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Teaching Innovative Thinking: Future Directions

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Abstract

This paper focuses on enhancing innovative thinking skills of undergraduate engineering students. We present a “big picture” view on this subject and suggest specific ways for implementing it.

The paper addresses the following three major questions:

1. What are the most relevant skills to become more innovative?
2. What kind of environment, curricula, and activities are essential to enhance these skills and stimulate innovation?
3. How can the identified environment, curricula, and activities be implemented and assessed?

For engineers of the future, technical capability alone will no longer be a distinguishing feature. Clearly, a broader-based educational experience that teaches leadership, innovation, and entrepreneurship is required in an environment that enhances and extends “non-traditional Engineering” curricula. The “Stay within the lines,” “Do not break the crayon” and “Find the ‘right’ (and only) answer” attitudes are archaic. Instead, we must focus on thinking outside-the-box, taking risks, and being critical thinkers, creative and imaginative. Graduates must be prepared for a work environment that uses so-called “soft skills” and encourages trust and respect for individuals and ideas.

The most relevant skills are clustered in four categories: (a) Problem solving, (b) “Big picture”, (c) Personal, and (d) Social.

Following these skill “list”, we describe multiple hands-on activity-based innovation modules, each of which aims at specific skills, with focused objectives and outcomes. The modules are divided into ten categories, specifically: Community, Camps, Short Courses, Competitions, Projects, Challenges, Puzzles, Workshops, Meetings, Beyond Engineering, and Business and Industry. Each module is detailed and discussed.

Implementation of a program that deals with the above skills has begun. The College of Engineering and Computer Science began the first cohort of Honors Scholars in the Innovation Leadership Honors Program in the Fall 2008 Semester. The program overlays the existing curricula and provides a select group of students an enhanced background and training in innovation, entrepreneurship, leadership, and communication. The status of the program is reported here.

The paper concludes with some additional suggestions for implementing and assessing the skills and activities.

Teaching Innovative Thinking: Future Directions

Introduction

For engineers of the future, technical capability alone will no longer be a distinguishing feature. Clearly, a broader-based educational experience that teaches leadership, innovation, and entrepreneurship is required in an environment that enhances and extends “non-traditional Engineering” curricula. The “Stay within the lines,” “Do not break the crayon” and “Find the ‘right’ (and only) answer” attitudes are archaic. Instead, we must focus on thinking outside-the-box, taking risks, and being critical thinkers, creative and imaginative.

The so-called “soft skills” not previously associated with technical people have become vital workplace tools. New graduates must be prepared for a work environment that breaks down feelings of anonymity and encourages trust and respect for individuals and ideas. Graduates are now called upon to contribute to a dynamic global economy. They are sharing projects with colleagues around the world, and must exhibit managerial and entrepreneurial skills with a clearer understanding of other cultures and ethics.

Solution

We have begun the first implementation phase of a project that will:

- Explore the most relevant skills to become more innovative
- Develop multiple hands-on activity-based Innovation Modules, each of which aims at specific skills, and with focused objectives and outcomes
- Aggregate the modules into the curriculum
- Implement and assess of the Innovation Modules

The proposed environment will focus on enhancing innovation-related skills such as **(a) Problem solving, (b) “Big picture”, (c) Personal, and (d) Social.**

The new student-centered environment will help students to develop a can-do, proactive, innovative mindset; an environment that will light the students’ spark of innovation, and provide them with resources to translate their ideas from paper to prototype. This will be achieved using modules composed of multi-sensory activities that will be synthesized to create an interactive, empirical, authentic, and team-based multi-disciplinary experience.

The environment will emphasize interaction with a cultural-, racial- and age-diverse community. It will be based on building-up interpersonal relationships that will develop as a result of additional supervision provided to the students. This unique “personal touch” feature will not be compromised by using IT-tools. The feeling of belonging experienced by the students will serve to build self-confidence and self-reliance, i.e., qualities of individuals willing to take a risk, think outside-the-box, and develop new and unique solutions to problems and impediments that they will encounter.

