120th ASEE Annual Conference & Exposition
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June 23-26, 2013

Paper ID #7847

Assessment and Accreditation of a Nanosystems Engineering Degree at Louisiana Tech University

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Introduction

This document describes the evolution of an ABET accredited Bachelor of Science in Nanosystems Engineering (NSE) degree. Louisiana Tech University has a heritage of establishing new multidisciplinary engineering degrees. The Biomedical Engineering degree was created in 1970 and was among the first few in the Nation. In 1999, the science and engineering colleges were combined to become the College of Engineering and Science. This reorganization and the administrative changes led to a new vision for the college to be the best at integrating engineering and science in both education and research[1,2]. With this new vision, nanotechnology was determined to be a strategic area of focus. Funding was obtained to build a research center, the Institute for Micromanufacturing in 1999. Several faculty were hired with expertise in nanotechnology, and graduate courses were added to the roster until a full Micro/Nano concentration was established in the Ph.D. Engineering degree offered by the College. A professional track Masters program was also created to serve the large number of non-thesis students seeking training and skills in micro/nanotechnology. These micro/nanotechnology graduate programs formed the foundation to build an undergraduate degree program in this field.

Initial planning for the new nanosystems engineering undergraduate degree began in the summer of 2003, when the College's Engineering and Science Foundation (industrial advisory board) was approached about the possibility of establishing an undergraduate degree program focusing on nanotechnology. The advisory board unanimously endorsed the concept. As a result, in the Fall of 2003, an interdisciplinary team of faculty from within the College was formed that included representation from biomedical engineering, chemical engineering, electrical engineering, mechanical engineering, chemistry, and physics. This team of faculty was primarily responsible for developing the curriculum with selected input from other faculty and students. A formal proposal to establish the degree was submitted in March of 2004 to the University of Louisiana System Board of Supervisors and, subsequently to the Louisiana State Board of Regents. During the approval process, the degree program and curriculum were reviewed by an external consultant selected by the State Board of Regents. His review was very favorable of the program design, faculty, and facilities available for the program. The primary concerns raised were the need for ongoing resources, primarily in terms of equipment and supporting infrastructure to sustain the program. The program received conditional approval for the Fall of 2005 and was initiated with transfer students from the college and from other universities. Initial enrollment during the first year was solely transfer students from existing engineering majors, but the program rapidly grew to average enrollment of 75-80 students within the first three years

of the program. The program produced its first graduate in the Spring of 2007.

Curricular Structure

The bachelor of science of nanosystems engineering degree was designed to be an ABET accreditable engineering degree with the goal of providing our graduates the knowledge and skills to interface development in nanotechnology with various engineering disciplines in order to produce useful technology for society. The curriculum currently is a 128 semester credit hour program like all of the other engineering degree programs at Louisiana Tech University. Recognizing that nanotechnology is a highly interdisciplinary field, our approach was to build off existing engineering curricula within our college and incorporate additional courses to cover topics that are more specialized to the field. It was decided that the undergraduate degree would need a progression of "nanosystems engineering" courses, which would provide students with understanding and practice in relating engineering and science topics to problems at the nanoscale. A breakdown of the curriculum structure is provided in table 1. Louisiana Tech University operates on a quarter calendar system that provides course credits in semester credit hours. Courses are taught over a ten-week period using longer lecture periods (e.g., a typical lecture period is one hour and fifteen minutes).

Table 1: Curricular Structure of NSE degree program.

Category	Number of Semester Credit Hours
Engineering Fundamentals	22
Micro/nanosystems Engineering	19
Directed Electives	18
Mathematics and Basic Sciences	39
General Education	30

The engineering fundamentals courses consist of a project-driven freshman engineering curriculum taken by all engineering majors at Louisiana Tech University as well as fundamental core courses in statics and strengths of materials, electrical circuits, thermodynamics, engineering materials, electronics, and measurement and instrumentation. These engineering courses range from two to three semester credit hours and are sophomore to junior level courses within the curriculum.

The microsystems and nanosystems engineering courses are engineering courses that provide the students a greater depth of knowledge within this field. A first introductory level courses in nanosystems engineering is taken at the sophomore level that provides students a broad overview of the field and its many areas of application. The other courses in this category include a nanomanufacturing laboratory course, a micro/nano materials course, a micro/nano characterization course, a molecular modeling course, a nanosystems analysis and design course,

as well as a senior capstone design sequence that provides students a design experience in executing an engineering project.

