AC 2008-1529: DEVELOPMENT OF AN ON-LINE INTRODUCTION TO NANOTECHNOLOGY COURSE: ISSUES AND CHALLENGES

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Development of an On-line Introduction to Nanotechnology Course: Issues and Challenges

Abstract

The emerging field of Nanotechnology is leading to a technological revolution in the new millennium. Realizing the need for providing nanotechnology education and training at the undergraduate level to technicians and technologists, Excelsior College, a well respected distance learning institution in higher education has recently embarked upon a plan to develop and implement an on-line 4-year nanotechnology degree program. Since the Excelsior learning model permits offering a course of study with a significant amount of the coursework and other requirements met by external courses and workforce experience, hence the on-line instruction elements will be phased in gradually. Initially, two on-line nanotechnology core courses will be developed. The first one, titled "Introduction to Nanotechnology" is currently under development. The second one, titled "Basic Nanofabrication Process" will be developed during Summer 2008.

This manuscript describes the development of on-line nanotechnology courses at Excelsior College. The manuscript discusses several issues to be dealt with during the development of the above mentioned introductory on-line/web-based nanotechnology courses and provides details regarding the course development strategy Excelsior College will be using to address the above mentioned issues. The manuscript also describes the innovative course development model used by Excelsior College. This course model combines virtual reality, graphics, text, and sound. The model features a multidisciplinary perspective and is designed specifically for the needs of working adults.

Introduction

Nanotechnology is the creation of functional materials, devices, and systems through control of matter on the nanometer length scale and the exploitation of novel properties and phenomena developed at that scale. Nanotechnology holds singular promise to revolutionize science, engineering, and technology. It already has significant impact in countless industries including communications, medicine, environmental cleanup, agriculture, and more. Innovative materials, components, and systems based on nanotechnologies are recognized as promising growth innovators for the years to come. It is expected that eventually nanotechnologies will merge into a technology cluster offering a complete range of functionalities in information, energy, construction, environmental, and biomedical domains. The extensive use of nanotechnology will create a significant demand for workers who can provide technical assistance in the development of products and processes using nanotechnology concepts.

As estimated by the National Science Foundation (NSF), two million technical workers will be needed to support nanotechnology industries worldwide within the next 15 years

[1]. It is necessary that science and technology graduates develop a good understanding of this rapidly expanding technology. They should be able to integrate the key concepts of nanotechnology into their knowledge bases. Academic programs in nanotechnology should be interdisciplinary in nature and must include several academic disciplines such as chemistry, materials, biology, mechanics, and electronics.

Realizing the need for providing nanotechnology education and training at the undergraduate level to technicians and technologists, Excelsior College, a well respected distance learning institution in higher education, has recently embarked upon a plan to develop and implement an on-line 4-year nanotechnology degree program. Excelsior College (EC) has been a pioneer in the service of non-traditional students since 1971. This institution was quick to adopt web-based asynchronous distance learning systems as the primary mode of instruction for the predominantly non-traditional adult student population of the college. During the last 5 years, the Schools of Liberal Arts, Nursing, Health Science, and Business and Technology have developed several hundred web-based on-line courses for management and delivery through the WebCT Distance Learning System [2].

The Excelsior College Bachelor of Science in Nanotechnology graduate will be typically employed as a technologist in industry with responsibilities that may include product design and development, manufacturing, field engineering, production management, systems supervision, and quality assurance. The graduate will exhibit a firm grounding in the fundamental sciences, computation and mathematics, a working knowledge of the tools and techniques of electronic nanotechnology, good written and oral communication, and an awareness of teamwork, project management, quality, and ethical and social responsibilities.

On-line Instruction: Opportunities and Challenges

With the advancement of Internet, on-line instruction is becoming popular in engineering education [3]. Although not yet “mainstream”, on-line courses delivered over the Internet are becoming more common [4]. Traditional and non-traditional colleges and universities are now using a variety of instructional tools and techniques to deliver on-line courses to their students. There are many advantages of on-line learning. It is borderless and is a practical way for learning for those who cannot travel to attend classes at an educational institution. It is flexible and allows students to learn at their own pace.

In the On-line distance learning environment, the instructor, the technology, and the course content are the key components of the learning process for the student. The technology based instruction delivery system is generally fixed once the institution selects the distance learning technology. In the case of Excelsior College, the instruction delivery is achieved primarily through the WebCT distance learning system.

