AC 2011-421: INTEGRATION OF KNOWLEDGE IN ENGINEERING/SCIENCE VIA NANOTECHNOLOGY PROGRAMS

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Integration of Knowledge in Engineering/Science via Nanotechnology Programs

Abstract

A new Bachelor of Science Nanotechnology track within the School of Engineering and Technology at Indiana University Purdue University Indianapolis (IUPUI) is being developed under NSF NUE program*. This paper covers the educational elements from the first phase of the project. A sequence of two courses was offered in the fall and spring semesters within both the School of Engineering & Technology and the School of Sciences. Students from electrical engineering, computer engineering, mechanical engineering, biomedical engineering, physics, and chemistry disciplines, were enrolled in these courses. A total of five faculty members from both engineering and sciences collaborated in developing and teaching these two courses. Integrated Nanosystems Development Institute (INDI), a nanotechnology umbrella institute at IUPUI, played a leading role in bringing together the two schools, five departments, and a number of faculties to collaborate and develop these courses, including examples of multidisciplinary projects and term papers prepared by the students will be presented. The syllabus and the contents of the courses were developed by combining the research and teaching experience of the faculty members at the IUPUI campus. The paper also details the teaching and learning methodologies implemented in the class and outside of the class which integrates the traditional means of learning from textbooks with new tools and technologies including scientific journal articles, web-based communication and file sharing, multimedia, and simulation and modeling software (e.g. Coventor). The paper also presents the organization of the courses, including usage of laboratories for hands-on experience and software for learning through simulation and modeling. Students' feedback, reflecting the impact of the two courses on their career prospective will also be reported.

1. Introduction

Nanotechnology is a field with emerging technologies that include various engineering and science disciplines. An integrated nanotechnology system may require background from physics, biology, chemistry, computer instrumentations and software, and many others. Engineers and scientists from various majors such as electrical, mechanical, biomedical, and material engineering may join together to pursue a nanotechnology multidisciplinary project. The integration of knowledge throughout course projects or term papers develop better understanding of the importance of science components used in future nanotechnology applications.

Course materials, including lecture and laboratory components assist students with establishing good research foundation that may prepare them to the nanotechnology workforce and to the graduate program in both engineering and sciences. At Indiana University-Purdue University Indianapolis (IUPUI), a formal nanotechnology track within the electrical, computer, and mechanical engineering programs is formed for undergraduate programs. Due to the multidisciplinary nature of nanotechnology, undergraduate students are introduced early in the career to plan for a coherent nanotechnology program. The paper summarizes briefly the new nanotechnology program and the initial outcomes.

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2. Nanotechnology Track

IUPUI started a new B.S. program that will establish a new, dynamic academic and research-based nanotechnology track in engineering. The Integrating Nanotechnology in Engineering Curriculum program (the IUPUI "INEC") defined by this new nanotechnology track is integrated into the established degrees of the Bachelor of Science in Electrical and Computer Engineering (ECE), and the Bachelor of Science in Mechanical Engineering (ME) within the IUPUI Purdue School of Engineering and Technology. INEC also is affiliated with the Integrated Nanosystems Development Institute (INDI)[1], which has been recently established at IUPUI to house faculty research in nanotechnology. INEC brings together student/faculty collaborative research and academic teams to provide undergraduate students with curricula that integrate research and education in nanotechnology.

