Charting a Pathway for Nanotechnology in Engineering Technology Education

Jinwen Zhu, Virendra Varma
Department of Engineering Technology
Missouri Western State University
jzhu@missouriwestern.edu, varma@missouriwestern.edu

Abstract

The development of micro-scale engineering in the area of electronics and computer engineering demonstrates low cost, and high efficiency technology advancements in miniaturization. These efforts have led to the emergence of nanotechnology dealing with a wide range of engineering applications at the nano scale. Nanotechnology has future impacts in the application markets such as medicine, healthcare, biotechnology, communications, and electronics. This paper discusses the current development of nanotechnology in education and research in China and the United States, and the challenges facing the overall development of the field of nanotechnology. Due to rapid development and broad impact of nanotechnology, education and training of a new generation of workforce skilled in this field will play an important role in the development and applications of nanotechnology. Although there are efforts under way to teach and engage students in nanotechnology in engineering disciplines, a few exist in engineering technology programs. How to embrace nanotechnology in engineering technology education is a challenge for the engineering technology educators as we find how intricately nanotechnology is related to science and technology. This paper addresses the curriculum design of a baccalaureate-level program in nanotechnology in the realm of engineering technology and specifically provides three models for a flexible design of a nanotechnology curriculum.

Introduction

In 1959, Richard Feyman set the stage for research at the nano scale. Since then, the development of micro-scale engineering in the area of electronics and computer engineering has demonstrated low cost, and high efficiency technology advancements in miniaturization. These efforts have led to the emergence of nanotechnology dealing with a wide range of engineering applications at the nano scale. Especially, there are many advances in research, development, and commercialization of nanotechnology during the last two decades. Nanotechnology is concerned with the design, characterization, and fabrication of new materials, devices, and systems on the nanometer scale, with their properties dramatically improved from their bulk counterpart. Nanotechnology converges multidiscipline including physics, chemistry, biology, and engineering, and covers the use of quantum effects, synthesis and processing of nanoparticles, self-assembly nanostructure, fabrication of nanostructure and devices including chemical and biological sensors. Nanoscale science and technology impact application markets such as medicine, healthcare, biotechnology, communications, and electronics. Realizing the potential impact of nanotechnology on science and technology and economy, all industrialized countries and some developing countries have developed a national strategy for nanotechnology ranging from a general science research strategy to applications-motivated strategy. This has resulted in an increase in the levels of government investments as well as funding from the private companies.

With the fast advancements in nanotechnology, it is estimated that about 2 million scientists, engineers, and skilled workers in the field of nanotechnology will be needed worldwide in the next decade. Thus, the education and training of a new generation of technicians and engineers in nanotechnology is extremely important. However, due to the interdisciplinary nature of nanotechnology, there is a major challenge for engineering and technology educators to modify the existing curricula that primarily focus on one single discipline. Although some efforts have recently been devoted to develop undergraduate programs in nanotechnology, only a few exist in the two-year programs, and none in the four-year engineering technology programs. It is therefore vital to develop nanotechnology programs under the umbrella of engineering technology to supply the needed workforce in the nanotechnology field.

The following sections describe the research and education efforts in nanotechnology in China and USA. Also are discussed the challenges that the engineering technology educators face in teaching nanotechnology as it relates to undergraduate education. The guidance for curriculum design for a baccalaureate-level nanotechnology program in the realm of engineering technology is provided, and specifically three possible models are discussed to facilitate the curriculum design.

Nanotechnology Research and Education in China and USA

In the middle of 1980s, China started research in nanotechnology with the development of scanning probe microscopes (SPMs) and other scientific instruments for observing materials on nanoscale, with support from the Chinese Academy of Sciences (CAS) and National Natural Science Foundation of China (NSFC). The ‘Climbing up' project from the Ministry of Science and Technology of China supported nanomaterial science research for ten successive years from 1990 to 1999. As a persistence support, the Ministry of Science and Technology in 1999 started another national key research project ‘Nanomaterial and Nanostructure' to support the basic research on nanomaterials such as nanotubes. The National High Technology Plan also established a series of projects for nanomaterial applications [[1]].

The major funding agencies in China for Nanotechnology are the Chinese Academy of Sciences (CAS), the National Natural Science Foundation of China (NSFC), the Ministry of Education (MOE), and the Ministry of Science and Technology (MOST). The short-term strategy of China is to integrate nanoscale science and technology with the traditional industries and develop novel products with superior quality and performance.

