written work, or is sloppy and hard to follow. | **3.0** |
| 5. Construct hand drawn semi log graphs. | Does this on all work, without being asked. | Graphs are clearly labeled. Tabular data are checked against formula calculation. | Draws good graphs (with straight edge or French curve) in neat manner. | Draws good semi-log graphs in neat manner. | Does not show written work, or is sloppy and hard to follow. | **3.0** |
| 6. Obtain exponential function ($y = k e^{mx}$) coefficients. | Does this on all work, without being asked. | Graphs are clearly labeled. Tabular data are checked against formula calculation. | Draws good graphs (with French curve) in neat manner. | Draws good log *y* vs. *x* graph in neat manner and calculates *m log k*, and *k*. | Does not show all written work, or is sloppy and hard to follow. | **2.8** |
| 7. Participate as a group member and/or leader in a study group. | Leads by collaboration and consensus. | Contributes in class. Takes charge in a group. | Contributes in class. Does delegated tasks. | Does delegated tasks minimally. | Poor attitude. Does not contribute and watches others do the work. | **3.2** |

**Table II: Direct Measures for ENGR 104 from Spring Semester 2005**

| Course Learning Objective | 5<br>Exemplary | 4<br>Very Good | 3<br>Proficient | 2<br>Adequate | 1<br>Poor | Average<br>Score of Class |
|---|---|---|---|---|---|---|
| 1. .Prepare documented problem solutions within the software application Excel. | Does this on all work, without being asked. | Uses Excel documentation format with clear input and output. | Good format for input and output. | Gets input and output. | Misapplies formulas/logic taught. | **1.7** |
| 2. Construct flowcharts for use in computer programming. | Flowchart correct and well labeled. | Does flowchart at the start and revises after the code is changed. | Flowchart is done first, but not revised. | Flowchart is drawn after code is complete. | Does not turn in flow chart. | **3.1** |
| 3. Write and debug software using Visual Basic for Applications (VBA) within Excel. | Debugged for items above and beyond requested. | Efficient code writing with organized indents and comments. | Uses flow chart for writing code. Code is debugged for foreseen input variations. | Code too long or in- efficient, or written by trial an error. Not de-bugged for all input. | Code not debugged. | **3.1** |
| 4. Determine the sequential, selective and repetitive steps of a computer program. | Does all coding correctly with no intervention. | Can write own code for arrays, For…next sequences, Do Loops, and If and Else statements. | Can write own code for Do Loops, If and Else statements. | Can write own code for If and Else statements. | Cannot write own code for If and Else statements. | **3.1** |
| 5. .Participate as a group member and/or leader in a study or laboratory group. | Leads by collaboration and consensus. | Contributes in class. Takes charge in a group. | Contributes in class. Does delegated tasks. | Does delegated tasks minimally. | Poor attitude. Does not contribute, and watches others do the work | **2.5** |

**Indirect Measures**

Each student who was present for class during the last week of the semester completed a survey of how strongly that they agree, on a 1-5 scale, that they have met each CLO. The average score for each CLO are all above an acceptable level of 3.0/5.0, as shown in Table III for ENGR 103 and Table IV for ENGR 104.

It is interesting to note that the rating for each CLO was higher using the indirect measures (student surveys) compared to the direct measures. There are several possible reasons for this, including:

- The metrics for each scale are different. The adequate rating on the direct measure scale is a 2.0/5.0, but using a different metric one could set that as 3.0/5.0.
- The direct measures were based on selected assignments evaluated throughout the semester, while the indirect measures were all done at the end of the semester. It could be that some students did poorly on a CLO assignment early in the semester but then mastered the material later.
- The students on average may feel that they have learned more than what they really can do.

**Table III: Indirect Measures for ENGR 103 (Principles of Problem Solving) from student survey at the end of Fall Semester 2005.**

| After completing this course, students were asked anonymously how strongly they feel they have the ability to: | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | Line Total Responses | Weighted Assessment |
|---|---|---|---|---|---|---|---|
| | **Number of Responses from the 12 Students Who Participated** | | | | | | |
| 1. List organized steps of a problem solving method | 4 | 8 | 0 | 0 | 0 | 12 | 4.3 |
| 2. Identify the known and unknown variables in complex problems | 3 | 9 | 0 | 0 | 0 | 12 | 4.3 |
| 3. Select the correct trigonometry principals to solve a problem. | 3 | 7 | 2 | 0 | 0 | 12 | 4.1 |
| 4. Obtain straight line function (y = mx + b) coefficients | 4 | 8 | 0 | 0 | 0 | 12 | 4.3 |
| 5. Construct hand drawn semi-log graphs | 3 | 7 | 2 | 0 | 0 | 12 | 4.1 |
| 6. Obtain exponential function ($y = k\ 10^{mx)}$ coefficients | 3 | 8 | 1 | 0 | 0 | 12 | 4.2 |
| 7. Participate as a group member and/or leader in a study group | 3 | 8 | 1 | 0 | 0 | 12 | 4.2 |