The modules are:

- Community (e.g., help in teaching k-12 students)
- Camps (e.g., cross a real river with a large group and limited resources)
- Short courses (e.g., learn systematic methods for inventive problem solving)
- Competitions (e.g., build a robot that can autonomously exit a maze...first)
- Projects (e.g., invent a warning system that detects those who do not wash their hands before leaving the bathroom)
- Challenges (e.g., solve 3-D puzzles)
- Workshops (e.g., discover yourself and appreciate diversity)
- Meetings (e.g., learn about professional societies)
- Beyond engineering (e.g., listen to music and read books)
- Business and industry (e.g., work with industry)

Support

The 25-member Executive Advisory Council of the College of Engineering and Computer Science has recognized the urgency of the national needs and has initiated and supported the development of an Innovation Leadership Program. The intent of this program is to focus greater attention on innovation, leadership and entrepreneurship in the College. This Council, a select group of executive level business, community and technology leaders, is committed to the long-term support of the proposed work, and views it as a part of the larger-scale longer-term Innovation Leadership Initiative.

Broader Impacts

The simplicity of the new program allows it to serve as a national model, as it can easily be implemented, replicated in part or in its entirety, as well as scaled or modified to fit other schools' needs. It is anticipated that engineering accreditation will evolve to include innovation as well as leadership and entrepreneurship skills, and it is expected that this project will help to accelerate this process.

The program is flexible as it allows for small and large scale changes in its content, the curriculum, and the participation of different faculty and invited scholars from different disciplines and institutions. This particular feature of the program will lead to a change in the university academic culture, i.e., it will encourage the faculty to take calculated risks, be more innovative and to experiment with different teaching methods, allowing for amplification of knowledge and techniques into other, more traditional programs, thereby having a long-term effect on students and society.

Related work

This proposed program assumes a general understanding of the term innovation, like the definition by the 3M Company “new ideas plus action or implementation which results in an improvement” (Gundling, 2000). It focuses on teaching and learning the ability of becoming a more innovative engineer. Radcliffe (2005) refers to traits and abilities of innovators as an integrative meta-attribute that overarches other traditional engineering attributes. In spite of the fact that this innovation meta-attribute is a multi-faceted one, with difficult to quantify effects, it is possible to develop a specific set of innovation skills and to create a list of activities that foster them.

Attempts to weave innovation into the curricula have usually been limited to creative problem solving as in Leach (2005) and Chau (2005). Several colleges have been teaching creativity in different forms, for example Olin College, Penn State, MIT, and Stanford University. In addition, there are ongoing efforts to infuse innovation and entrepreneurship into the engineering curriculum, an effort led by national institutions, such as National Collegiate Inventors and Innovators Alliance (NCIIA) and the Kauffmann Foundation. Steiner (1998) expresses a worry that weaving innovation into the engineering curriculum will lead students into becoming more commercially pragmatic, and steer them away from the engineering paradigm towards functioning “unscientifically in the public world rather than theoretically and scientifically in the special world of engineering.” However, due to the accumulated technological advances of the last sixty years we now all live in that “special world of engineering” to which Steiner refers.

Osborn (1963) and Eberle (1977) suggested the SCAMPER method for creative problem-solving, which is primarily a framework for ‘playing’ with the traits and functions of components in a system, or their interrelations. The method consists of techniques that allow for focused thinking: *Substitute*, *Combine*, *Adapt*, *Magnify*, *Modify*, *Put to other uses*, *Eliminate or divide*, *Rearrange*, and *Reverse*.

Altshuler (1988) suggested a comprehensive method for seeking inventive solutions to engineering problems, entitled TRIZ (the Russian acronym for the Theory of Inventive Problem-Solving). This method consists of the following three stages: (a) The resolution of technical and physical contradictions in a system, (b) The evolution of systems, and (c) The reference to the ideal system and ideal solution. TRIZ is often presented in the literature through the “40 Techniques for Overcoming System Conflicts” such as: Segmenting, Extracting, Using Asymmetry, and Combining. The TRIZ method has been implemented in large corporations such as Motorola, Xerox, Kodak, McDonnell Douglas and Rolls Royce.

Building on the roots of SCAMPER and TRIZ, researchers such as Horowitz and Maimon (1997) and Goldenberg et al. (1999, 2002) developed the Systematic Inventive Thinking (SIT) method for problem-solving that can be used in product innovation. Barak and Goffer (2002) have reported how SIT

workshops led to improvements of specific products.