The directed electives courses are mostly engineering courses but up to six semester credit hours of upper level science courses can be selected by students. Students are required to select an area of engineering concentration that encompasses twelve of the eighteen semester credit hours. NSE majors are allowed to choose a concentration area from biomedical engineering, chemical engineering, electrical engineering, mechanical engineering, or microsystems engineering. Besides providing greater flexibility in the degree program, the concentration tracks allow students to develop a greater depth of knowledge in an area of potential application of nanotechnology. The additional six semester credit hours of directed electives may be chosen from upper-level science or engineering courses. This choice is dependent on the engineering concentration area chosen by the student as well as their individual background preparation.

The mathematics and basic science courses consist of 15 mathematics credits including calculus, differential equations, and statistics and 17 semester credit hours from basic sciences including biology, chemistry, and physics. Students take freshman general chemistry and the associated laboratory courses as well as organic chemistry and an organic chemistry laboratory course. Students also take the general calculus-based physics courses as well as a solid state physics course.

The general education courses are defined by Louisiana Tech University and must be completed by all students at the University. These include nine credit hours of required English composition and literature courses, 15 credit hours of approved humanities, arts, and social science courses. An additional six credit hours including an additional English course and a speech course are required. NSE students are required to take a technical writing course and technical presentations course to satisfy this requirement.

Assessment and Continuous Improvement of the Program

Since the initial establishment of the degree program, the program education objectives have undergone multiple revisions to better reflect the needs of the program's constituents as well as meet refinements in ABET's definition of program educational objectives. The current Program Education Objectives (PEOs) of the NSE degree program are:

Graduates of the NSE Program are expected to within a few year of graduation to have:

PEO1. Established themselves as practicing professionals and/or engaged in advanced study in an engineering or related field.
PEO2. Received positive recognition and reward for the productive application of their skills and knowledge.
PEO3. Engaged in life-long learning in order to remain technically current in their chosen field.

These educational objectives are much more general than when the program first began. As mentioned above, the present objectives were selected to better capture the diverse areas that our graduates are pursuing with ABET's greater emphasis on what a program's graduates are attaining within a few years of graduation.

Alumni surveys are primarily used to assess achievement of the Program Educational Objectives. Since the program only produced its first graduate in 2007, the first alumni survey was not conducted until the summer of 2009. Alumni surveys were conducted in the summers of 2010 and 2012 as well. All of the alumni surveys to date have been distributed to all alumni of the program since the sample size is so small. While the population pool for the survey is fairly limited, the response rates have been very good (71.4%, 85.7%, and 55.6% response rates for 2009, 2010, and 2012 alumni surveys, respectively). The surveys were developed in-house and have been slightly modified over time to reflect the changes in the PEOs as well as to gather additional information that could be used to better measure attainment of the PEOs. Table 2 provides assessment data for the NSE PEOs from the alumni surveys.

Table 2. Alumni Survey assessments of NSE PEOs.

Educational Objective Assessment	PEO1	PEO2	PEO3
Alumni opinion on a 7 point Likert scale (7 = strongly agree objective achieved)	6.7 (6.1 – 2010) (6.3 – 2009)	5.5 (no historical data for this PEO)	5.8 (6.6 – 2010) (6.3 – 2009)
% of alumni completed/pursuing advanced degree	67% (67% – 2010) (67% – 2009)		
Average number of professional development hours reported			38.4 hrs (19.8 hrs – 2010) (30.5 hrs – 2009)
% of alumni employed beyond entry-level position*		75% (no historical data for this PEO)	

*Alumni responses for graduates at least 2 or more years past graduation

The current NSE Student Outcomes are the ABET General Criterion 3 Student Outcomes a-k[3]. Initially, the program established NSE Program Outcomes (ABET terminology at that time) that were more specialized to the degree program and were mapped to the ABET General Criterion 3 a-k outcomes. As part of a college-wide review, all engineering degree programs uniformly adopted the ABET General Criterion 3 a-k Student Outcomes this past year. Table 3 provides the current Student Outcomes for the NSE program.

Table 3. Student Outcomes for the NSE Program (ABET General Criterion 3 a-k[3]).

NSE Student Outcome
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.

The following assessments are currently being used by the program to evaluate student achievement of these outcomes:

1. *Mock Fundamentals of Engineering Exam.* Junior-level NSE students take an in-house version of the fundamentals of engineering (FE) exam. This two hour exam is administered college-wide to all of the engineering majors and covers topics from the a.m. portion of the FE exam. Questions covering mathematics, chemistry, physics, statics, strength of materials, thermodynamics, electrical circuits, computers, fluid mechanics, materials, economics, and ethics are included. This assessment is used for evaluating Student Outcomes a, e, and f. Originally, a commercial FE exam product (PPI Exam Café) was used but in 2010 the college created its own online version of the exam modeled after a published sample FE exam by NCEES. In prior years, performance by NSE students on the exam has been measured against a global average reported by PPI

Exam Café with NSE students performing above the reported global averages from PPI Exam Café. Since 2010, the college-wide performance average has been used as a basis for evaluation.