WebCT is an on-line tool that facilitates the creation of sophisticated WWW (World Wide Web) based educational environments by non-technical users. It can be used to

create on-line courses, or to simply publish materials that supplement existing courses [5]. The key features of WebCT are described in [6] and [7].

Excelsior College's On-line Nanotechnology Courses

As mentioned earlier, Excelsior College is currently developing an on-line 4-year nanotechnology degree program. This degree program will require 124 semester hours of credit, including at least 60 credits in the arts and sciences component and at least 48 credits in the nanotechnology component. The lower-level courses in this degree program will provide solid grounding in mathematics, physics, chemistry, and computer applications. Upper-level coursework would include such topics as electronics, nanofabrication, and materials. English, economics, and several technical electives will round out the program. The core courses include:

- **Introduction to Nanotechnology** Introduction to the underlying principles of nanotechnology, nanoscience, and nanoengineering. Introduces scientific principles and laws relevant on the nanoscale. Discusses applications in engineering, physics, chemistry, and biology.
- **Basic Nanofabrication Processes** Provides an overview of basic processing steps in Nanofabrication (contact lithography, basic etching, and deposition techniques). The majority of this course details a step-by-step description of the equipment and processes needed to fabricate devices and structures. Contamination issues in nanofabrication are discussed in detail.
- **Process Equipment** Covers basic vacuum systems including pumping methods, pressure measurement, gas analysis, and leak detection and plasma-aided manufacturing including RF power delivery, plasma physics, and process monitoring techniques. Also covers basic pneumatic systems including actuators, control elements, and system qualification.
- **Introduction to Nanofabrication Manufacturing Technology** Provides an introduction to the fundamentals of Nanofabrication Manufacturing Technology. Students will study the Nanofabrication Manufacturing Technology (NMT) industry and learn applications in MEMS, Bionanofab Technology, and Nanochemical Technology. Students will become familiar with the basic concepts of NMT including atoms, nano-particles, tubes and rods, semiconductors, transistors, and integrated circuits. This course will be available to all the engineering technology majors at Excelsior College.
- **Nanotech Practicum** This work experience will expose students to participation in real-world science and engineering teams and familiarize them with the specialized tools and techniques that nano-technicians and technologists must master. Initial discussions have already been held with staff at the Albany Nanotechnology Center, Brookhaven National Laboratory, the Cornell Nanoscale Science and Technology Center, and the Nanofabrication Manufacturing Technology Partnership of Penn State regarding several week-long sessions at their locations.

The nanotechnology electives include:

- **Semiconductor Manufacturing: The Making of Integrated Circuits** Reviews the history of semiconductor manufacturing, the processes used in making integrated circuits, e.g. photolithography, deposition, implantation, etching, metallization, CMP, and packaging.
- **Micro-electro-mechanical Systems (MEMS)** Covers the applications of MEMS, e.g. sensors, microfluidics, bio-MEMS, among others. Includes bulk micromachining and packaging.
- **Material Science for Nanotechnology** Covers an introduction to the physics of the solid state, properties of individual nanoparticles, bulk-nano-structured materials, organic compounds and polymers, and biological materials.
- **Imaging and Characterization** Familiarizes students with the principles and practices of electron microscopy, micro-tomography, crystallography, simulation, and surface and volume visualization.

On-line Course Development and Implementation

At Excelsior College, the on-line instruction in nanotechnology will be phased in gradually.Initially, two introductory on-line nanotechnology core courses will be developed. The first one, titled "Introduction to Nanotechnology" will be developed during Spring 2008. This on-line course will be offered to the Excelsior College Engineering Technology students in Summer 2008. The second on-line course, titled "Basic Nanofabrication Processes" will be developed during Summer 2008 and offered during Fall 2008. Pending sufficient student students' interest in the nanotechnology offerings, two more on-line nanotechnology courses will be developed and offered during the year 2009. Any student who completed these four core on-line nanotechnology courses will be awarded a CERTIFICATE IN NANOTECHNOLOGY, which of course, could lead to a baccalaureate degree in nanotechnology.

The first on-line nanotechnology core course being developed at Excelsior College is titled "Introduction to Nanotechnology". It is a 3 credit-hour on-line lecture course. It does not have a lab component. The course will be offered at the junior level of a 4-year undergraduate degree. The topical coverage for this course will consist of:

- Solid State Physics
- Quantum Mechanics
- Electronic Nanodevices
- Photonic Nanodevices
- Nanomaterials: Fabrication
- Nanomaterials: Characterization
- Magnetic Nanodevices
- MEMs and NEMs

Upon completion of this course, students should be able to:

- Identify the fundamental aspects of nanotechnology
- List and describe the key nanotechnology applications

- Describe properties of individual nanoparticles
- Apply techniques for measurement of nanostructure properties
- Demonstrate ability to analyze nanostructures and nanodevices

Since this is an on-line course, all the students are required to have access to the following computing resources:

- A reasonably up-to-date personal computer that runs Windows 98 or later
- Availability to MS-Office, especially Word
- Capability to open and display PDF files
- A working and reliable internet connection with a current Web Browser.

