AC 2012-4450: DEVELOPING INNOVATION SKILLS AND ASSESSING STUDENT LEARNING AT MUSE

Dr. R. Radharamanan, Mercer University

R. Radharamanan is currently working as professor of industrial engineering and Director of Mercer Center for Innovation and Entrepreneurship (MCIE) at Mercer University in Macon, Ga. He has 38 years of teaching, research, and consulting experiences. His previous administrative experiences include President of International Society for Productivity Enhancement (ISPE), Acting Director of Industrial Engineering, as well as Director of Advanced Manufacturing Center at Marquette University and Research Director of CAM and Robotics Center at San Diego State University. His primary research and teaching interests are in the areas of innovation and entrepreneurship, manufacturing systems, robotics and automation, quality engineering, and product and process development. He has organized and chaired five international conferences, co-chaired two, and organized and chaired two regional conferences. He has received two teaching awards and several research and service awards in the United States and in Brazil. His professional affiliations include ASEE, IIE, ASQ, SME, ASME, and ISPE.
Developing Innovation Skills and Assessing Student Learning at MUSE

Abstract

This paper presents the innovation and entrepreneurship education activities of Mercer Engineering Entrepreneurship Education Program (MEEEP) developed and implemented through Kern Family Foundation grants in 2007. How Mercer University School of Engineering (MUSE) promotes entrepreneurial mindset and develop innovation-related skills among engineering students are presented in term of curriculum development, entrepreneurship club activities, recruiting and involving students and faculty, assessment of entrepreneurship courses, the challenges encountered in implementing/sustaining the program and the lessons learned.

The course sequence developed and implemented integrates elements of entrepreneurship with engineering education and instills entrepreneurial mindset among engineering students; fosters innovation and creativity in engineering disciplines; helps the students to develop business plans for the entrepreneurial design projects and compete in the annual business plan competition, and promotes new ventures creation. The program outcome is measured based on the percentage of students impacted, faculty involvement, students’ participation in conferences, patents applied, commercial products developed, companies formed, and the feedback from graduating students. The students learning outcomes and their professional competencies are assessed using KEEN-TTI assessment tools.

The expansion of this program through the recently established Mercer Center for Innovation and Entrepreneurship (MCIE) will support educational interdisciplinary curricula and co-curricular activities directly benefiting students and provide multi- and cross-disciplinary teaching, learning, and research opportunities on innovation and entrepreneurship to faculty and students.

Introduction

In recent years, the entrepreneurship education and research has focused a great deal of attention on opportunity recognition as a key aspect of research and practice [1]. The field of entrepreneurship has been defined as the “study of the sources of opportunities; the process of discovery, evaluation, and exploitation of opportunities” [2]. The entrepreneur has been described as “an innovator or developer who recognizes and seizes opportunities, converts these opportunities into workable and/or marketable ideas” [3].

Observations have been made on the changing role of universities in society [4]. The importance of entrepreneurship education has been emphasized in business and engineering schools. There is a growing need to enhance the entrepreneurship education in universities and colleges due to globalization and emerging international competitions [5-6]. Entrepreneurship requires learning methods, pedagogical processes and frames for education [7]. Managing innovation, integrating
technological, market, and organizational change have been studied by several authors and are being taught at business school [8-9]. Design for manufacture and assembly and concurrent engineering concepts have been addressed in technology ventures and engineering entrepreneurship education [10-12].

In addition to the traditional roles of knowledge production and diffusion through research and teaching, universities have become more actively involved in the commercialization of knowledge [4]. Creation of academic ventures and business incubation has received increased attention lately [13-15]. Academic ventures are seen as important means for enhancing local economic development, generating income to support research, and encouraging inventor involvement [16].

With the changing role of universities, the role of academics has also changed. From being more likely to have the role of advisors, facilitating the transfer of knowledge to the new venture, they are today more likely to be members of the entrepreneurial team, thus playing greater role in identifying and developing the entrepreneurial opportunities, acquiring resources, and organizing the venture [4].

Entrepreneurial education must include skill building courses in negotiation, leadership, new product development, creative thinking and exposure to new technological innovation [17]. Technology must be embraced within the classrooms. Solomon, Duffy and Tarabishy [18] conducted one of the most comprehensive empirical analyses on entrepreneurship education. In their view of entrepreneurship pedagogy, they stated, “A core objective of entrepreneurship education is that it differentiates from typical business education. Clearly, for entrepreneurship education to embrace the 21st century, professors must become more competent in the use of academic technology and also expand their pedagogies to include new and innovative approaches to the teaching of entrepreneurship.”

