AC 2008-2018: A FRESHMAN ENGINEERING CURRICULUM FOR A BACHELOR OF SCIENCE IN ENGINEERING PROGRAM

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A Freshman Engineering Curriculum for a Bachelor of Science in Engineering Program

Abstract

In 2002 a new Bachelor of Science degree program in Engineering was initiated at a regional university. Three freshman engineering courses were developed to allow incoming students immediate contact with both the engineering program and faculty. Students take Engineering Seminar during their first semester. The seminar is designed to expose students to engineering as a career, the various engineering specialties and details about the curriculum. The students also get to meet the faculty (and some upper class students) both during weekly presentations and during the annual picnic. The two other freshmen courses, Introduction to Engineering and Introduction to Design, are offered during the students' first and second semesters, respectively. Introduction to Engineering introduces students to a systematic, engineering problem solving method. Problems have been selected to preview many of the engineering courses that the students will take as sophomores, including statics and circuits. Additionally students learn computer applications EXCEL, MATLAB and VISUAL BASIC. Finally, Introduction to Design, taken during their second semester, has been developed to include two parallel paths. The first path focuses on learning how to solve open-ended design projects while working in teams. These projects vary from semester to semester, but normally consist of a mechanical focus, a civil focus, and an electrical engineering focus – which exposes students to the three areas of concentration that they must decide upon in their sophomore year. Also, a reverse engineering project is conducted early in the semester. The second parallel path in the Introduction to Design helps student develop skills in engineering communications that they apply in their design projects for this course as well as for future engineering design courses. Engineering communications include engineering graphics, technical writing, and oral presentations. Software that students learn in this course includes AutoCAD, Solid Edge, Microsoft PowerPoint, and Microsoft Project. Designing this new curriculum gave faculty and administrators very unique opportunities. This paper will focus on the details and characteristics of the first-year curriculum, including recent curricular changes and student learning outcomes.

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 USI to offer the Bachelor of Science in Engineering (BSE) degree. The University began offering this program in 2002 and had its first graduating class last May. In August 2007 the Accreditation Board for Engineering and Technology accredited this engineering program.

The University of Southern Indiana Bachelor of Science degree in Engineering is intended to offer the graduates a breadth of knowledge, while still mandating the depth of knowledge consistent with an engineering degree. When the curriculum was being developed, many universities were evaluated as models; Grand Valley State, University of Tennessee, Chattanooga and Arkansas State were most closely studied due to their successful development of breadth and depth in their respective multi-disciplinary curricula.

Emphases are offered in civil, electrical or mechanical engineering through the engineering electives courses shown in Figure 1. The students select their emphasis during their second year in the four-year program. As an example of the breadth of the program, students with an emphasis in electrical engineering must take a fluid mechanics class, while civil engineers take a class in circuits. Input from our Engineering Advisory Board, consisting of engineers from regional companies, indicates that the employers of our graduates value this breadth of knowledge in the employees that they hire with bachelor's degrees.

All students take 30 credits of engineering core courses. Students meet with their engineering faculty advisor to select courses for each semester, starting their freshman year. 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. Electives in industrial engineering will be offered starting in fall, 2008. Further details about the program can be found on its website[2].

It is well known that many times students are encouraged to enter engineering because they are "good at math and science" in high school; however, they may know very little about engineering as a career[3]. Furthermore, college freshman students not only have to decide if they want to be an engineer, but typically by their sophomore year must decide which engineering discipline they wish to pursue. It is not uncommon for students select their engineering discipline based on decisions such as nominal salary differences or gossip regarding the relative difficulty of each program. Luckily these poor decision practices have been identified and engineering programs now create opportunities for students to explore various engineering disciplines through introductory freshmen classes[4].

Two programs are offered in the engineering curriculum, depending upon the student's entry math level. The 'four-year engineering program', shown in Figure 1 is designed for students who enter the program ready to take differential calculus, MATH 230. Students that are at the pre-calculus level, enrolled in college-level algebra and trigonometry, MATH 118, are offered a 'five-year engineering program'. The first two years of these programs are available for comparison in Figure 2. Additional details about the five-year program are offered by R. Ruhala[5]. Students that enter the University of Southern Indiana to become engineers but are not

