AC 2012-4372: ASSESSING A UNIQUE ENGINEERING UNDERGRADUATE DEGREE PROGRAM

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Assessing a Unique Engineering Undergraduate Degree Program

Abstract
The ABET accredited Bachelor of Science in Engineering (BSE) degree program at Michigan Technological University allows students to customize their degree curriculum. With guidance students are allowed to select up to 40% of their degree requirements to meet their career goals. Due to the flexible nature of this degree, it is challenging to determine if Program Outcomes (ABET a-k) are being met because each degree may be different. To supplement our current assessment of student learning outcomes we have implemented a core competency exam which BSE students must complete before enrolling in a senior design project course. This paper will discuss the BSE degree program and its assessment, with emphasis on the development, implementation, and usefulness of the BSE Core Competency Exam in assessing Program Outcomes.

Introduction

The Bachelor of Science in Engineering (BSE) degree program was established at Michigan Tech in the early 1970s as an engineering degree program without modifiers that would allow the flexibility for students to tailor their study for specific career or preparatory goals when that could not be easily done in the engineering discipline departments. The program was initially accredited by ABET in 1975 and most recently accredited in 2011.

The BSE degree is now housed in the Department of Engineering Fundamentals, which also provides the first-year engineering program for all engineering departments. This degree program serves students 1) who have very specific career goals that are not met with a traditional engineering degree offered by the university; 2) who want a general engineering degree to provide a technical foundation for other advanced degrees in areas such as law, medicine, and public policy; and 3) who want to work in a new, emerging, or interdisciplinary engineering field.

The courses used in BSE degree pathways reside largely in the engineering departments, and in the other academic units of the University, and are uniquely combined under supervision to provide the individually specialized engineering education desired or needed for a student's goals. Currently, there are three pathway options in the BSE program, a student-proposed pathway and two pre-approved paths that lead to defined specializations.

Student-proposed pathways vary considerably from one student to the next, depending on individuals' career or preparatory goals. The student-proposed pathway serves students who have very specific career goals that are not met with a traditional engineering degree offered by the university. Student-centered or learner-driven education is promoted by the flexibility of this pathway of the degree program. The student-proposed pathway also serves students who want a general engineering degree to provide a technical foundation for other advanced degrees in areas such as law, medicine, and public policy. This pathway also is used for traditional disciplines for which we have expertise but not a formal degree program.

The pre-approved BSE pathways are 1) Industrial and Service Systems Engineering and 2) Geospatial Engineering. The Industrial and Service Systems Engineering pathway emphasizes

analysis, design, optimization, and the planning and management of manufacturing and service sector operations, including human factors. The courses for this pathway are from Service Systems Engineering, Mechanical Engineering, Business, and the Social Sciences. The Geospatial Engineering pathway was defined to integrate a variety of geospatial concepts that include measurements, modeling, data collection and acquisition techniques, maps and mapping technologies, data and metadata formats, and visualization into a coherent program of study. The approved plan reflects state-of-the-art geospatial research and technologies, and it includes courses from Surveying Engineering (in the School of Technology), Computer Science, Physics, and Business.

The great flexibility of the BSE degree program requires proper oversight to ensure that accreditation requirements are met for each case. The oversight is provided by the BSE Governance Committee and the BSE Curriculum Committee. The BSE Governance Committee, which comprises the Engineering Fundamentals department chair, the BSE academic advisor, and the College of Engineering Associate Dean for Academic Affairs, is a first-level oversight body. The BSE Governance Committee is responsible for approving any new defined pathways, approving decisions on student-proposed degree plans, and approving curricular changes. The BSE Curriculum Committee, which reports to the BSE Governance Committee, comprises the department chair, the BSE academic advisor, and three faculty members in the department. The BSE Curriculum Committee assesses, reviews, and makes recommendations on the core courses, curricula, and polices of the BSE degree program.