2. *Senior Exit Surveys*. A senior exit interview and survey is conducted by the NSE program chair with each graduating NSE student during his/her last quarter. The survey provides a measure of student impression of achievement for all a-k outcomes. Figure 1 provides a historical set of data that the NSE program has collected on the student outcomes.

3. *Capstone Project Evaluations*. At the completion of the senior design project sequence, all student teams participate in the senior design conference hosted by the college. This conference is held in conjunction with an industrial advisory board meeting for the NSE program. Advisory board members attend the senior design conference and provide an assessment of the senior projects.

4. *NSE faculty assessment*. In their junior year, all NSE students take a nanomanufacturing course (NSE 303) that is a project-based laboratory course where they are tasked to analyze and investigate the scale-up for commercial fabrication of a nanoparticle. At the end of the course, students provide a project presentation to the NSE faculty who provide an assessment that is used to evaluate most of the a-k student outcomes (all except Student Outcomes f and j). Table 3 provides an example set of assessment data collected from the spring of 2012. The individual statements in the assessment are mapped to the Student Outcomes a-k as indicated in the table.

5. *Course Specific assessment*. In the sophomore year, all NSE take an introductory nanosystems engineering course (NSE 201) that requires students to participate in an ethical debate from a variety of possible societal impacts from advances in nanotechnology. Student scores from these debates are used as an assessment for student outcomes f, g, h, and j.

6. *Alumni Survey*. The alumni surveys also include questions to collect graduate opinions on the achievement of all the student outcomes as well.

The chair of the NSE program serves as the ABET coordinator for the program and has the primary responsibility of managing the collection and regular evaluation of the data. The assessment data is evaluated by the NSE faculty on a quarterly basis and is also discussed with the NSE Industrial Advisory Board on a semiannual basis. The advisory board was established about a year before the program's accreditation visit and consists mostly (but not entirely) of alumni with interests in this field. As the program has matured, the board has started to include some alumni from the program as well. The advisory board meets with the NSE students to gather their feedback and concerns. The advisory board also includes two undergraduate NSE non-voting members to help provide additional student feedback in the continuous improvement process as well.