CURRICULUM for BACHELOR of SCIENCE IN ENGINEERING DEGREE ENGINEERING, MATH & PHYSICS COURSES Four-Year Program			
	First Year		
	Fall		Spring
ENGR 101	ENGINEERING ORIENTATION	ENGR 108	INTRODUCTION to DESIGN
ENGR 107	INTRODUCTION to ENGINEERING	MATH 330	CALCULUS II
MATH 230	CALCULUS I	PHYS 205	INTERMEDIATE PHYSICS I
	Second Year		
	Fall		Spring
ENGR 225	THERMODYNAMICS	ENGR 225	ELECTRICAL CIRCUITS
ENGR 225	STATICS	ENGR 275	DYNAMICS
MATH 335	CALCULUS III	MATH 433	DIFFERENTIAL EQUATIONS
PHYS 206	INTERMEDIATE PHYSICS II		
	Third Year		
	Fall		Spring
ENGR 335	STRENGTH of MATERIALS	ENGR 335	ENGINEERING ECONOMICS
	3 - ENGR ELECTIVES	ENGR 375	FLUID MECHANICS
			2 - ENGR ELECTIVES
	Fourth Year		
	Fall		Spring
ENGR 435	ENGINEERING STATISTICS	ENGR 491	SENIOR DESIGN
	2 - ENGR ELECTIVES		3 - ENGR ELECTIVES

Figure 1: Engineering & Science Curriculum - Four-Year Program

ready for college-level mathematics are referred to as "pre-engineering" students, and must pass intermediate algebra before they are eligible for the five-year program. Unfortunately it is highly unusual that pre-engineers are able to successfully complete the engineering curriculum[6]. Note that all math classes mentioned require a C to proceed.

While developing the curriculum, five freshmen engineering courses were specifically designed to bring students into immediate contact with both the engineering faculty and student peers[7]. Two courses were designed exclusively for students on the five-year plan. These are ENGR 103, Principles of Problem Solving, and ENGR 104, Applied Problem Solving[5].

Three courses were designed for all students; they are ENGR 101, Engineering Orientation, ENGR 107, Introduction to Engineering, and ENGR 108, Introduction to Design. These courses are taken by both incoming four-year students and five-year students that have passed ENGR 103 and 104. The freshman program is common to civil, electrical or mechanical emphases.

Overview of the First Year: Course Descriptions and Learning Objectives

CURRICULUM for BACHELOR of SCIENCE IN ENGINEERING DEGREE ENGINEERING, MATH & PHYSICS COURSES First Two Years: Five-Year Program			
	First Year		
	Fall		Spring
ENGR 101	ENGINEERING ORIENTATION	ENGR 104	APPLIED PROBLEM SOLVING
ENGR 103	PRINCIPLES of PROBLEM SOLVING	MATH 230	CALCULUS I
MATH 118	COLLEGE ALGEBRA & TRIGONOMETRY		
PHYS 101	INTRODUCTION to the PHYSICAL SCIENCES		
	Second Year		
	Fall		Spring
ENGR 107	INTRODUCTION to ENGINEERING	ENGR 108	INTRODUCTION to DESIGN
MATH 330	CALCULUS II	MATH 335	CALCULUS III
PHYS 205	INTERMEDIATE PHYSICS I	PHYS 206	INTERMEDIATE PHYSICS II

Figure 2: Engineering & Science Curriculum - Five-Year Program

The five freshman courses that were added to the curriculum are shown, italicized, in both Figure 1 and Figure 2. ENGR 103, 104, 107 and 108 are typically offered each semester and occasionally during the summer, depending upon need. The orientation class, ENGR 101, however, is only offered during the fall semester. Note that grades of C or above are required to proceed in the sequence. This paper will discuss the three classes all engineering students must pass: ENGR 101, 107 and 108. Students in the 4-year program take these classes their first year, while 5-year students take these classes during their second year.

Initially the program evaluated course outcomes for each class that were directly derived from the ABET program outcomes, a-k. Recently, however, it was determined that specific performance criteria would allow better direct measure assessment and allow more meaningful evaluation within those outcomes. As a result, all classes are responsible for measuring specific performance criteria that were evaluated both directly with student work and indirectly with student evaluation. This paper will illustrate the changes that were made to the three courses: ENGR 101, 107 and 108. However the effects of these changes, made just during this current semester, have not yet been measured.