The goal of this new program is to prepare students to enter the global workforce and become leaders of research and development in industry, business, and academia in the emerging era of nanotechnology. The nanotechnology track that is under implementation is a powerful pedagogical approach to comprehensively integrate nanotechnology into the curricula within the engineering degree programs. The nanotechnology track, throughout the four year ECE ad ME programs, focuses on the various elements of nanotechnology. During the freshman year, students from ECE and ME departments will be introduced to various modules of nanotechnology in the first semester introductory courses in engineering, *Introduction to Engineering (ENGR 196), Introduction to Engineering Profession (ENGR 195), Fundamentals of Speech Communications (COMM R110), Computer Programming (ENGR 197), Elementary Composition I (ENG W131),* and *Computer Tools for Engineers (ENGR 297)* linked through Theme Learning Communities (TLCs). A TLC is a set of three courses, including the introductory engineering course, a speech course, and an engineering seminar course (Introduction to the Engineering Profession), where students are enrolled by the IUPUI Registrar concurrently as cohorts. IUPUI's TLC program won the 2008 Outstanding Student Retention Program Award given by the Educational Policy Institute.

2.1 Curriculum Enhancements for the Nanotechnology Track: In addition to the nanotechnology modules integrated into the freshman engineering, new interdisciplinary sophomore-, junior-, and senior-level nanotechnology-based courses will be introduced into the curriculum for students in the INEC nanotechnology track. A new sophomore-level (NT201, Introduction to Nanotechnology and Applications), and a junior-level nanotechnology-based lab course (NT 301, Micro/Nanoscale Measurements and Characterization Systems), will give students a basic understanding of the fundamentals, equipment, and processes used in the fabrication and characterization of nanoscale devices, materials, and systems. The senior-level Nanosystems Principles (NT 401) and Integrated Nanosystems Processes and Devices (NT 402) course will focus on the system level and give students in-depth knowledge of nanotechnology.

Two courses Nanosystems Principles and Integrated Nanosystems Processes and Devices were developed and offered in sequence in fall 2010 and spring 2009. These two courses were designed to build on basic sciences from physics and chemistry, and integrate knowledge from ME, ECE, and BME. Students from electrical engineering, computer engineering, mechanical engineering, biomedical engineering, physics, and chemistry disciplines, with needed math/science courses background, were enrolled in these courses. Students in Engineering Technology programs generally do not take those courses. However, the students from Engineering Technology programs who may be interested in nanotechnology track can fulfill the required background by taking the prerequisite courses.

The participation of the students in Nanosystems Principle Course Fall 2010 is shown in Figure 1. A total of five faculty members from both engineering and sciences collaborated in developing and teaching these two courses. Integrated Nanosystems Development Institute (INDI), a nanotechnology umbrella institute at IUPUI, played a leading role in bringing together the two schools, five departments, and a number of faculties to collaborate and develop these courses. Table 1 shows students' survey that was taken at the end of the semester for 30 students.