Due to the flexible nature of this degree, it is challenging to determine if Program Outcomes (ABET a-k) are being met because each degree may be different. Additionally, almost all of the courses students take are outside of the department that administers the degree program, and it is difficult to separate assessment data for our few students from data for the students of the other departments. To supplement our current assessment of student learning outcomes we have implemented a core competency exam which BSE students must complete before enrolling in a senior design project course. The core competency exam covers the content of engineering courses common to all BSE degrees.

Curricular Structure

The philosophy behind the BSE degree was to design an engineering program based on courses that are fundamental to most engineering disciplines (math, basic sciences, and core engineering topics such as circuits and instrumentation, statics, strength of materials, thermodynamics, fluid mechanics, and materials) and to couple these with a sequence of additional courses in a technical emphasis area and with a set of directed electives that, combined, would provide a unique specialization for either an employment opportunity or for graduate studies – unique in the sense that the specialization could not be easily attained in a discipline degree program at Michigan Tech.

The curricular structure of the BSE degree program is provided in Table 1. The degree program consists of an Engineering Fundamentals core, a Technical Emphasis, and a set of Directed Electives, along with the required courses in math and sciences, general education, and free electives. In total, students must complete at least 127 credit hours.

Table 1: Curricular structure of BSE degree program.

Engineering Fundamentals Core	25-26
Technical Emphasis	22-23
Directed Electives	13 (minimum)
Mathematics and Basic Sciences	32
General Education	28
Free Electives	6

The Engineering Fundamentals Core courses are taken by all students in the BSE degree program. These courses include six credits of first-year engineering, four to six credits of Statics and Strength of Materials, four to six credits of Thermodynamics and Fluid Mechanics, three credits of Circuits and Instrumentation, and two-three credits of Materials or Programing. Students must also select one of four design implementation courses that expose them to the many facets of executing typical engineering projects and they must complete a minimum of one semester of a senior design project.

The Technical Emphasis courses must be engineering credits and are selected to provide the student with a coherent program of study. These courses are typically taken within one or more of the engineering departments on campus. In the pre-approved pathways these classes are already defined. For the student-proposed pathway, these courses are selected with guidance and approval from the BSE governance committee.

The Directed Electives, which can be any type of credit, allow further flexibility for students in the student-defined pathway to customize their degree. The courses must complement the technical emphasis courses and be consistent with their career goals. Again, these courses must be approved by the BSE governance committee.

The Mathematics and Basic Science courses consists of 15 core mathematics credits (Calculus I, Calculus II, Linear Algebra, Differential Equations, Statistics) and 8 core science credits (Chemistry I with lab, Physics I with lab) that all BSE students must take. The remaining 9 credits are selected by the student, with some restrictions, and may be used to satisfy prerequisite requirements for the desired Technical Emphasis or Directed Electives courses.

The General Education courses are defined by the University and must be completed by all students at Michigan Tech. There are four core courses (13 credits) that all students must take, 15 credits of electives that students select from a list of approved Humanities, Arts, and Social Sciences courses, and 3 units (not counted in the credit total) of approved co-curricular activities (primarily physical education courses).

The flexibility of the student-defined pathway of the BSE program is provided through choices in Technical Emphasis credits, Directed Electives credits, and Free Electives. Combined, this gives students a minimum of 41 credits that they can choose with guidance and approval to meet their career or preparatory needs. This flexibility is balanced by required courses in the Engineering Fundamentals Core and the Mathematics and Basic Sciences credits (58 minimum) to ensure that the fundamental essence of an engineering education is provided to each student,

so that he/she may successfully navigate the upper-level credits selected for Technical Emphasis and Directed Electives credits.

Assessment of the BSE degree program

The Program Educational Objectives (PEOs) of the BSE degree program are:

1. Join, or break ground in establishing, a workforce in an emerging or blended discipline of engineering; and
2. Secure employment in a profession or field for which an undergraduate engineering education is an asset; or
3. Gain admission to and successfully complete a graduate program in an engineering discipline or in another field for which an engineering undergraduate degree is recognized as appropriate preparation for graduate work.

These Program Educational Objectives are intentionally general due to the diverse nature of the degree program.