Engineering 101, Engineering Seminar

Engineering Seminar is a weekly colloquium with the primary goal of exposing first-semester engineering students to the various fields of engineering. The class is intended to illustrate what engineers do, how they do it, and why. With this information, students can make an informed

Week	ENGR 101, 0 credits, Fall 2007	ENGR 102x, 1 credit, Fall 2008
1	Introductions	Introductions
2	Student Club Presentations	Breakout Session – Writing/Organization
3	Engr Picnic	Engr Picnic / Student Chapter Presentations
4	Careers in Engr / Planning	Careers in Engr/Planning/Professionalism
5	Co-op Program	Student Chapter Meetings
6	Engr Student Club Meetings	Civil Engineering Program
7	Mechanical Engr Program	Breakout Session – Note-taking/Sketching
8	Civil Engr Program	Electrical Engr Program
9	Electrical Engr Program	Breakout Session – Graphs/Tables
10	Engr Ethics	Industrial Supervision/Adv. Manufacturing
11	Adv. Manufacturing/Industrial Sup.	Ethics/Life-Long Learning
12	Engr Professionalism	Mechanical Engr Program
13	Thanksgiving – no classes	
14	Life-Long Learning/Assessment	Industrial Engr Program
15	Engr Student Club Meetings	Co-Op/Internships/Assessment
16	Final Exam Week – no class	Final Exam Week – Assignment due

Figure 3: Updated Engineering Seminar Course

decision when selecting their engineering major, or even deciding whether engineering is the field that they want to enter. Perhaps most importantly, the course is designed to help address the perennial student question, "what do engineers do?"

Since the engineering program began, ENGR 101 has been taught as a 0-credit, 1-hour per week colloquium comprised of discussions about the major engineering disciplines, engineering ethics, professionalism, and life-long learning. Guest lecturers routinely joined the class to discuss relevant topics. It was a pass/fail course, with the grade solely dependent upon the mandatory student attendance of twelve of the fourteen sessions. The course was very similar to the original seminar course in the now-obsolete Technology program, TECH 101.

Following both a departmental initiative and an inter-university evaluation, we realized that this course needed to be changed both in content and credit. Starting in fall 2008, the course will be designed with break-out sessions that will expose students to writing and thinking as engineers. Work will be assigned that will allow the performance criteria to be measured directly. A textbook, which describes success strategies for engineering students, is also being added to this course[8]. A comparison of the old and new course schedules is shown in Figure 3.

One of the early sessions of the seminar class has been, and will continue to be, reserved for the popular annual engineering picnic. This time is considered valuable because it allows an opportunity for freshmen to be introduced to upperclassmen, and facilitate casual conversation with faculty.

Three class sessions were initially reserved for student clubs. During the first "student club" day, members from each club gave presentations to illustrate their various activities such as the BAJA car, concrete canoe and robot for SAE, ASCE and IEEE clubs, respectively. The ENGR 101 class broke into professional clubs twice again, in the middle and end of the semester. In the future the club presentations will be made at the picnic, and additional meeting times will be outside of class. By taking back these sessions, more content will be able to be covered. "Breakout sessions" have been added to the new schedule to allow coverage of special topics designed for student success such as technical writing, planning, note-taking, sketching, etc.

The course will continue to spend time describing the major engineering specialties. Guest speakers, often graduates of the program, will be brought in to discuss careers in the various fields. Without fail, speakers will be asked to answer the question of what engineers "do".

The last time that ENGR 101 was taught it was with the following performance criteria, relating to ABET a-k. The new seminar course will have very similar performance criteria.

ABET Outcome F: have an understanding of both professional responsibilities and workplace ethics

Performance Criteria:

- Distinguish the application of workplace ethics in the engineering profession.
- Recognize the importance of professional registration in the engineering profession.

ABET Outcome H: have the broad education necessary to understand the impact of engineering solutions in a global and societal context

Performance Criteria:

- Recognize the impact of engineering solutions in society

ABET Outcome I: have a recognition of the need for and an ability to engage in life-long learning

Performance Criteria:

- Identify the need for lifelong learning.
- Recognize the role of student clubs in the role of an engineering student at USI.
- Identify the differences between Civil, Electrical, and Mechanical Engineering professions

ABET Outcome J: will gain an industry awareness and knowledge of contemporary problems through practical industrial applications and optional work experience

Performance Criteria:

- Gain an awareness and knowledge of contemporary problems in the industry.

Prior to the recent structural change to the performance criteria, the student learning outcomes had included the following thirteen items. Note that the department had included a twelfth program outcome, l, in addition to the ABET a-k. This twelfth outcome was continuous improvement of departmental learning tools, and is no longer being evaluated by the department.