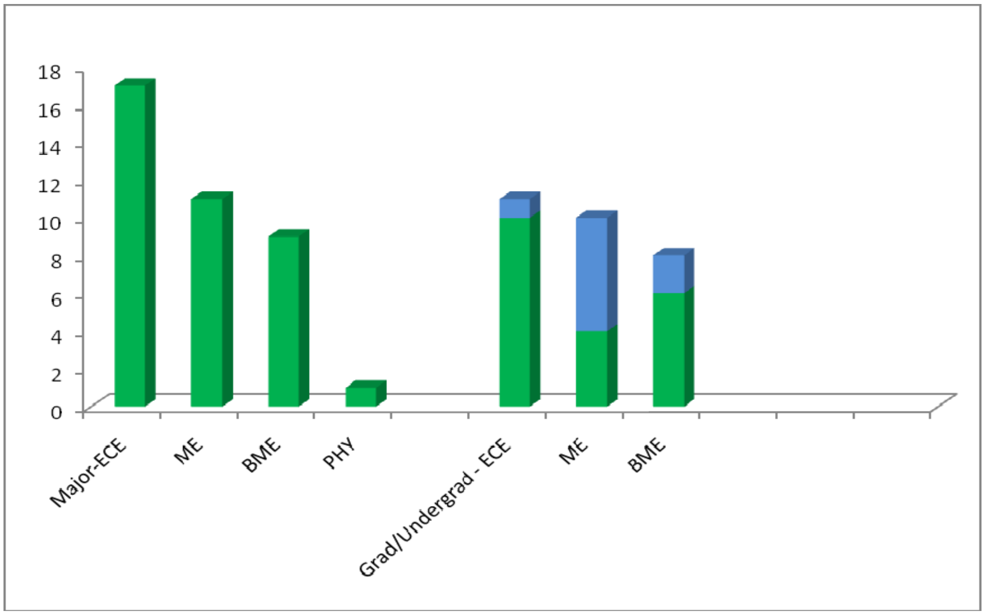

Figure 1: Studetns participation by department and level in Nanosystems Principles Fall 2010.

Table 1: Course Survey (30 students)

	Questions	Total (5)
4	Course objectives were clearly stated	4.2
5	Content was appropriate	4.1
6	Content was logically organized	3.8
7	Assignments were appropriate	4.3
8	Class presentations were well planned	4.2
9	Effective teaching by instructors	3.9
10	Instructors were helpful and easily accessible	4.0
11	I enjoyed the multidisciplinary aspects of this course	4.1
12	I enjoyed the team of instruction	3.9
13	My science background assisted me with this	4.2

	course	
14	Lecture notes and other materials provided were adequate	4.0
15	This course helped me gain knowledge in nanotechnology and its applications	4.3
16	The term paper and poster presentation were helpful to learn about nanotechnology and improve self learning and writing skills	4.0
17	Ranking this course with other elective courses I have taken at IUPUI, I found this course as one of the most interesting courses	4.2
18	Overall, I am very satisfied with the outcomes of this course	4.3

2.2 Establishing Research-based Learning: In the sophomore year, the selected INEC students will participate in faculty-mentored nanotechnology research projects and will then be required to consistently participate in this powerful pedagogy. The senior design and research projects will focus on areas covered in the new curricula. Both research and course work will explore different aspects of engineering applications in nanoscale such as scanning probe methods, devices using nanotubes, bottom-up and top-down syntheses of nanoscale materials, self-assembly, nanobiotechnology, environmental aspects of nanotechnology, applications of nanotechnology to information technology, properties and fundamental phenomena in nanoscale materials, computational methods for modeling nanoscale materials, nanoscale devices, nanoscale systems, and design principles at nanoscale.

A recent evaluation of National Science Foundation (NSF)-funded undergraduate research experiences recommends that students in Science, Technology, Engineering, or Mathematics (STEM) disciplines should be engaged in undergraduate research as first- or second-year students. Furthermore this study showed the longer undergraduates participated in research the more likely they were to pursue post-baccalaureate degrees[2]. Studies about the benefits of independent faculty-mentored research have also shown that students who undertake research projects are more likely to complete their undergraduate education[3,4] and go on to graduate school or professional training compared to students who do not have a research experience [5,6]. This project will provide valuable experiences for undergraduate students to hone their skills in multidisciplinary team settings and will allow acquisition of enough sophistication to gain all the benefits that undergraduate research can provide (such as publication in professional journals and presentation at professional meetings).

2.3 Term Papers: The nanotechnology track courses also will incorporate term papers to widen the knowledge and understanding the students into the emerging fields of nanotechnology. The terms paper will improve the writing and research skill of the students. The important elements sought in the term paper will include: a thorough survey of the literature on the subject; an in-depth understanding of the phenomena related to the subject; and an innovative analysis of possible solutions based on your theoretical studies. As part of this, a theoretically-based physical description of the phenomena considered and their applications must be provided. In the two courses offered in fall and spring semester of 2009, Nanosystems Principles and Integrated Nanosystems Processes and Devices, the term paper topic were chosen from cutting-edge fields of nanotechnology such as, nanotechnology employment in future care vehicles, nanotechnology in quantum computers, nanotechnology for solar renewable energy, nanotechnology for safety of future car, and nanotechnology in drug delivery. The term paper presented by the students in these two courses included the following sections:

1. Title Page: Title of paper, author's name, course name, date, and abstract
2. Abstract: Summary (typically one paragraph) of paper (key points, results, conclusions)
3. Introduction: Background information about the subject and brief outline of the paper
4. Main Body: Main part of the paper, containing a theoretical and experimental and a results and discussion sections, with figures, etc.
5. Conclusions: Summary of what has been presented and what conclusions are drawn.
6. References: List of referenced publications (use format in IEEE Electron Devices Letter)

The term papers also included end of the semester poster presentation in a formal poster session. The poster session had a great impact on all students and faculty. Faculty members from both science and engineering schools attended the session and discussed the outcomes of the students' term paper and understanding of the topic.

3. Educational Elements

This program will enhance team work, multidisciplinary activities, new teaching methodology, research based learning, and integration of knowledge through:

Team Work Projects: Team work projects are included in the capstone senior design. In the nanotechnology track a mix from ME and ECE students may pursue the same project in nanotechnology.

Multidisciplinary Activities: The new track combines technical strengths from different majors combined into one project.

New Teaching Methodologies: The teaching methodology introduced in this track follow innovative paths. An application will be selected and theories will be covered to serve that application. This is a departure from the traditional curricula.

Research-based Learning: This program emphasizes research early in the program and graduate students will mentor undergraduate students in research projects.

Hand- on Lab Experiences: The new track will provide hands on lab experiences for the students and will help them to pursue careers in nanotechnology

Integration of Knowledge: The new program integrates knowledge from science and engineering into nanotechnology projects. Students at the early stage of the program will be able to invasion the immediate need of the science and math components they study.

4. Impact of the Program on Education

The newly developed track provides a departure from the traditional teaching and learning methodologies. It provides three modules of research based courses in three years, in addition to the team capstone design project that students must pursue at the senior year. Below is a detail on these two components. The track also offers project based portfolio courses where laboratory components are associated with the course projects. The curricula of this track are rich with hands on experience to prepare graduates to the graduate program and the industrial workforce in this area.

4.1 ECE 492/ME 492: Senior Capstone Design Project

In this course, all ECE and ME students are required to do two semester project that incorporate design components from various courses throughout the curricula. This course assists students with design methodology, consideration of alternative solutions and project planning in engineering design. Oral presentation and report writing are required for this course. For students in the nanotechnology track the requirements will be same with emphasis on nanotechnology (e.g. safety, reliability, economics and aesthetics on nanosystems, NanoElectroMechanical Systems (NEMS), nano-optical systems, nanomaterials and devices for renewable energy applications).

4.2 Research Modules in Nanotechnology

The research modules will be designed to attract students in the INEC program and encourage them to pursue their graduate programs following their Bachelor of Science degrees. The following are the models for new research modules that nanotechnology track students will pursue:

1. The research modules are combined into one comprehensive research project that students may start working on it during the sophomore year and continue until the senior year.
2. The research modules may include more than one research projects within the three years: sophomore, junior, and senior year.
3. The research modules may be linked with graduate students' research work to learn about research hypotheses, assumptions, limitations, simulation tools, and use of nanotechnology equipment for the research projects.

5. Outreach Plan

One of the most significant outreach activities, with a potentially far-reaching impact, will be our events arranged for K-12 students and teachers (e.g. Nanotechnology Discovery Summer Camp, (see the site for details[7]. Indiana University-Purdue University (IUPUI) has formal relationships with the Indianapolis Public School (IPS) system and with several surrounding township schools, including a science magnet high school. The campus routinely works with teachers at all levels at these surrounding institutions to train them in modern science education as well as to bring students from elementary grades through high school onto campus for numerous workshops, tours, symposia, short courses, summer camps, and other events.