The Excelsior College's Standard Template for on-line courses will be used to develop the on-line nanotechnology course.

The first page of any course is considered the "Homepage". It is basically the controller for the course that students will use. There are 2 sections of the Homepage. The section to the left is called the Course Menu and the section to the right is the Course Homepage.

The course homepage gives the student the title of the course. The course homepage is condensed to as little number of course icons as possible. By limiting the modules on the homepage, the instructor/faculty can use the selective release feature. This feature allows instructors to open up sections of the course at different times. For example, the instructor may want to allow the students to view the course information and calendar, but block the actual tools and course data. By using the selective release function, they can. By limiting the number of icons on the homepage, one makes this administration more efficient. It also gives students an easier way to navigate their course.

The icons that art made available on the homepage are as follows:

- Information about this course (or Course Information)
- Course Content modules
- Course Tools (Includes glossary as well)
- Calendar (All deadlines and due dates included)
- Students Tips

In addition to the above icons, announcements and messages can be posted in the upper and/or lower text block on the homepage. Under the course information, following items are included:

- Welcome
- Course Introduction (Course title, number, brief description, and required materials)
- Instructor Bio
- Contact Information
- Basic Course Information (Course title, number, prerequisites, start and end dates, etc.)

- Course Syllabus
- Systems Information (System Requirements and Tech Support Information)
- Policies (Excelsior College policies of Academic Honesty, Electronic Use, etc.)

Under the syllabus, following items are addressed:

- Detailed Course Description
- Course goals, objectives/outcomes
- Required and recommended Course Materials
- Library and Reserve readings
- Course Outline with due date schedule
- Procedure for communicating with the faculty
- Course Assessment (Exams, projects, discussions, quizzes, etc.)
- Grading Policy (weights and Excelsior grading scale)
- Course Policies (e.g. honesty, plagiarism, late submissions, effective writing, etc.)
- Other Course Instructions (WebCT Institutional bookmark: Excelsior College Virtual Library, Electronic Peer Network, Bookstore, etc.)

Assessment of Quality of the On-line Nanotechnology Course: A Key Issue

For assessing the quality of subject matter content of each on-line course offered by the Excelsior College's School of Business and Technology (SBT), the "Quality Matters" Rubric developed by the Quality Matters Organization is used. This rubric is shown in Table 1. As shown in Table 1, course attributes such as the clarity of course Overview/Introduction and Learning Objectives, quality of Course Resources and Materials, the availability of adequate technology for the delivery of instruction, the infrastructure for learner support, the potential of the course for facilitating learner engagement in class activities, and the accessibility features of the course are scored to decide if the course being evaluated meets the "Quality Matters" standards.

Possible Benefits of Offering On-line Nanotechnology Courses

The key advantage of offering on-line nanotechnology courses will be a virtual classroom that is available anywhere: at school, at work, at home, or even on a trip. In addition to the geographic and temporal independence, the on-line nanotechnology courses being developed by Excelsior College will be of significant help in enhancing the communication skills of students. The students taking these courses will be able to communicate both synchronously and asynchronously using web-based electronic mail, chat rooms, and electronic whiteboards. As described by McCormack and Jones [8], students will often say more in an electronic forum than they would in a face-to-face situation. A record of all web-based students' communication may be stored in the course website making it possible for students to retrieve, search, edit, and share the content easily. The enhancement of students' communication skills is an important advantage knowing that excellent communication skills are in high demand in the job market for engineers and technologists. The above mentioned on-line nanotechnology courses can help to improve this aspect of engineering and technology education.