Goals and Objectives

The short term goal of the program is to enhance innovative thinking and implementation skills of undergraduate engineering and computer science students. The longer term goal is to infuse the engineering curriculum with overarching traits of innovation, leadership, and entrepreneurship, so that, at the end of their formal studies, all engineering and computer science students will become “Innovation Ambassadors” who think and lead innovatively.

The work proposed addresses the following three major questions:

1. What are the most relevant skills to become more innovative?
2. What kind of environment, curricula, and activities are essential to enhance these skills and stimulate innovation?
3. How can the identified environment, curricula, and activities be implemented and assessed?

Approach

Description

Beginning with the end in mind, a list of necessary skills that define an innovative individual will be developed with the help of the Executive Advisory Council. This list of “innovation skills” will be the attributes that the graduates of the program will be expected to acquire. Each of the identified skills will then be associated with activities that specifically demonstrate, teach, and allow the students to experience the benefits of the particular skill. Next these activities will be associated with one or more modules that provide the best means of engaging the students in those particular activities.

A preliminary list of “innovation skills” has been prepared for the purpose of prototyping the proposed program. Figure 1 shows the four main groups of skills that are essential to becoming more innovative.

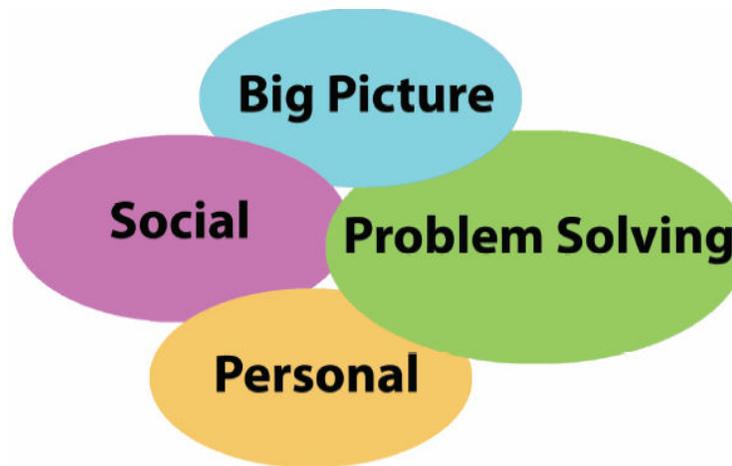


Figure 1: Innovation Skills

They include, but are not limited to:

- **Problem solving and entrepreneurial skills**, such as explorative, divergent, convergent and critical thinking, as well as intuition, estimation, imagination, knowledge integration, and the ability to act on ideas.
- **“Big picture” skills**, such as the observation of problems in wider contexts, and familiarities with non engineering disciplines.
- **Personal skills**, such as persistence, curiosity, risk taking, reading and comprehension, humor, teamwork, communication, the cultivation of a positive can-do attitude, as well as life-long, lateral learning and artistic abilities.
- **Social skills**, such as economic, political, cultural, ethical, and environmental awareness.

Figure 2 shows the ten Module types currently represented in the program prototype that will be designed to stimulate innovative thinking. They will provide the basis for the environment, curriculum, and activities components of this program. Note that even though the focus of this project is on teaching and learning innovation, some activities are suitable for experiencing leadership or entrepreneurship as well.

An example of the association of the skills, activities and modules is shown in Table 1. The x, xx and xxx notation in the “skills” column signifies the relevance of the activities to the specific skills. It must be noted that this list is an intelligent guess based on literature on the subject and accumulated experiences. A more complete list is currently being developed.

Following are brief descriptions of the ten types of modules. Note that a certain type of module, e.g., “Camps” may appear more than once in a cohort’s four year program. The difference between the different modules that carry the same name lies in the specific activities that comprise them.

1. **“Community Modules”**: Our university unique location allows interaction with a cultural-, racial- and age-diverse community for enriching the learning and teaching environment. This module makes use of this diversity and consists of several elements. One of these elements is reaching out to the K-12 community where some of the students in the program will help in teaching technology at local schools. Students from each cohort will be engaged in hands-on laboratory experiments. For example, they might design, build and test miniature bridges using dedicated computer programs; use fiber-optics technology to teach optics and communication basics; or apply computers to control multi-cylinder pneumatic systems. Another “Community” element that will be conducted by other students could be reaching out and helping the elderly community in our geographic region, as well as collaborating with retired professionals to enhance teaching and to help teachers in local schools.