1. Gain an understanding of professional responsibility and workplace ethics.
2. Gain and understanding of the impact of engineering solutions in society.
3. Recognize the need for life-long learning.
4. Gain an awareness and knowledge of contemporary problems in industry.
5. Recognize the role of student clubs in the role of an engineering student at the University of Southern Indiana.
6. Learn about the civil, electrical and mechanical engineering professions.
7. Recognize the importance of professional registration in the engineering profession.
8. Recognize the role of the Engineering Department in providing modern tools, equipment and technology to enhance the student's experience at the University of Southern Indiana.

Engineering 107, Introduction to Engineering

Introduction to Engineering meets for three hours, twice per week, and students must be co-registered in at least differential calculus. This course is the first in a sequence that introduces students to engineering and design. Combined, Introduction to Engineering and Design (ENGR 107 and 108) teach structured problem solving methods by previewing core engineering topics and involve student in team-oriented, hands-on, reverse and forward design projects, modern computer programs such as AutoCAD, Solid Edge, MATLAB, Excel and Visual Basic. Similar to the State University of New York at Binghamton, academic survival skills such as time-management, class preparation and test preparation skills are also emphasized[7].

One of the primary objectives of Introduction to Engineering is for the students to learn a rigorous problem solving method that they can use on virtually any problem. The problem solving method includes using engineering paper, evaluating the problem statement to extract both the information that is given and what they need to find, drawing a schematic as needed, using units throughout the calculations, and understanding the reasons behind the need for significant figures. Since the context is secondary, a preview of common engineering topics was chosen with the support of an accompanying textbook[9]. These topics include equilibrium, strength, energy and DC circuit problems. By selecting applications that the students will see in future classes, it is possible to teach them some of the fundamentals in these important topics. This also gives the students an idea of what to expect in their engineering core classes, which may help them decide if engineering is the right major for them, and which engineering discipline interests them the most.

Approximately half the semester is spent on problems solving skills in the 'engineering preview' portion of the class. During the remaining weeks the students begin to learn about using computer solutions to solve problems, including the fundamentals of logic and programming. To compare computer and hand solutions, many problems are used in the computer sessions that were initially used in the engineering preview section[10].

The computer portion begins with MS Excel. However, it is noted that the majority of students have used that program by the time that they arrive in Introduction to Engineering[9]. The next program taught is new to the majority of students, MS VBA: Visual Basic. VBA is taught instead of Visual Basic 6.0 since the majority of the regional companies do not have VB, but have MS VBA as a part of MS EXCEL. The last weeks of the course are used to introduce MATLAB.

The student learning outcomes are evaluated annually, and, as described above, have recently changed to include:

ABET Outcome A: the ability to apply knowledge of mathematics, science and engineering

Performance Criteria:

- describe elementary concepts of engineering stress and strain;
- apply the Laws of Kirchhoff's and Ohm to DC electrical circuits;

ABET Outcome D: an ability to function on multi-disciplinary teams

Performance Criteria:

- Perform well as a member of an engineering team.

ABET Outcome E: the ability to identify, formulate and solve engineering problems

Performance Criteria:

- apply a structured method for solving problems, including what to do if you are stuck or don't know how to begin
- Sketch a free-body diagram of a coplanar force system;
- Calculate unknown forces in a coplanar force system using a static equilibrium analysis;

ABET Outcome J: a knowledge of contemporary issues

Performance Criteria:

- describe Engineering as a career and the importance of Engineering ethics;

ABET Outcome K: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Performance Criteria:

- Perform engineering calculations using Microsoft Excel;
- Prepare quality engineering charts using Microsoft Excel;
- Prepare a user interface computer program using Microsoft Visual Basic;
- create a script file for MATLAB that will generate, manipulate, and plot engineering data;

Prior to the recent structural change to the performance criteria, the course outcomes had included the following thirteen items, related to ABET program outcomes a-k and the departmental outcome, l, described above.

1. understand Engineering as a career and the importance of Engineering ethics;
2. know how to use a structured method for solving problems, including what to do if you are stuck or don't know how to begin;
3. appreciate the importance of a structured problem solving method;
4. learn how to work as a member of an engineering team;
5. sketch a free-body diagram of a coplanar force system;
6. use a static equilibrium analysis to solve for an unknown force in a coplanar force system;
7. have an elementary knowledge of the concepts of engineering stress and strain;
8. in DC electrical circuits, understand the Laws of Kirchhoff's and Ohm;
9. understand the various forms of stored energy;

10. have a working knowledge of the 1st and 2nd Laws of Thermodynamics;
11. use Microsoft Excel to perform repetitive engineering calculations and create quality engineering charts;
12. use Microsoft Visual Basic to create a user interface computer program;
13. create a script file for MATLAB that will generate, manipulate, and plot engineering data).