Table 1

All Quality Matters Rubric Standards with Assigned Point Values

	Standard		Points
Course Overview and Introduction	I.1	Navigational instructions make the organization of the course easy to understand	3
	I.2	A statement introduces the student to the course and to the structure of the student learning and, in the case of a hybrid course, clarifies the relationship between the face-to-face and online components.	3
	I.3	Etiquette expectations with regard to discussions, email, and other forms of communication are stated clearly	2
	I.4	The self-introduction by the instructor is appropriate and available online	1
	I.5	Students are requested to introduce themselves to the class	1
	I.6	Minimum technology requirements, minimum student skills, and, if applicable, prerequisite knowledge in the discipline are clearly stated	1
Learning Objectives	II.1	The course learning objectives describe outcomes that are measurable	3
	II.2	The module/unit learning objectives describe outcomes that are measurable and consistent with the course-level objectives	3
	II.3	The learning objectives are stated clearly and written from the students' perspective	2
	II.4	Instructions to students on how to meet the learning objectives are adequate and stated clearly	2
	II.5	The learning objectives address content mastery, critical thinking skills, and core learning skills	2
Assessment and Measurement	III.1	The types of assessments selected measure the stated learning objectives and are consistent with course activities and resources	3
	III.2	The course grading policy is stated clearly	3
	III.3	Specific and descriptive criteria are provided for the evaluation of students' work and participation	3
	III.4	The assessment instruments selected are sequenced, varied, and appropriate to the content being assessed	2
	III.5	"Self-check" or practice types of assignments are provided for timely student feedback	1
Resources and Materials	IV. 1	The instructional materials support the stated learning objectives	3
	IV.2	The instructional materials have sufficient breadth, depth, and currency for the student to learn the subject	3
	IV.3	The purpose of each course element is explained	2
	IV.4	The instructional materials are logically sequenced and integrated	1
	IV.5	All resources and materials used in the course are appropriately cited	1
Learner Engagement	V.1	The learning activities promote the achievement of stated learning objectives	3
	V.2	Learning activities foster instructor-student, content-student, and if appropriate to this course, student-student interaction	3
	V.3	Clear standards are set for instructor response and availability (turn-around time for email, grade posting, etc.)	3
	V.4	The requirements for course interaction are clearly articulated	2
	V.5	The course design prompts the instructor to be active and engaged with the students	2
Course Technology	VI. 1	The tools and media support the learning objectives, and are appropriately chosen to deliver the content of the course	3
	VI.2	The tools and media enhance student interactivity and guide the student to become a more active learner	2
	VI.3	Technologies required for this course are either provided or easily downloadable	2
	VI.4	The course components are compatible with existing standards of delivery modes	1
	VI.5	Instructions on how to access resources at a distance are sufficient and easy to understand	1
	VI.6	The course design takes full advantage of available tools and media	1
Learner Support	VII. 1	The course instructions articulate or link to a clear description of the technical support offered	2
	VII.2	Course instructions articulate or link to an explanation of how the institution's academic support system can assist the student in effectively using the resources provided	2
	VII.3	Course instructions articulate or link to an explanation of how the institution's student support services can assist the student in effectively using the resources provided	1
	VII.4	Course instructions articulate or link to tutorials and resources that answer basic questions related to research, writing, technology, etc.	1
Accessibility	VIII.1	The course acknowledges the importance of ADA requirements	3
	VIII.2	Course pages and course materials provide equivalent alternatives to auditory and visual content	1
	VIII.3	Course pages have links that are self-describing and meaningful	1
	VIII.4	The course demonstrates sensitivity to readability issues	1

To meet Quality Matters review expectations a course must: Answer 'Yes' to all 3-point Essential Standards I.1, I.2, II.1, II.2, III.1, III.2, III.3, IV.1, IV.2, V.1, V.2, V.3, VI.1, VIII.1 *AND* Earn 68 or more points

Source: QualityMatters.org (Quality Matters/Maryland Online)

Conclusion

This manuscript focuses on the development and delivery of on-line nanotechnology courses at Excelsior College. The manuscript describes several issues to be addressed during the development of the above mentioned introductory on-line/web-based nanotechnology courses. One of the key issues is the use of an appropriate software tool for the development and delivery of on-line instruction. This issue is addressed through the use of WebCT which facilitates the creation of a web-based educational environment. Another key issue is the assessment of the quality of course content. This issue is addressed through the use of the "Quality Matters" Rubric developed by the Quality Matters Organization. Course attributes such as the clarity of course Overview/Introduction and Learning Objectives, quality of course Resources and Materials, the availability of adequate technology for the delivery of instruction, the infrastructure for learner support, the potential of the course for facilitating learner engagement in class activities, and the accessibility features of the course are scored to decide whether the course being evaluated meets the "Quality Matters" standards.

Since the Excelsior College distance education philosophy allows offering a degree program with significant amount of the course work and other requirements, such as lab work, met by external courses and work experience, the above mentioned on-line instruction in nanotechnology will be phased in gradually.

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