Alumni Surveys are used to assess achievement of the Program Educational Objectives. The alumni surveys are distributed annually by the College of Engineering to students who received their degrees six and three years prior. The survey instrument recently changed from an in-house instrument to one provided by Educational Benchmarking Inc (EBI). The current EBI survey is an on-line instrument that routes alumni to special questions tailored for a specific department/discipline based on the selected response to the primary academic major question. These special questions were tailored for each degree program's PEOs and for any other special program assessment.

In order to ensure that students will be able to attain the Program Education Objectives, the BSE curriculum has Program Outcomes that all students will, before they graduate, attain. The only Program Outcomes for the BSE are ABET's General Criterion 3 Student Outcomes a-k.[1] These Program Outcomes for 2012-2013 are provided in Table 2.

The following five assessment modes are currently in place to evaluate the BSE program's ability to achieve Program Outcomes:

1. *Senior exit interviews and surveys*. A senior exit interview is conducted by the BSE academic advisor with each graduating BSE student near the end of his/her last semester. Graduates are also given two surveys, one is a paper survey that they are asked to complete during their exit interview, and the other is an on-line survey given by the College of Engineering. The on-line senior exit survey is provided by Educational Benchmarking Inc (EBI) and contains items that address ABET Criterion 3 a-k outcomes.

2. *Alumni surveys*. Each year the College of Engineering administers a survey to alumni who graduated six years and three years prior. Details about the instrument used are discussed above.

Table 2: Program Outcomes for the BSE students ABET's General Criterion 3 a-k, retrieved from http://www.abet.org/engineering-criteria-2012-2013/.

	ABET Criterion 3 / BSE Program Outcomes
a	An ability to apply knowledge of mathematics, science, and engineering
b	An ability to design and conduct experiments, as well as to analyze and interpret data
c	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d	An ability to function on multidisciplinary teams
e	An ability to identify, formulate, and solve engineering problems
f	An understanding of professional and ethical responsibility
g	An ability to communicate effectively
h	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i	A recognition of the need for, and an ability to engage in life-long learning
j	A knowledge of contemporary issues
k	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

3. *Fundamentals of Engineering Exam (NCEES).*[2] Each BSE graduate is required to take the Fundamentals of Engineering (FE) Exam administered by the National Council of Examiners for Engineering and Surveying (NCEES). There is, however, no requirement that the students pass the exam, and this may impact BSE performance. The exam is taken during what is usually a very hectic time for students who are preparing to graduate and have very little time for any extra activities. On the FE exam, BSE students are asked to identify their major program as "General Engineering." The exam is given in two sessions: the first part of the examination (the AM, or morning session) is on general engineering content for all examinees, and students select the PM content area from among the usual engineering disciplines and a "General" option. Most BSE students opt to take the general PM (afternoon) session, though some students do take a discipline specific PM session. The Department of Engineering Fundamentals pays the exam fee for each BSE student. For the general AM session, NCEES provides a detailed breakdown of performance in the various content areas of the test (e.g., statics and dynamics, ethics and business).

4. *Senior Design Project/Enterprise Program Outcomes*. BSE students have three routes in which to satisfy the culminating major design experience requirement. They may choose

to enroll in the senior design experience courses for one of the traditional engineering degree programs, they may join an Enterprise program, or they may take the BSE option for senior design provided that there are three or more BSE students ready and willing to take the BSE option. The assessment of a senior design project focuses on the written and oral reports for the project and on the prototypes developed. To help ensure that each students' senior design project meets BSE Program Outcomes, all BSE students are required to complete a Senior Design Form. On this form the student outlines their project scope and deliverables. The faculty advisor for the project is required to identify which Program Outcomes are being met by this project. The student, faculty member, and Engineering Fundamentals department chair all must approve this project before the student is allowed to begin their project work.