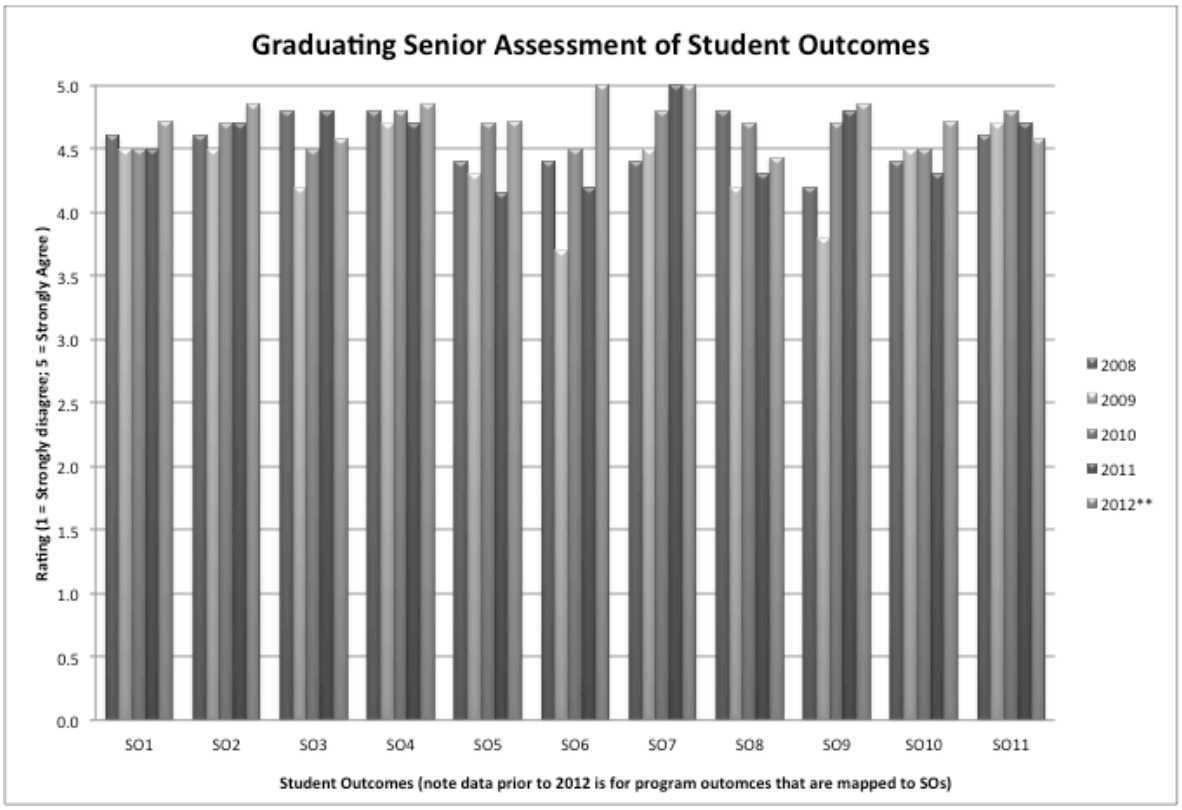

Figure 1. Senior Exit Survey Assessment of Student Outcomes.

Table 3. NSE Faculty Assessment of Nanomanufacturing Project (NSE 303 course).

NSE 303 Final Project Evaluation Spring 2012	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Average Score	Percentage Score
Please indicate how strongly you agree/disagree with the following statements.	**1**	**2**	**3**	**4**	**5**		
1. The student(s) demonstrated an ability to communicate effectively using appropriate technology and efficiently used information resources. [Student Outcome(g)]	0	2	5	9	10	4.0	81%
2. The team demonstrated an ability to work collaboratively on their project. [Student Outcome (d)]	0	1	6	10	9	4.0	81%
3. The student(s) demonstrated the use of engineering knowledge and scientific principles and the ability to apply these to the design and analysis of their project. [Student Outcome (e)]	1	0	5	13	6	3.9	78%
4. The student(s) displayed appropriate use of outside resources – references, journal articles, patents, etc – to solve the problem. [Student Outcome (i)]	0	1	4	10	11	4.2	84%
5. The student(s) exhibited an ability to apply knowledge of mathematics, science, and/or engineering to the analysis of their project. [Student Ouutcome (a)]	0	1	9	13	3	3.7	74%
6. The student(s) demonstrated the ability to perform characterization of their products using appropriate modern testing and analytical techniques. [Student Outcome (k)]	1	2	4	12	7	3.8	77%
7. The student(s) were able to conduct experiments that provided meaningful data and were able to interpret their results. [Student Outcome (b)]	1	4	6	8	7	3.6	72%
8. It is evident that the student(s) accounted for safety considerations and environment concerns of their selected fabrication process. [Student Outcome (h)	0	2	2	16	6	4.0	80%
9. It is evident that the student(s) accounted for economics of their selected fabrication process. [Student Outcome (h)]	1	2	3	12	8	3.9	78%
10. The student(s) demonstrated the ability to design a process to meet a desired need subject to realistic constratins such as economic, environmental, health an d safety, and manufacturability. [Student Outcome (c)]	0	3	6	11	6	3.8	75%

* Percentage score reflect a conversion of the 1-5 response into a percentage (e.g, 4/5=80%)

Thus far, the assessment tools being used have been sustainable for the program to continue to use and have provided useful feedback for changes that have been made in the curricula as well as in addressing student concerns and difficulties in the program. To date, probably the most useful assessment tools have primarily been the senior exit surveys, the NSE 303 project evaluations by the faculty, and the capstone project evaluations by the NSE Industrial Advisory Board and NSE faculty. These specific assessments have led to small changes such as slight modification of course content to more significant changes in the curriculum to add entire courses or restructure existing ones.

Impact of Program

To date, the program has produced 41 graduates. Of these graduates, 20 (48.8%) are currently pursuing a graduate degree, 15 (36.6%) are currently employed in industry, and the remaining 5 (12.2%) status is unknown. Those employed in industry are working in a variety of sectors ranging from semiconductors, oil/gas, chemical, automotive, and defense. Half of those employed in industry have obtained a graduate degree as well. Of those currently pursuing a graduate degree, 13 are seeking a PhD degree. The program has been very effective in expanding the recruitment of out of state students to Louisiana Tech University. One third of the current enrollment of nanosystems engineering majors is out of state students as compared to the university average of only 14% of students being out-of-state residents. Additionally, the uniqueness of the degree has helped to elevate the university to be recognized for its micro/nanotechnology education and research. In the past five years, our college has had three NSF Career award winners (all but one for the entire college), which have used this unique degree program as part of their required educational component of their grants. In addition, the NSE faculty have also received two NSF Nanotechnology Undergraduate Education awards that have assisted with course and laboratory developments for the program.

References

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