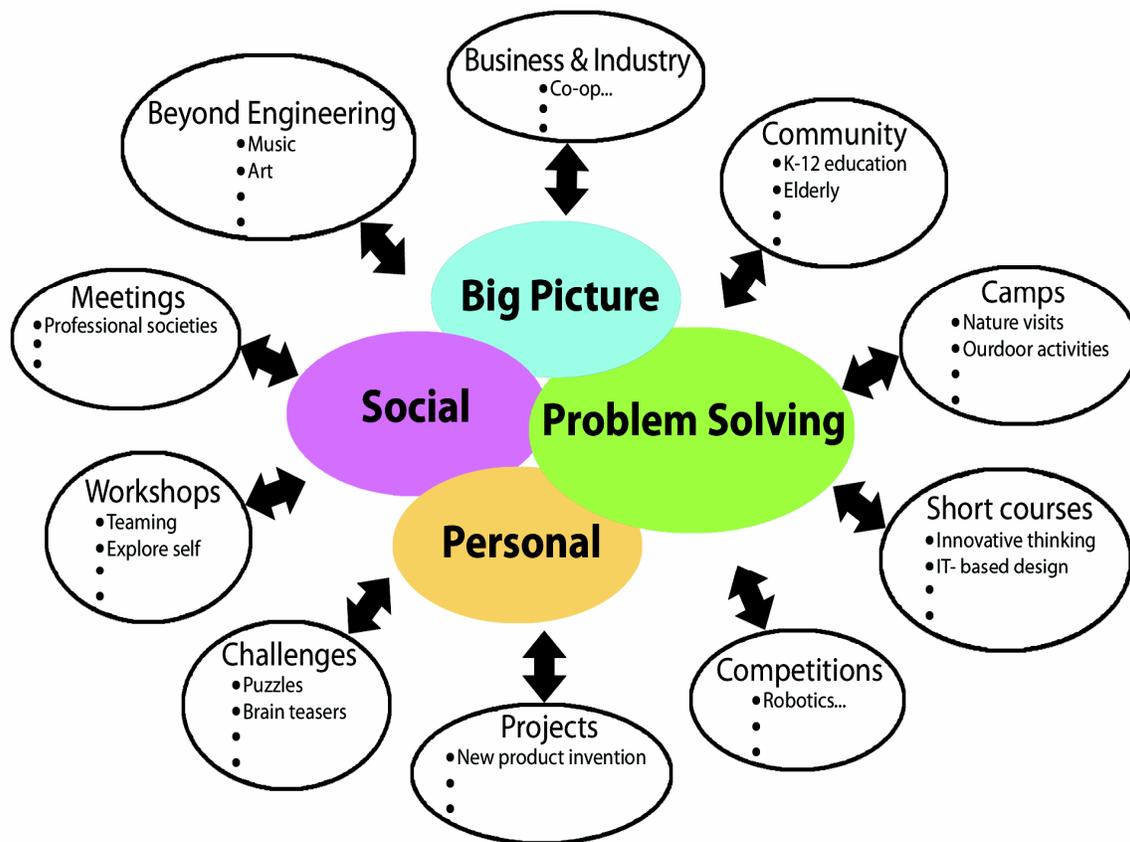


Figure 2: Innovation Modules

2. **“Camps Modules”**: In one instance students will learn to know each other’s qualities including their own and to deal with teaming issues through indoor and outdoor activities. These activities will

include measuring the height of a building using a mirror and ruler, rope-based team-building exercises, crossing an imaginary river with limited resources and large teams, sports activities, and/or the electric maze, an activity where two teams must cross a maze with buzzing floor mats that replace imaginary walls. Other “Camps” opportunities include nature visits, i.e., a set of one-day visits to local, State and National parks. The idea is to experience different problem solving activities outside the laboratory that emphasize the universality and transferability of innovative skills. An example for such team-based activity is crossing a real river using limited resources (e.g., small boat, some short rope, several wooden logs) and multiple constraints (e.g., time limit, max weight allowed on a boat). These nature and outdoor activities will be followed by oral presentations and written reports by the students.