Since 2006 KEEN (Kern Entrepreneurship Education Network) schools are preparing more entrepreneurial engineers in the United States [19]. There are 22 KEEN schools that share the same vision to instill entrepreneurial mindset into engineering undergraduates. MUSE, one of the KEEN schools, has recently established the Mercer Center for Innovation and Entrepreneurship (MCIE) to promote entrepreneurship education at Mercer campus and collaborate with other KEEN schools in the areas of common interest that include but not limited to: low cost rapid prototyping, smart product design, assistive technologies, alternate energy technologies, and integration of engineering and general education.

**Mercer Engineering Entrepreneurship Education Program (MEEEP) [20]**

The purpose of Mercer University’s School of Engineering is to educate a student who is prepared to be practicing engineer, one who can responsibly contribute to a global society that is becoming ever more dependent on technology. While the focus of the engineering school is to educate engineers, its graduates may enter many fields of graduate studies, especially those requiring the disciplined problem solving methods developed in the undergraduate curriculum. The engineering graduates have entered professional graduate programs in medicine, law, and business, as well as graduate engineering programs. There are 420 undergraduate and 150
graduate students at Mercer School of Engineering. The ABET accredited undergraduate program has biomedical, computer, electrical, environmental, industrial, and mechanical engineering specializations. There are 28 engineering faculty engaged in teaching undergraduate and graduate programs [21].

The entrepreneurship certificate program was established through Kern Family Foundation Grants in 2007. This program is open to all engineering students at MUSE. Students who complete the course requirements will receive a Certificate of Achievement in Engineering Entrepreneurship. The entrepreneurship certificate program requires completion of the following courses:

- MKT 361: Principles of Marketing
- MGT 363: Principles of Management
- MGT 427: Entrepreneurship
- EGR 482: Engineering Innovation and Creativity
- EGR 483: Entrepreneurship in Engineering Design

**Note:** EGR 482 must be taken with EGR 487: Engineering Design Exhibit I and EGR 483 must be taken with EGR 488: Engineering Design Exhibit II.

In addition to the above courses the engineering students are encouraged to take ECN 150: Principles of Microeconomics during their sophomore year. Table 1 shows the courses taken by semester to complete the certificate program in entrepreneurship. The catalog description of the entrepreneurship certificate program courses are found in Mercer University Catalog [21].

<table>
<thead>
<tr>
<th>Sophomore-1</th>
<th>Sophomore-2</th>
<th>Junior-1</th>
<th>Junior-2</th>
<th>Senior-1</th>
<th>Senior-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>EGR 480</td>
<td>EGR 487</td>
<td>EGR 488</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MGT 427</td>
<td>EGR 482</td>
<td>EGR 483</td>
</tr>
<tr>
<td>(ECN 150)</td>
<td>MKT 361</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MGT 363</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1: Fall semester; 2: Spring semester.

In addition to the certificate program courses, course modules on creativity, invention, innovation, and entrepreneurship have been developed and taught in the following freshman through senior level courses: EGR 107: Introduction to Engineering Design; MAE 205: Visualization and Graphics; EGR 245: Electrical Engineering Fundamentals; ISE 370: Manufacturing Processes; MAE 305L: Manufacturing Practices Lab; ISE 425: Computer Assisted Manufacturing Systems & Lab; ISE 429: Robotics; BME412: Biomechanics; and BME413: Advanced Biomechanics. The MEEEP courses and modules provide opportunities for all engineering students to be part of entrepreneurship program at MUSE.

Since 2007, all engineering students took one or more courses and/or modules listed in the entrepreneurship certificate program; 25 entrepreneurial senior design projects were funded; 100 or more students participated in the business plan/entrepreneurial senior design project competitions; one of the projects received national and state recognition; ten projects received
regional/Mercer awards; more than 40 papers were presented in regional, national, and international conferences by faculty and students; students and faculty applied for 5 provisional patents and 2 utility patents; students and faculty are in the process of forming at least two startup companies focusing on low cost electromechanical and biomedical devices; and more than 25 students are working as intrapreneurs in major industries/corporations in Georgia and neighboring states. Students and faculty team organized “Mercer Innovation Chase” competition among Mercer students during March 18-20, 2011. The winning team participated in the “Chicago Innovation Chase” competition held during September 8-11, 2011. The second “Mercer Innovation Chase” competition will be held during April 12-14, 2012.