In the INEC program, the facility will invite IPS and township science students and teachers and will present their research in terms that each group will find it exciting and relevant while also introducing them to INEC program at IUPUI. Recently, during the weeks of June 14-18 and June 21-25, the Integrated Nanotechnology Development Institute (INDI)[1], in partnership with the Center for Research and Learning (CRL)[8], hosted over thirty students from local high schools at the IUPUI Nanotechnology Discovery Camp. This summer day camp provided high school students with a unique opportunity to explore the interdisciplinary field of nanotechnology. Along with the classroom lectures/discussions and campus research lab tours, camp activities included demonstration of various equipment (for e.g. Scanning Electron Microscopes, Atomic Force Microscope, Scanning Tunneling Microscope, and Photolithography instruments), fabrication and testing of solar cells, testing of fuel cells, and the fabrication and testing of micro/nanofluidic devices. The classroom/lecture series included the demonstration of research instruments and hands-on-experience. This camp had tremendous impact and created a center of attention for higher education and research among the participating high school students. Having received positive feedback from both the parents and the students, we expect that some of these students from the Nanotechnology Discovery Camp will enroll in the INEC program. Moreover, INDI is planning to host the Nanotechnology Summer Camp for both the high school students (two sessions of one week long, June 6-10 and June 20-24, 2011) and high school teachers (one session of one week long, July 11- 15, 2011).

Once the INEC program and its modules are developed, we will use this information to further enhance our summer camps. Moreover, we will modify the modules developed for the freshmen year in INEC, to develop a module for a high school physics class, and disseminate it to our local high schools. This can be achieved by developing a "*Nano week*" theme for the local high school physics departments. In addition, that week would culminate in a visit to IUPUI's INDI research labs by the participating high schools. We will partner with Minority Engineering Advancement Program **(**MEAP) hosted at IUPUI every summer to include nanotechnology theme. MEAP is a week-long, summer, non-residential camp on the IUPUI campus and is designed for students who have completed 6th through 11th grade levels. The camp is designed for students that are underrepresented in engineering and technology careers.

We intend to broaden the participation of qualified students/individuals to our INEC program and/or our summer events from the local community. Metropolitan Indianapolis is the center of the regional economy with an emphasis on life sciences, automobile sporting and manufacturing industries. Some examples of companies around Indianapolis area are EnerDel (advance lithium batteries), Delphi Electronics (high density, low mass, and environmentally friendly materials), Raytheon (military systems such as power supplies and power sources). We will collaborate with our industrial board of advisers in facilitating these events.

6. Impact on Society:

The new program will provide a regional and national model for building a research-based curriculum derived from a strong campus infrastructure that supports undergraduate research, integrated with available lab resources within the campus. Students graduating from this program will have interdisciplinary lecture, laboratory and research experience that equips them to enter the global workforce and become leaders of research and development in industry, business, and academia in the emerging era of nanotechnology. Utilizing undergraduate research and underrepresented student programs available on every campus (for example UROP, McNair, LSAMP, and MURI programs)[9], will facilitate expanding the population and success of underrepresented students in the nanotechnology tracks. In addition, students graduating from the INEC program will be prepared, through lecture, laboratory and research experiences that provide them the problem-solving skills and perspective on their discipline, to participate as leaders in a global workforce and to make significant contributions to research and development in industry, business, and academia in an emerging era of nanotechnology.

7. Conclusion:

The Bachelor of Science Nanotechnology track within the School of Engineering and Technology at Indiana University Purdue University Indianapolis (IUPUI) being developed under NSF NUE program has been discussed. A sequence of two courses was offered in the fall and spring semesters within both the School of Engineering & Technology and the School of Sciences. The courses attracted students from different disciplines of sciences and engineering. The syllabi and the contents of the courses were developed by combining the research and teaching experience of the faculty members at the IUPUI campus. The interests shown by students and faculty to these two courses provide a preview for the forthcoming nanotechnology track. The nanotechnology track will provide a regional and national model for building a research-based curriculum derived from a strong campus infrastructure that supports undergraduate research.

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