In 2000, eleven institutes of CAS made joint efforts in a major research project of “Nanoscience and Nanotechnology” sponsored by the Knowledge Innovation Program, with an investment of more than three million US dollars. This project was targeted to improve or to invent new synthetic methods and techniques for nanostructures, and to produce new nanomaterials and nanodevices of important significance. Initiatives that are more aggressive were launched. The National Center for NanoScience and Technology of China (NCNST) is built in Bejing with a total investment of $33 million. The National Center for Nanoscience and Technology of China (NCNST) provides the scientific community of China with a technological platform and research center for nanoscience and technology with advanced facilities in nano-fabrication and characterization. The research focuses on four key directions of nanotechnology: nano-structures and materials; characterization and measurement of nano-structures; nano-devices and fabrication; nano-biotechnology and nano-medicine. The orientation of NCNST is the basic and applied research of nano science and technology, with its significant application prospects [2]. The National Center for Nano-engineering in Shanghai is an important addition to the research on nanotechnology in China. However, considerable differences of overall funding levels still exist between China and other developed countries, especially in the area of nanoscale devices and in industrialization.

To become more competitive in nanoscience and nanotechnology, China continues to expand its now-limited research infrastructure. China has extended its collaboration overseas with a joint project with an U.S. company, Veeco Instruments Inc., to provide access of Veeco nanotech instruments to Chinese researchers [3]. Korea-China Nanotechnology Research Center was established in 2005 to promote cooperation between the two countries in nanoscale science and technology research. In addition, a new accreditation committee for nanotechnology, a branch of the China National Board for Laboratories, has been established, which is responsible for lab accreditation of nano-related research, development, and products.

To date, more than 50 universities, 20 institutes of CAS, and 300 enterprises have engaged in the research and development of nanoscience and nanotechnology. Several centers for research and development of nanoscience and technology have been established in CAS, Peking University, Tsinghua University, Nanjing University, Jiaotong University, East China University of Science and Technology, Fudan University, Zhejiang University, and others. The education for nanotechnology in China focuses on graduate education based on the research activities in the universities and research centers. Currently, there is no nanotechnology program at the undergraduate level except for programs in materials science, microelectronics, etc.

The major funding agencies in USA for Nanotechnology are the federal agencies and large multinational companies. The federal agencies include the National Science Foundation (NSF), DOD, DOE, DOC (including NIST), NASA, NIH, EPA, and others. Companies in private sector, such as Dow, Dupont, Motorola, Hewlett Packard, etc., have established their own research labs and groups for nano scale science and technology. The funded research in nanotechnology covers a wide range from science-based to application-driven, which include introduction of new principles for nanoscale devices, modeling and simulation techniques, creation of nanostructured materials and their industrial applications, nanofabrication of electronic devices, nanobio device and system, nanomaterials for energy and environment applications [4]. With its largest investment in the world and the diligent efforts of its scientists and engineers, USA puts itself in the leadership position in nanotechnology research in the world. So does its education in nanotechnology with the education efforts and funding from the National Science Foundation (NSF), the National Nanotechnology Infrastructure Network (NNIN), and the National Nanotechnology Initiative (NNI). Different nanotechnology related courses or programs were developed for undergraduate and graduate levels. The National Nanotechnology Infrastructure Network (NNIN), an integrated networking partnership of thirteen universities supported by the

NSF, provides user facilities serving the resource needs of nanoscale science, engineering and technology, and supports a wide range of educational programs [5]. The National Nanofabrication User Network (NNUN), with the lead institution of the Cornell University, offers undergraduate and graduate courses and laboratory services for nanotechnology community. National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT) was established at the Northwestern University, with a partnership between Northwestern, Purdue University, the University of Michigan, Argonne National Laboratory, and the University of Illinois at Chicago and Urbana-Champaign, to develop educators to introduce the nanoscale science and engineering concepts into schools and undergraduate classrooms [6]. All above projects focus on science and engineering education. However, there are only a few projects, which addressed the challenges in technological education for nanotechnology. The projects include the "regional center for nanofabrication manufacturing education" created at the Pennsylvania State University with grant support from the state and NSF. A partnership between the state, universities and community colleges inside Pennsylvania has been established to deliver an associate degree program in Nanofabrication Technology via new curricula at community colleges [7]. Another project in technological education for nanotechnology sponsored by NSF is the A.A.S. Degree program in Nanoscience Technology led by Deb Newberry at Dakota County Technical College, Minnesota [8]. There is still a big gap for nanotechnology education in engineering technology even though it is an extremely important issue for the sustainable development and commercialization of nanotechnology.

Nanoscience and Nanoengineering in Engineering Technology

With the huge investments from government and private sectors in nanotechnology, nanotechnology has developed at a great pace during the last two decades, and so has the commercialization of nanotechnology. A key challenge to sustain this development trend is to provide needed researchers and skilled workers with interdisciplinary backgrounds. Although many courses and programs have been developed for universities and research centers to train future engineers and scientists in this field, a great many support technologist and technicians are required as well. It is this great challenge that the engineering technology educators face to develop a new curriculum for nanotechnology education.

The interdisciplinary nature of the nanotechnology field encompasses biology, chemistry, physics, materials science, and engineering. The traditional curriculum has defined boundaries between these disciplines. It is a key challenge to develop nanotechnology experts with interdisciplinary skills. A variety of equipment and techniques from different disciplines is used in the development of materials and devices at the nanoscale. Many of the advanced facilities are too expensive for one individual investigator or program to own when it is not being used frequently. Therefore, the collaboration between the labs in different disciplines is strongly encouraged. Engineering technology program traditionally centers on hands-on education. A thorough grounding in physics, chemistry, biology, and mathematics is a basic requirement for nanotechnology program, and is a challenge for both students and educators.