Mercer Center for Innovation and Entrepreneurship (MCIE)

In 2010, Mercer’s Academic Initiatives Monetary Fund (AIM Fund) has approved the creation of the “Mercer Center for Innovation and Entrepreneurship” at MUSE, to enhance the activities of MEEEP across Mercer campus. The center is operating since August 2010. The MCIE focuses on cross-disciplinary educational programs (teaching, collaboration, and learning) as well as research and scholarly activities among Mercer faculty and students. This unique center initially involves the School of Engineering, School of Medicine, School of Law, School of Business and Economics, and College of Liberal Arts. Possible future participation is envisioned from other colleges and schools such as College of Nursing, College of Pharmacy and Health Sciences, School of Theology, and School of Music. The MCIE provides an interdisciplinary collaboration that is necessary for submitting competitive extramural funding proposals. It serves as a platform for diverse scholarly activities, curricular and co-curricular enhancements.

On August 20, 2010, the MCIE and MEEEP organized a workshop for the entire engineering faculty on “entrepreneurial education through case studies.” The workshop had sessions on (1) entrepreneurial thinking/entrepreneurial mindset (2) importance of entrepreneurship in engineering education (3) role of engineering faculty and faculty development and (4) team work on entrepreneurial thinking and case study. All 28 engineering faculty participated in the workshop.

During September 16-17, 2010, KEEN Regional Conference on Innovation and Entrepreneurship was hosted by the MCIE and MEEEP at the Mercer University School of Engineering. The overall objective of the conference was to bring together faculty and students from KEEN schools on a common platform and discuss about the progress made in each KEEN school in the areas of invention, innovation and entrepreneurship through faculty and student presentations and promote future collaboration among participating KEEN schools: (1) initiate collaboration in teaching, senior design projects, and exchange of faculty and students; (2) identify directions for future regional conferences; (3) promote faculty and students interactions; and (4) explore submitting joint proposals to funding agencies.

Faculty, staff and students from eight KEEN Schools (Baylor University, Calvin College, Illinois Institute of Technology, Lawrence Technological University, Mercer University, Milwaukee School of Engineering, Saint Louis University, and University of Detroit Mercy) participated and presented their projects and research work on invention, innovation, and entrepreneurship and discussed possible collaboration among KEEN schools and future direction for the KEEN
regional conferences. More than a hundred faculty, students, administrators, and industry personnel participated in the regional conference.

For future regional conferences, the faculty participants recommended the following:

- face-to-face meetings to begin collaborations allowing student and faculty to interact;
- panel of faculty advisors in different areas (patent applications, marketing, design for manufacture/assembly etc.) allowing students to ask questions in their specific areas of need relating to their project;
- more opportunity for networking or regional faculty development opportunities;
- seed grants for KEEN schools to submit joint proposals to funding agencies;
- opportunity to bring students to regional conferences;
- effective faculty development workshops; and
- students work together on projects across the network.

The student group came up with the following recommendations:

- data base of skills and equipment available on the KEEN website;
- entrepreneurship camp that is run by an entrepreneur;
- student network on the KEEN website;
- business incubator to help students launch their business ideas;
- members of the KEEN network review student projects 1-2 months before (when first prototype is created);
- professors at different schools teach classes over the internet to get a different perspective on entrepreneurship;
- record guest speakers and make them available to other KEEN schools or do it live over the internet;
- summer exchange program between schools;
- program that allows students to shadow entrepreneurs; and
- podcast every two weeks in which an entrepreneur sends in a problem and students can present their solutions.

The KEEN Second Regional Conference on Innovation and Entrepreneurship Education was hosted and held at Mercer University Campus, Macon, GA during March 15-17, 2012. The objective of this meeting is to bring together administrators, faculty, students, and staff from KEEN Schools on a common platform to discuss about the Innovation and Entrepreneurship Education at KEEN Schools as well as possible collaboration between them on topics of common interest that include but not limited to:

- Entrepreneurially-minded Education and Culture
- Intrapreneurship Education
- Entrepreneurial Project-based Education
- Collaboration within and between Dense Networks
- Integration of Engineering and General Education
- Entrepreneurial Engineering and Enterprise
- Web-based Entrepreneurial Education between KEEN Schools
- KEEN/ABET Assessment
• Long-term Sustainability of Entrepreneurship Education
• Students' Project/Poster Presentations & Product Demonstrations
• Testimonial Presentations from Student Teams on KEEN Initiatives

Faculty, staff and students from seven KEEN Schools (Gonzaga University, Kettering University, Lawrence Technological University, Mercer University, Milwaukee School of Engineering, Saint Louis University, and University of Evansville) and members of Eurekatory, NFP, and representatives from Kern Family Foundation participated and presented their papers, projects and research work on invention, innovation, and entrepreneurship and discussed possible collaboration within and between KEEN Dense Networks in teaching, design projects, and exchange of faculty and students. The conference also had sessions on “Integration of Engineering and General Education”, “Assessment of KEEN Student Outcomes”, “Student Design Project/Poster Presentations & Product Demonstrations”, “Student Testimonial Presentations Highlighting Impact of KEEN Initiatives on Engineering Education and Student Learning” and “Future Direction for the KEEN Regional Conferences”. More than a hundred faculty, students, administrators, and industry personnel participated in the regional conference.