Module	Activities	Skills			
		Big picture	Problem solving	Social	Personal
Community	Mentoring & Big Brother/Sister care K-12 Teacher assistants Community projects Elderly assistance	xx	x	xxx	
Camps	Creativity boot camp & nature visits Electric maze game Measuring height of the building problem Outdoor teambuilding rope activities		xx	xxx	x
Short Course	Innovative Thinking New Product Invention IT-based Database Management		xx	x	xxx
Competitions	YouTube inventors video competition Robotics competition FIRST-type design competition		xxx	x	xx
Projects	Intelligent speed bump "Smart" elevator Hand-washing warning system Solar powered house	xx	xxx	x	
Challenges	Brain teasers/3D puzzles Constrained driving assignments Rough estimation problems (Fermi questions)		xxx	x	xx
Workshops	Self-discovery (personality traits) Corporate culture & you panel discussion Teambuilding Negotiation game	xx	x		xxx
Meetings	Student professional societies Professional networking Graduate/Professional studies seminar	xxx		xx	x
Beyond Engineering	Music appreciation Book reading & discussion Performing arts Drawing on the right-side of the brain	xxx		xx	x
Business & Industry	Internship assignment Student presentations on internships Industry panel discussions Business/Industry projects	xx	xxx	x	

Table 1: Module-activity-skill Relationship

3. **“Short Course Modules”** These types of modules are meant to deliver material that normally needs at least 15 hours of teaching and additional 15 hours for self learning, reflecting and practice. The plan is to have two courses which will run during the second year of each cohort. The first course titled: **Inventive and Innovative Problem Solving**, focuses on teaching and fostering methods for inventive and innovative thinking. Specifically systematic methodologies will be presented for thinking out-of-the-box based on well established literature and the cumulative experience of the authors. The following topics could be included in such a short course:

- The idea behind inventive/innovative thinking; Is it teachable? Can it be learned? Inventive/innovative problem-solving as a combination of divergent and convergent thinking.
- Problem exploration and definition.
- Brainstorming: guidelines and practice.
- 'Systematic Inventive Thinking' (SIT) method derived from TRIZ and SCAMPER. Participants will learn concepts of inventive/innovative problem-solving and new product development, such as, The Closed World principle and heuristics like Inversion, Duplication, and Breaking Symmetry.
- 8D methodology for innovative Problem Solving. Participants will experience problem solving by exploring ideas in eight different dimensions, namely, Uniqueness, Dimensionality, Directionality, Consolidation, Segmentation, Modification, Similarity and Experimentation.

The material in the course will be complemented with activities from the “Projects”, “Competitions”, and “Challenges” modules.

The second course is a multi-disciplinary class titled: **Innovative Design in Practice**. This course consists of project-based learning in subjects related to information technologies (IT). The project aims at learning the development of an innovative data system for an existing real-life application. Participants will learn and apply necessary basic programming skills/knowledge to explore and implement innovative solutions. A typical process of developing an information system, often called the 'Project Life Cycle,' is described in Figure 3 (Yourdon, 2007).



Figure 3: Project Life Cycle

In this course, student teams will develop a data system for a real-time 911 call handling dispatch system, hospital emergency rooms, a space station, or a dental clinic. In the latter the system will enable the clinic management and employees to store and handle all the information necessary for the business, (customers’ medical information, suppliers, stock management, accounting, etc.). The developers will construct a range of databases and a range of interfaces for different users, such as doctors, secretaries and office managers. The design and testing of the system will take place in a fully computerized environment, using software packages such as Computer Assisted Software Engineering (CASE).

The area of information system design is interdisciplinary in nature and suitable for fostering students’ innovative thinking in non-engineering areas. In this exercise students will be confronted with issues and problems in diverse areas such as project management, accounting, programming, system-thinking, information technologies, graphics and visualization. Students will deal with socio-economic issues, security and protection of a person’s private medical information and the associated ethical considerations and implications. The students will work in teams on the development of relatively simple systems, with the aim of ensuring that each participant will experience the entire project development process and the group will produce a useful and innovative product.

This work provides an excellent opportunity for learning, preparing and posting e-portfolios on the web. Web-based portfolios are a relatively new way for students to describe, explain, reflect, demonstrate, and assess what they have done. It is a new integrative learning experience. The e-partfolios will also

allow for a more efficient interaction with faculty and staff at the university, and enrich the advising process.