The nanotechnology program in engineering technology should provide its graduates with the ability for understanding, characterization, and measurements of nanostructure properties, should provide its graduates with the ability for synthesis, processing, and manufacturing of nanodevices and nanosystems. Although nanotechnology is interdisciplinary in nature, one however, needs to be trained in a discipline. One cannot be an interdisciplinarian without a home discipline. Therefore, a baccalaureate degree (B.S.) in engineering technology for nanotechnology should have a different concentration depending on the home discipline. The curriculum for nanotechnology program should consist of four categories: general studies, interdisciplinary fundamentals, core courses within concentration, and hands-on capstone courses.

In order to accomplish the curriculum requirements for nanotechnology education in engineering technology, a much broader collaboration is required. Due to resource limitations of the engineering technology programs, especially the lack of advanced equipment and facilities, and sometimes faculty in the nano field, collaborations from outside of the program is normally sought. The interdisciplinary fundamentals, including the basic principles of chemistry, biology, physics, mathematics, and computer science, can be accomplished with partnerships between individual departments within the university. The faculty from the various diverse fields should, in general, teach the core courses relative to different concentrations.

For the hands-on capstone courses, a partnership between different universities is advisable due to requirements for utilization of many advanced facilities in the program. Three models can be applied to carry out the hands-on capstone courses.

- First Model: Students spend one or two semesters in a partner university to finish the capstone courses. This partner university could be one of the universities of the National Nanotechnology Infrastructure Network (NNIN) and the National Nanofabrication User Network (NNUN). The students can fully utilize the nanotechnology infrastructure sponsored by federal agencies.
- Second Model: Uses virtual collaboration for courses and hands-on experience through intensive internship. The students stay at their home university for lecture/laboratory classes and share resources of the advanced laboratory using virtual reality techniques through internet. Students also spend two months at the nano facilities in the partner university for an intensive internship.
- Third Model: Involves hands-on experience through intensive internship and coursework taught by home university faculty. The students will have an internship as in the second model though the courses are taught by faculty with the aid of simulation software and/or other teaching software to facilitate understanding. More interactions occur between students and faculty, and thus enable students achieve better understanding compared to the second model.

Charting a pathway for nanotechnology in engineering technology is a complex task. The curriculum requires a high-level of integration. The students, the faculty, and the collaborating labs and institutions, must all work coordinately. The graduates from this kind of a program will provide the needed workforce in nanotechnology field for the 21st century. The best advantage is that the graduates could enter the job market in a variety of areas, such as nanobio, nanoelectronics, medicine, materials, environment, etc. The sky is the limit.

Conclusion

Due to rapid development and broad impact of nanotechnology, education and training of a new generation of workforce skilled in this field will play an important role in the development and applications of nanotechnology in the future. How to embrace nanotechnology in engineering technology education is a challenge for the engineering technology educators as we find how intricately connected is nanotechnology to the home disciplines of biology, chemistry, physics, materials science, and engineering. The models discussed in this paper for delivery of nanotechnology education can serve as a model for the design of curriculums in a variety of engineering technology curriculums at the baccalaureate level. It is a challenge for engineering technology educators to develop new content and new teaching and learning tools for nanotechnology education to prepare the new generation of engineering workforce for the emerging nanoscale technology but it is a challenge that is worth taking, and it is worth taking now.

Bibliography

[1] Bai, Chunli. “Ascent of Nanoscience in China.” Science, Vol. 309, No. 5731, 2005, pp. 61–63.
[2] World-Wide Web URL http://www.nanoctr.cn.
[3] Nemets, Alexandr. “China's nanotech revolution.” Association for Asian Research, 23 August 2004, www.asianresearch.org.
[4] World-Wide Web URL http://www.nsf.gov.
[5] World-Wide Web URL http://www.nnin.org.
[6] World-Wide Web URL http://www.nclt.us.
[7] Fonash, S. J. “Education and Training of the Nanotechnology Workforce.” Journal of Nanoparticle Research, Vol. 3, No. 1, 2001, pp. 79-82.
[8] World-Wide Web URL http://www.dctc.edu.

Biographies

JINWEN ZHU, Ph.D., is Assistant Professor of Electronics/Computer Engineering Technology at Missouri Western State University. He joined the faculty at Missouri Western State University in August 2005, after completing his Ph.D. in Electrical Engineering and M.S. in Computer Science at the University of North Carolina, Charlotte. He teaches a variety of courses for the Department of Engineering Technology at Missouri Western State University.

VIRENDRA VARMA, Ph.D., P.E., F. ASCE, is Professor and Chairman, Department of Engineering Technology at Missouri Western State University.