**Table IV: Indirect Measures for ENGR 104 from student surveys at the end of Spring Semester 2005.**

| After completing this course, students were asked anonymously how strongly they feel they have the ability to: | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | Line Total Responses | Weighted Assessment |
|---|---|---|---|---|---|---|---|
| | **Number of Responses from the 11 Students Who Participated** | | | | | | |
| 1.Prepare documented problem solutions within the software application Excel | 0 | 10 | 1 | 0 | 0 | 11 | 3.9 |
| 2.Construct flowcharts for use in computer programming | 2 | 8 | 1 | 0 | 0 | 11 | 4.1 |
| 3.Write and debug software using Visual Basic for Applications (VBA) within Excel | 1 | 9 | 1 | 0 | 0 | 11 | 4.0 |
| 4.Determine the sequential, selective and repetitive steps of a computer program | 0 | 8 | 3 | 0 | 0 | 11 | 3.7 |
| 5.Participate as a group member and/or leader in a study or laboratory group | 2 | 7 | 1 | 1 | 0 | 11 | 3.9 |

**Retention**

Although the program is has not been in existence long enough to establish a five-year graduation rate, two retention studies have been done and are presented here.

Students who started in the engineering program in 2002 and who also took ENGR 101 their first semester were tracked for three years. These students were grouped as 4-year, 5-year, or pre-engineering students. (Recall that pre-engineering students at USI are those who start below the college algebra level.) These results are presented in Table V, and show that the three-year retention rate for the 5-year students is 30%, compared with 43% for the 4-year students and 4% for the pre-engineering students.

A second investigation in retention of students in the 5-year program involved tracking students who started ENGR 103 in the fall of 2004. These results are shown in Table VI. Students were tracked if they were on schedule with the 5-year plan during the next two years. This is a more stringent retention statistic compared to tracking if they are still in the engineering program, as it does not count the students who have fallen behind schedule but are still enrolled in the engineering program. Experience from the faculty at USI, especially those who had developed a rigorous engineering technology program, suggests that students who pass ENGR 235 - Statics on schedule have a very high success rate for completing their engineering degree within the next three years. Five of the 28 students who started ENGR 103 were enrolled in ENGR 235 – Statics - in the fall semester of their third year. This is a small but significant number of students who may not have been in the engineering program without the 5-year plan. In is interesting to note that 3 of those 5 students are women, which is significantly higher percentage than all women enrolled in the engineering program at USI.

**Table V: Retention of engineering students who started Fall 2002 and were enrolled in ENGR 101.**

| Engineering Level | Number of Student in Engineering 101 (Fall 2002) | Number of those Student still in engineering (Fall 2005) | Retention Rate (After three years) |
|---|---|---|---|
| Pre-engineering (starting math level is less than college algebra) | 25 | 1 | 4% |
| 5-year plan (starting math at college algebra & trig) | 27 | 8 | 30% |
| 4-year plan (starting math at calculus I or higher) | 21 | 9 | 43% |

**Table VI: Tracking the students who started the 5-year engineering program at USI in Fall 2004 and were enrolled in ENGR 103.**

| | Enrolled In ENGR 103 Fall 2004 | Passed ENGR 103 Fall 2004 | Enrolled In ENGR 107 Fall 2005 | Passed 108 Spring 2006 | Enrolled In ENGR 235 – Statics - Fall 2006 |
|---|---|---|---|---|---|
| Number of Students | 28 | 21 | 9 | 9 | 5 |
| Percent | 100% | 75% | 32% | 32% | 18% |

## SUMMARY

A five-year plan of study leading to a Bachelor of Science in Engineering (BSE) degree has been developed at the University of Southern Indiana for students who are not ready for calculus their first semester, but are ready for college algebra. Two pre-calculus engineering courses have been taught at USI as part of this five-year engineering program since 2002: ENGR 103 - Principles of Problem Solving and ENGR 104 – Applied Problems Solving. These courses are designed to acclimate these students into the engineering program their first year and provide then with the skills they will need to succeed in the engineering curriculum if they choose to do so. Direct and indirect measures show that most of the students are meeting the Course Learning Objectives (CLOs) for these two courses. However, the class average ratings from the direct measures (evaluated by the instructor) were consistently lower than the indirect measures (evaluated by the students) for each CLO when evaluated in 2005. Retention statistics show that approximately 30% of students who started the 5-year plan are still in the engineering program after three years, and nearly 20% are on target with earning their BSE in five years.

One challenge with adding these two pre-calculus engineering courses is to prepare students for the engineering courses ENGR 107 (Introduction to Engineering) and ENGR 108 (Introduction to Design) – as required by all engineering students - that they will take their second year, while at the same time not overlapping too much of the material covered. As with many freshman engineering courses across the US, these courses are continually evolving.

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