4. **“Competitions Modules”**: These modules are geared towards teaming and communication skills. For example, the Task Force on the Future of American Innovation sponsors a competition for teams to create a short video that presents an inspiring story about scientific innovation in America. The video is expected to illustrate how scientific discoveries resulting from federally funded research in the physical sciences have changed our lives. The video can focus on past transformational research or showcase what the future might bring. Participants are encouraged to use music, humor, or other formats to help celebrate American innovation, now and for the future.

The use of LEGO® MindStorms™ wheeled sensor-based programmable mini-robots to accomplish a strategy-oriented robotic task is another well known method for a “Competitions” module. The programming is done in a high-level language. Examples for such competitions are team-based autonomous competition such as “get there first” and “getting out of a maze” competitions. The specific instructions for the “maze” competition are: design and build an autonomous robot that will get out of the maze. The starting point of the maze is kept confidential until the beginning of the race. First robot of the two to complete the task is the winner.

Another “Competition” alternative is the Solar Decathlon is a competition sponsored by the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy, in partnership with its National Renewable Energy Laboratory (NREL). In this instance, teams from colleges and universities around the globe, participate in an unparalleled solar competition to design, build, and operate the most attractive and energy-efficient solar-powered home. There are 10 separate contests used to determine an overall winner. Using only energy from the sun, the teams generate enough electricity to run a modern household. With an eye on energy efficiency, the students carefully choose the systems, products, and appliances used in their houses.

5. **“Projects Modules”**: These modules are designed to engage students in a creative problem solving situation from initial exploration to final demonstration. Based on experiences from the “Bridge to Engineering” approach, students will:

- explore historical, current, and edge-cutting technologies,
- discover new knowledge,
- become more creative and inventive,
- interact with peers and team members and lead teams,
- share their knowledge and solutions with others, and
- “put it all together” for the betterment of the community.

Examples for projects in these modules could include:

- (a) Problem: Some people do not wash their hands before leaving public restroom. Solve it!
- (b) Design a new speed bump that adjusts its height based on the approaching car: the faster the car, the higher the bump.

6. **“Challenges Modules”**: Modules of this type consist of simple sounding assignments designed to make the student become aware of their unconscious thought patterns that lead the mind into different modes of thinking in order to successfully complete the assignment. The modules might begin with team-based untying chain puzzles, move to solving 3-D mechanical puzzles, and culminate with the following sequence of driving assignments:

- Make a complete stop and wait at least 2 seconds at every stop sign
- Drive in a speed lower than the speed limit
- Wait at least 5 seconds before changing a lane
- Drive as if a policeman is driving behind you.

Judging by students’ feedback, these activities turned out to be very useful in making the students aware of their unconscious habits and the struggle to change them.

It should be noted here that a set of unique IT activities that incorporate human-centered experience for studying computer science concepts will be employed as part of the “Competitions”, “Projects” and “Challenges” modules. For example, instead of teaching “ordering” and “binary search” algorithms,

“numbered” students will be asked to silently move in the classroom and explore “optimal” algorithms by observing their peers’ numbers and making local decisions. The self-explored algorithms will later be discussed and programmed. This kind of class activity has proven to be very helpful in developing a more fun and creative environment. This hands-on human-based approach brings a new twist for learning and teaching in IT and CS.

7. **“Workshops Modules”**: These modules are based on our experience from an NSF-funded STEP program. The success of this program indicates that incorporating its major concepts into the proposed program will meaningfully enhance students’ innovation-related skills. The “Workshops” modules will run twice over two semesters. Participants will appreciate the importance and basic elements of teamwork in school, business and industry. They will understand the basic elements of effective work and communication in teams, understand the role of industry internships in engineering education, and be acquainted with the expectations that employers have for interns. In these workshops, students will understand their own personality traits, become more motivated to develop a career plan, understand how to best present themselves, and gain additional experience in making professional presentations with feedback from fellow students.

8. **“Meetings Modules”**: These modules will provide the participating students with the opportunity to participate in the College of Engineering and Computer Science student professional societies and be acquainted with University administrators as well as representatives from business and industry. Professional speakers will be invited to discuss trends in technologies, professional opportunities, and the workplace. In addition, student participation will be facilitated through a variety of panel discussions with representatives of the University as well as business, government, and industry.