Engineering 108, Introduction to Design

ENGR 108 is the second in the two-course engineering & design sequence, and meets for 3 hours, twice per week. This course has two identities running simultaneously. The first identity is that of a CAD course, while the second is that of a project-based design course.

The semester begins with fundamentals of engineering graphics; including teaching the students sketching techniques, tolerance, and how to read blueprints. Once those basic skills are taught, the class focuses on computer aided design as the students learn AutoCAD. Though instruction is offered, most students learn the software by completing tutorials. Their progress is monitored with in-class quizzes.

After engineering graphics is introduced, the students begin working on team-oriented, hands-on engineering projects, using both reverse and forward design, while concurrently continuing to learn AutoCAD and Solid Edge. Students use Microsoft Project to manage projects, AutoCAD 2006 for the computer aided design of projects, and Microsoft PowerPoint and Word for the dissemination of their results. Students also get practice documenting and defending their projects.

The students enjoy the reverse-engineering project assigned early in the semester. Small kitchen appliances such as can openers and mixers are typically used for the reverse design projects. The students are required to write a report and give a presentation describing how their appliance works, including sketches of key components and design improvement suggestions.

The forward-design projects are chosen carefully to ensure that civil, electrical and mechanical engineering disciplines are included. Some projects result in paper-only designs, such as a steel bridge. However, with the recent addition of a 3-D printer, they now also have the opportunity to create physical models of some designs. Furthermore, some projects involve kits where the students get a chance to build and test a design, such as an autonomous Lego robot. In 2003 the freshmen ENGR 108 class developed the hull-design that was used that year by the ASCE concrete canoe team.

The students present their reports orally with slides created by MS PowerPoint. To teach the students how to speak to a variety of audiences with different degrees of technical backgrounds, each student team is given a group to which they pretend they're speaking to. By the end of the semester, students learn to cater their presentations to their audience, such as superiors, colleagues or subordinates.

The student learning outcomes are evaluated annually, and most recently have included:

ABET Outcome C: the ability to design an engineering system, component, or process to meet desired needs

Performance Criteria:

- design a bridge made of balsa wood to given specifications
- design a robot that has a path following ability
- given a completed designed robot, be able to reverse engineer a robot that can accomplish the same task;

ABET Outcome E: the ability to identify, formulate and solve engineering problems

Performance Criteria:

- design using computer software such as AUTOCAD and Solid Edge

ABET Outcome G: the ability to communicate effectively

Performance Criteria:

- write technical reports detailing their design process
- present results in class

Prior to the recent structural change to the performance criteria, the course outcomes had included the following thirteen items, related to ABET program outcomes as shown below.

1. understand and appreciate engineering design and the design process;
2. read and understand engineering graphics;
3. describe and specify an engineering design using a computer aided graphics package such as AutoCAD;
4. use computer tools, such as MS Project, to plan, schedule, and track projects;
5. apply engineering principles and mathematics to a design;
6. work with a team of your peers to successfully complete an engineering design project;

7. use the library, the Internet, or other sources of knowledge to aid in an engineering design;
8. disseminate your engineering design in a technical report with graphics;
9. present your engineering design in a technical presentation to your peers;
10. decide if engineering is the right career choice for you; and which engineering area of interest you wish to study at the University of Southern Indiana: Civil, Electrical, or Mechanical.

Summary

The University of Southern Indiana has recently earned ABET accreditation for their new, multi-disciplinary Bachelor of Science in Engineering program. Three specialties have been offered to date, civil, electrical and mechanical engineering, and industrial engineering will begin in fall, 2008. The students share a common freshman program consisting of ENGR 101, Engineering Seminar, ENGR 107, Introduction to Engineering, and ENGR 108, Introduction to Design. Additional introductory courses, not described above, are available for students not yet in differential calculus.

This new engineering curriculum has offered unique opportunities to design a freshman program, and lessons learned along the way that have been both curricular and assessment in nature. It is hoped that our freshman program will allow students to make an informed choice about whether they want to become engineers, be able to decide which of the major branches of engineering interest them the most, and be better prepared for future engineering courses.

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