Fostering Creativity and Innovation in Engineering Students

[1]Chung Y. Yu, M.F.A. and [2]David T. Shaw, PhD

[1]Department of Media Study
State University of New York at Buffalo, Amherst NY USA

[2]Professor, Center for Innovation Engineering Learning
Electrical Engineering Department
State University of New York at Buffalo, Amherst NY USA
chungyulyu@hotmail.com, dshaw@buffalo.edu

Abstract

In a recent article in Harvard Business Review, it's argued that a country's economic compositeness is tied directly to its ability to mobilize and harness the creative energies of its people[1]. Although America may be the land of opportunity in the 20th century, it's on the verge of losing the competitive edge in the 21st century because, in the post 9/11 era, it is confronting the possibility of a reverse brain drain — i.e., the country may be losing out a host of foreign-borne creative and innovative professionals. Among the strategies suggested to negate and rebuild the creative infrastructure, invest generously in education to tap into future professional's creative capacities is view as one of the top priority items for the higher education community. Nanotechnology and microelectromechanical systems, two courses used in teaching creativity, are excellent subjects for students to learn about the processing and fabrication of new structures at molecular/nano/micron levels and the creation of new materials and devices with fundamentally different structures and properties. The courses offer opportunities for students to exploit the physical, chemical and biological properties by gaining control of structures and devices at atomic/molecular, and nano/micron levels and to learn engineering applications of these devices[2]. Both classes identify such application areas as information/communication electronic, optical and biological systems, medical and environmental applications, etc. Special attention is placed on the potential commercial developments and their marketing strategies.

Before the students embark on their class projects which emphasize innovative ideas, they learn about the importance of creativity in the knowledge-based economy using case study materials form the Harvard Business School. Extensive literatures on creativity and entrepreneurship are posted in the Blackboard-based course-website as references. A multi-faceted view of creative developments is presented to students. Factors generally accepted as essential to creativity are discussed in a brain-storming session. A creative problem-based learning cycle that influence intrinsic motivation for creativity – dreamer, realist, critic -- is used to challenge students to integrate creative concepts into their class projects.

Nanotechnology Education for Active Learning

Nanotechnology is an excellent subject for students to learn about the processing and fabrication of new structures at molecular level and the creation of new materials with fundamentally different properties. The course, Nanostructure Materials and Devices, offers an opportunity for students to exploit the physical, chemical and biological properties by gaining control of structures and devices at atomic, molecular, and supramolecular levels and to learn engineering applications of these devices.

Engineering undergraduate educators are urged to adopt active-learning strategies and other alternatives to uninterrupted lectures. Russ Edgerton introduced the term "pedagogies of engagement" in his 2001 *Education White Paper*[3], in which he reflected: "Learning 'about' things does not enable students to acquire the abilities and understanding they will need for the twenty first century. We need new pedagogies of engagement that will turn out the kinds of resourceful, engaged workers and citizens that America now requires." Innovative knowledge and skills are being produced today like cars and steel were produced decades ago. Those, like Bill Gates and Steve Jobs, who know how to produce creative ideas better than others reap the rewards, just as those who produced cars and steel became the magnates of that era[4].

The field of nanostructure science and technology has been growing rapidly in the past few years. Since 1998, such an elective course has been offered annually in the Department of Electrical

Engineering for seniors and first-year graduate students. The course is divided in three parts: (a) Nanofabrication, synthesis and assembly techniques, (b) nanostructure materials and devices, and (c) creativity and new product development. The discussions on parts (a) and b) rely heavily on the two reports published on NSF's website on the National Nanotechnology Initiative www.nsf.gov/nano). Only the basic concepts and design principles are formally discussed in class (e.g., quantum confinement effects, low-dimensional phenomena, nanoscaling laws, etc.). In part (c), students are encouraged to consider design problems with real financial consequences in their class projects. A required section in the project report concerns the conceptual design of a nanoscale marketable product. The final project presentation is an executive briefing, in which they must consider market viability of their new products.

Since the announcement of the National Nanotechnology Innovative (NNI) in 2000, the emerging fields of nanoscience and nanoengineering have given us numerous new materials and devices, leading us to unprecedented understanding and control over the fundamental building blocks of all physical things. According to Neal Stephenson's acclaimed science fiction novel "The Diamond Age", nanotechnology is the basis for remarkable machines called "matter compilers" which are capable of creating just about any object one can imagine, assembling these constructs atom by atom, molecule by molecule. Although the novel is only a science fiction, it does reflects some unique aspects of the nanotechnological design: In nanotechnology, it's possible to tailoring the design for new materials based on specific requirements of an application. As shown in Figure 1, the traditional design path starts with a process and a material with specific characteristics and properties, which lead to a number of useful applications.

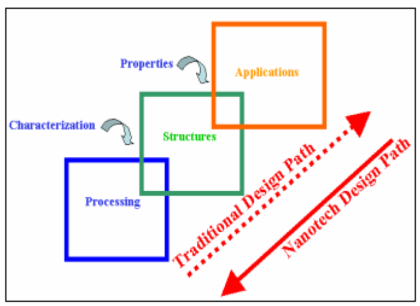

Figure 1: The Emerging Revolution in Technological Design

A good example of these traditional design is the doping of the silicon single crystals for the microelectronic applications. In nanotechnology, however, new materials can be designed to fit the specific device application requirements. For example, silicon-based quantum dots (QDs) are a useful material for inexpensive light emitting diodes even though bulk silicon is not an optical material (because of it's indirect band gap). By controlling the size of the QDs, one can vary the magnitude of the band gap, and thus the LED's electroluminescence wavelengths.