9. **“Beyond Engineering Modules”**: These modules are provided to make technically oriented students aware that an essential part of broader-based educational experience lies in areas completely outside of science and mathematics. Students will be exposed to music, art, theatre, book-reading and so on. For example, they will experience artistic drawings using concepts from Edwards (1999). In a different activity students will be divided into several reading groups. Each team will read a book and discuss it with the whole class. In addition, specific books, e.g., “Blink,” will be read by all students for class discussions. Here are some examples for relevant books:

- *Blink*, by Malcom Gladwell
- *The Seven Habits of Highly Effective People*, by Stephen R. Covey
- *The Art of Innovation*, by Tom Kelley and the Deep Dive story
- *Five Dysfunctions of a Team*, by Patrick M. Lencioni

10. **“Business and Industry Module”**: This module is a culmination of the innovation odyssey that the students have experienced in the past three years. This particular module includes internship in industry with periodic feedback, interaction with the university, and assessment. This is where students put their knowledge and skills together to become “Innovation Ambassadors”.

Status of the program

The College of Engineering and Computer Science at Florida Atlantic University began the first cohort of Honors Scholars in the Innovation Leadership Honors Program in the Fall 2008 Semester. The program overlays our existing curricula in engineering and computer science and provides a select group of students an enhanced background and training in innovation, entrepreneurship, leadership, and communication. Our Honors Scholars complete both the degree requirements of their major and the special requirements of the Innovation Leadership Program.

The inaugural cohort of twenty-six students began the program by enrolling in a special section of our **Fundamentals of Engineering** course that emphasized a “systems approach” to show the integrated and interconnected nature of the seemingly disparate parts of an engineering problem. The course demonstrated that certain fundamentals are common to all disciplines and exposed students to the value of modeling and systems analysis in the design process. There were two major projects in that class that provided the hands-on experience necessary to demonstrate the design concepts

presented in class lectures. In the first project, five student teams were each provided an old bicycle and a new electric blender which to build a “Human-powered Smoothie Machine”. These machines competed against each other to demonstrate their capabilities as part of the FAU Sustainability Day festivities. The second major project used Electronic Article Surveillance equipment donated by a member of our Executive Advisory Council to practice the skills of on-line research, hypothesis forming and testing, and reverse engineering to determine how these devices actually worked.

This course includes a Short Course Module (for a system level understanding), Projects Module for hands-on appreciation and understanding of engineering, and a portion of a Challenges Module.

This same cohort is currently enrolled in the *Technical Writing* course. This course is specifically designed to familiarize our engineering students with the content, organization, format, and style of specific types of engineering documents. The students are learning to compose within various genres such as instructions, reports, manuals, frequently-asked-questions, as well as object and process descriptions. Opportunities to exercise oral and graphical presentation skills are also planned in the second half of the course.

Students’ reactions to these classes have been very positive and constructive. Recruitment of the next cohort of Honors Scholars is well underway for the Fall semester of 2009.

Assessment

Program assessment will consist of two major ingredients (Scriven, 1991):

- **Formative evaluation** is aimed at providing information and feedback on performance, to improve the program as it develops and progresses and on supporting recommendations to continue, modify, or eliminate specific project activities and strategies. This evaluation will typically take place in short intervals, for example during each course or workshop.
 - **Summative evaluation is intended to** identify larger patterns and trends in performance, judge whether the project is proceeding as planned and evaluate whether it is meeting its stated goals and objectives according to the proposed timeline. The major aim of this sort of evaluation is to provide critical data for decision-making at all steps of project development and implementation. This level of evaluation will typically be conducted over longer intervals such as every six- to twelve- months.

As is common in the literature on evaluation of social and educational projects, two evaluation methods will be combined as follows (Denzin, N.K. and Lincoln, Y.S. (eds), 1994)

- **Qualitative evaluation** aimed at discovering, examining and analyzing phenomena, behaviors and relationships that can not be described numerically or analyzed by mathematical models. This sort of evaluation will consist of data collected by methods such as: observations in classes, videotaping selected activities, semi-structured interviews with individuals or small groups, talks with the instructors, on-going self and peer evaluations, IU and program exit interviews, and portfolio (and e-portfolios).
- **Quantitative evaluation** is based on more 'hard' data like students’ grades in various courses and the percentage they attend and succeed in the courses and other activities. Quantitative evaluation will also include administering feedback questionnaires and electronic surveys during each course or at the end of the academic year.