5. *BSE Core competencies checks*. The assessment of competencies in the Engineering Fundamentals Core courses is limited to the common Core courses that all BSE students take: ENG1101, ENG1102, ENG2120, ENG3200, EE3010, and MY2100. This assessment involves the use of exam questions to determine if course learning objectives are being met. In order to relate the assessment to Program Outcomes, each course's learning objectives are mapped with the BSE Program Outcomes, which are ABET Criterion 3 a-k outcomes. This assessment provides information to course instructors and to the departments offering the courses as to whether any revision in course delivery or content is warranted. However, as the number of BSE students is very small compared to the many other engineering students in these courses, this general course assessment actually provides little direct information on whether the BSE degree Program Outcomes are being met by BSE students.

Due to the limited usefulness of the general course assessment of each common Core course, the BSE Curriculum Committee was charged with proposing and implementing another method of assessing student competencies in the common Engineering Fundamentals Core courses.

Additional Core Competency Checks

Other degree programs on campus assess student core competencies based on their assessment of required courses. Additionally, some degree programs further assess students in a design course specific to their majors. Due to the wide variety of courses selected to complete student-proposed and pre-approved pathways and the fairly low number of BSE students, it is difficult to use either of these methods to assess core competencies. Similar challenges were also noted by Krudysz and Wittig.[3]

To assess core competencies, the BSE Curriculum Committee recommended that a Core Competency Exam be given to students prior to enrolling in senior design project work. The first Core Competency exam was written and implemented during the fall of 2011. All students are required to complete the Engineering Fundamentals Core. The exam was designed to cover the topic areas from those courses. Table 3 provides a list of these topics.

Table 3: Topics included in BSE Core Competency Exam

1. Engineering Analysis and Problem Solving
2. Engineering Modeling and Design
3. Circuits and Instrumentation
4. Statics
5. Strength of Materials
6. Thermodynamics
7. Fluid Mechanics
8. Materials Science or Programming (based on degree pathway)

To create the Core Competency Exam, instructors of the core courses were asked to provide several questions that would cover key concepts from the course at a level typically found on a final exam for the class. From these, the BSE Curriculum Committee selected the questions to be included on the exam.

The students were given two hours to complete the Core Competency Exam and were not allowed to use any notes or books. Students were allowed to use a non-programming calculator.

To ensure consistency in grading the exams, each problem was assigned a grader. The grader developed a rubric for the problem and graded that problem for all students. There were four graders, including one from outside Engineering Fundamentals. Each topic area was weighted equally, with each area consisting of 20 points.

The first group of students took the BSE Core Competency Exam in the fall of 2011. There were five students in this group, three students in the pre-defined Industrial and Service Systems path, and two students following a self-defined path.

After all problems were graded, the BSE Curriculum Committee met to review student performance on the exam. The pre-determined threshold for satisfactory competency was 50% overall. Three of the students clearly exceeded this threshold, one was very close to this threshold, and one was below expectations.

Students were then notified as to whether their performance on the exam was adequate, somewhat deficient, or deficient. In deficient cases, it was recommended that students review these topics on their own. Currently the BSE Core Competency Exam is strictly used to assess student core competency and it is not required that students exceed the threshold.

Future Directions

We plan to continue to give the Core Competency Exam to monitor student competency within the BSE program. In the past this program had become a choice for engineering students who had difficulty finishing a discipline degree program. Changes have since been made to the degree program to prevent this unintended use.

Currently the Core Competency Exam assesses BSE student competency in the common Engineering Fundamentals Core courses. In the future, the content of the test will be mapped to the BSE Program Outcomes (ABET Criterion 3 a-k). To help guide decisions on core course degree requirements, we also plan to further examine the relationship of core course grades earned and FE exam results to Core Competency Test performance.

Additionally, we would like to ensure that students take this exam seriously. One method that we are considering is to add a Senior Design Fundamentals course. Assessment of the BSE Program Outcomes including the Core Competency Exam could be incorporated into this course, which could also allow students to address areas where their performance was deficient.

Bibliography

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[3]Krudysz, M. & Wittig, A.(2011). Challenges in Assessing Interdisciplinary Engineering Programs. Proceedings from *ASEE 2011 Annual Conference and Exposition.* Vancouver, B.C. Canada.