Creativity in Nanoscale Design

Creativity in nanoscale design is accepted to mean the generation of innovative ideas for the construction of original products containing: new concepts, new methods of arranging nanoscale building blocks and new systems. Creative problem-based learning can be observed in three phases based on the Disney Creative Cycle (Figure 2): the DREAMER, the REALIST and the CRITIC[5].

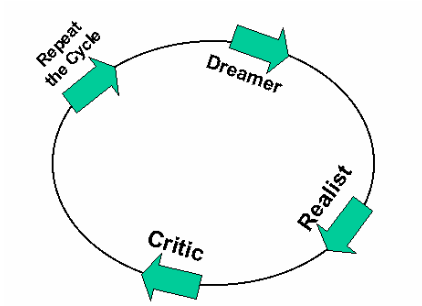

Figure 2: Creative Problem-based Learning Cycle

The dreamer is the phase to creatively develop new ideas, no matter whether they are realistic or not. This is the part that students are encouraged to follow the nanotechnology design path (Figure 1) to create new materials to fit the specific requirements of the materials properties, and develop processing techniques for the production of such materials. Without the dreamer, there would be no innovation. The realist is the actual planner, or the technocrat. He knows such real-world constraints related to costs and market competition, and is able to make conceptual design plan out of a dream. Finally, the critic reviews and improve the design to minimize potential risks.

The Dreamer Phase. The attitude of the dreamer is: "Anything is possible". In this phase of the planning, it is not necessary to consider neither for the product realizability, nor for market or capital constraints. Students are asked to answer the following questions as an engineer in a small business company: (1) What do you want to do? (2) Why do you want to do it? (3) What are the benefit? (4) How will you know that you have achieved the benefits? (5) Where do you want the idea to benefit the company? As a dreamer, students are asked to play two different roles : the explorer, where you are excited to learn skills and knowledge about a topic, and the artist where you are encouraged to think divergently and to progressively try different ways of designing nanoscale things.

Educational programs of art and design tends to value and affirm divergent thinking in learning and teaching[6]. By encouraging divergent thinking as an artist, students try different approaches of doing and making, experience continuing changing opportunities for revision and self-constitution. In contrast to convergent learning in which students concentrate on recognizing, recalling, and conforming, the artist's approach emphasizes inventiveness, innovation, and going beyond the status quo. During the dreamer phase, students are required to apply cognitive processes (e.g., learning, remembering, perception, etc.) as well as non-cognitive factors (e.g., emotion, curiosity, etc.) to explore, and build a knowledge data base. Such information gathering is critically important to motivate students as explorers because it provides the "latent" knowledge base for creative decisions.

The Realist Phase. The attitude of the realist is to ask if the dream is realizable. Students are expected to evaluate the probability of success by considering the following questions: (1) What are the specific steps to implement the project? (2) Who are your market competitors? (3) What is the probability of success? This phase seeks to evaluate the strength and weakness of the novel concept created in the dreamer phase. As a pre-requisite to the realist phase, students are encouraged to survey market data and perspective information.

The Critic Phase. Once conceptually derived, the design must be communicated to the project partners (typically 2-3 persons) and to class. The course is delivered to students using university's Blakboard.com[SM] e-learning system which is a powerful tool for communication and collaborative learning. The course makes extensive use of the learning tools available within the system, including the Discussion Boards, email, and Virtual Classroom.

Repeat Phase. The nanotechnogical product -- subjected to market and societal evaluations during the critic phase – typically requires modifications to improve its effectiveness and relevance. For example, the critic may have formulate that " the product's application safety is questionable", and the design may have to go through several cycles before completion.

Summary

In this paper, we have reported the use of a creative problem based learning model for a nanotechnology course. The class project asks students to design a marketable product based on a creative problem-based learning model based on Disney's Creativity Cycle derived from a combined dreamer/realist/critic/repeat learning phases. Special emphases are placed on the importance of divergent and convergent thinking in the dreamer phase, knowledge of market-driven competition in the realist phase, as well as communication and collaborative learning in the critic phase. The paper shows the utility of the Disney's Creativity Cycle as a means for guiding and fostering creativity and innovation in engineering education.

References

1. Florida, R. (2004) 'America's looming Creativity Crisis', Harvard Business Review, 82 (10) 122
2. R. W.Siegel, E. Hu, M. C. Roco, D. T. Shaw, et al '***Nanostructure Science and Technology—R&D Status and Trends in Nanoparticles, Nanostructure Materials, and Nanodevices*** (1999)
3. Edgerton, R., *Education White Paper*, 2001, *http://www. pewundergradforum.org/wp1.html*.
4. Thurow, L.C. *Building Wealth: The New Rules for Individuals, Companies, and Nations in a Knowledge-Based Economy,* Harper Collins Publishing, 2000
5. Dilts, R.B., *Strategies of Genius*, Vol. 1 (http://www.nlpu.com/)
6. Danvers, J., *Towards a Radical Pedagogy: Provisional Notes on Learning and Teaching in Art & Design*. International Journal of Art Design Education, 22(1) 47