While the results of qualitative evaluation will be presented through verbal reports or conceptual models, the findings of quantitative techniques will involve the extensive use of mathematics and reports based on graphs and empirical data. The curriculum can and will be modified in response to on-going formative and summative feedback gathered from the preceding cohorts. Currently we are exploring new ways for assessing the teaching and learning of innovation.

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References

Altshuller, G.S. (1988). *Creativity as an exact science: The theory of the solution of inventive problems*, New York: Gordon and Breach.

Barak, M. & Mesika, P. (2007). Teaching methods for inventive problem solving in junior high school, *Thinking Skills and Creativity*, 2(1), 19-29.

Barak, M. (2004). Systematic approaches for inventive thinking and problem solving: Implications for engineering education, *International Journal of Engineering Education*, 20(4), 612-618.

Barak, M. (2006). Idea focusing versus idea generating: A course for teachers on inventive problem solving, *Innovations in Education and Teaching International*.

Barak, M. and Goffer, N. (2002). Fostering systematic innovative thinking and problem solving: Lessons education can learn from industry, *International Journal of Technology and Design Education* 12(3), 227-247.

Chau, K. W. (2005). Problem-Based Learning Approach in Accomplishing Innovation and Entrepreneurship of Civil engineering Undergraduates, *International Journal for Engineering Education*, 21 (2), 200-204.

Denzin, N.K. and Lincoln, Y.S. (eds) (1994). *Handbook of Qualitative Research*, Thousand Oaks, California: SAGE.

Eberle, B.F. (1977). *SCAMPER*, Buffalo, NY: D.O.K. Publishers.

Edwards, B. (1999). *Drawing on the Right Side of the Brain*, Tarcher Putnam, New York.

Goldenberg, J. and Mazurski, D. (2002). *Creativity in Product Innovation*, Cambridge, UK: Cambridge University Press.

Goldenberg, J., Mazurski, D. and Solomon, S. (1999). Creative sparks, *Science* 285(5433), 1495-1496.

Gundling, E. (2000). *The 3M Way to Innovation*, Kodansha International, Tokyo.

Horowitz R. & Maimon, O. (1997). Creative design methodology and the SIT method, Proceedings of DETC'97, ASME Design Engineering Technical Conference, Sacramento.

Leach, E. & Little, T (2005). Weaving Innovation into the Fabric of Engineering Education, *International Journal for Engineering Education*, 21 (2) 200-204.

Osborn, A.F. (1963). *Applied Imagination: Principles and Procedures of Creative Thinking* (3rd ed.), New York: Scribner.

Radcliffe, D. (2005). Innovation as a Meta-Attribute for Graduate engineers, *International Journal for Engineering Education*, 21 (2), 194-199.

Raviv, D. (2002a). "Eight Dimensional Methodology for Innovative Thinking", Proceedings of the American Society of Engineering Education (ASEE), National Conference, Montreal, Canada, June.

Raviv, D. (2002b). "Do We Teach Them How to Think?" Proceedings of the American Society of Engineering Education (ASEE), National Conference, Montreal, Canada, June 2002.

Raviv, D. (2003). "Learning Systematic Problem Solving: Case Studies", Proceedings of the American Society of Engineering Education (ASEE), National Conference, VA, June.

Raviv, D. (2004). "Hands on Activities for Innovative Problem Solving," Proceedings of the American Society of Engineering Education (ASEE), National Conference, Salt Lake City, Utah, June.

Raviv, D., Morris, M. and Ginsberg, K. (2005). "On Teaching and Assessing Engineering Innovation, Proceedings of the American Society of Engineering Education (ASEE), National conference, Portland, Oregon, June.

Raviv, D. (2006). "On Teaching and Assessing Engineering Innovation: Participants' Perception," Proceedings of the American Society of Engineering Education (ASEE), National conference, Chicago IL, June.

Steiner, C. S. (1998). Educating for Innovation and Management: The Engineering Educators' Dilemma, *IEEE Transactions on Education*, 41(1), 1-7.

Scriven, Michael (1991). Beyond Formative and Summative Evaluation', in McLaughlin, M.W. and Phillips, D.C. (eds) *Evaluation and Education: At Quarter Century, 90th Yearbook of the National Society for the Study of Education*, Chicago: University of Chicago Press: 18-64.

Yourdon, E. (2007). *Structured Analysis* (online and updated version of the book *Modern Analysis*, 1989). <http://www.yourdon.com/jesa/jesa.php>.