Low Cost 3-D Scanning and 3-D Printing Facility: The low cost 3-D scanning/printing facility has been added to the MCIE to enhance innovation and creativity aspects among engineering students as well as to instill entrepreneurial mindset that includes making prototypes of their design products as well as learning to commercialize the products they made. During the fall semester (2011) more than 50 seniors, juniors, freshman, and honors students were trained to scan 3D objects as well as design and print 3D parts/products in the new facility. During the spring semester (2012) so far 60 students were trained in this facility that includes honors students/projects, senior design projects, class projects and special projects. Another 3-D printer has been added to the facility to meet the growing need for the rapid prototyping and 3-D printing needs of Mercer engineering students.

Mercer Entrepreneurship Student Club

Mercer Entrepreneurship Student Club (MESC) started in 2007, as part of MEEEP to promote students activities on innovation and entrepreneurship across Mercer campus. More than 60 engineering students through MESC are actively engaged in: recruiting students to the entrepreneurship program; participating in the entrepreneurship certificate program; taking entrepreneurship related courses; participating in entrepreneurial senior design projects, listening to successful entrepreneurs through invited speakers and seminar; developing business plans and competing in the design and business plan competitions; promoting activities during national entrepreneurship week; raising funds to participate and present technical papers on their senior design and business plans through “Cookout” lunches and dinners and selling T-shirts that were designed and made by entrepreneurship club students; presenting technical papers in the national and international conferences; and actively participating in the activities of MCIE that include:

1. Participated in the KEEN Regional Conference on Innovation and Entrepreneurship, held at Mercer University School of Engineering during September 16-17, 2010 and interacted with the faculty and students from other KEEN schools; sixty Mercer students participated in the conference; fifteen students (5 student teams) presented their
entrepreneurial design projects in the student paper/poster and product demonstration competition and one student team got the 2 place and cash award.

2. Promoted and organized Annual Mercer Innovation Chase Competitions (March 2011); eighteen students (five student teams) participated in the competition; the winning team was sent to Chicago Innovation Chase Competition (September 2011).

3. Twelve students (5 student teams) participated in the Ford-UDM online innovation competition during September-November 2011.

4. Promoted and helped to organize the KEEN Second Regional Conference on Innovation and Entrepreneurship Education held at Mercer Campus during March 15-17, 2012. Twenty four Mercer students (eight student teams) presented and competed in the design projects competition. One student team got the 3 place and cash award.

5. Promoted organized spaghetti and marshmallow tower building competition to 110 freshman students (34 teams) and the top five teams received awarded (February 2012).

6. Twelve students will be participating in the Math, Engineering and Science Conference (MESCON) during March 23-25, 2012 at the University of Evansville and present their design projects (paper/poster presentations).

7. Promoting and organizing the Second Mercer Innovation Chase Competition to be held during April 12-14, 2012. The winning team will be sent to the Chicago Innovation Chase competition in September 2012.

Entrepreneurial Design Projects

More than ninety students (thirty plus student teams) participated in the entrepreneurial senior design projects involving business plans and product design competition during the academic years 2007-2011. Selected design projects are briefly discussed below:

The Drop Foot Device: This device was designed to treat patients with drop foot due to the damage of common peroneal nerves. A motor, sensors, and microcontroller were used with ankle foot orthoses to construct the device. The device was selected and patented by Mercer University Research Office.

Elbow Brace: The purpose of the device is to provide stability of the elbow joint in three planes of motions for post-op elbow surgeries. A 3D elbow brace simulation model was developed using Solid Work and analyzed to determine the optimal stresses and dimension of the design. The elbow brace was then designed, built, and tested by the student team.

Microcontroller Knee Prosthesis: The knee prosthetic device composed of a tiny DC motor, microcontroller, shape memory alloys, and pressure sensors. Inventors Socket scan and Matt scan were used to analyze the stresses, and gait analysis.

Alarm Insole Sensor for Diabetes: The sensor insole was designed using pressure sensitive sensors and alarm alerting system to measure the highly abnormal peak pressure of the bottom of the diabetic foot to prevent developing unexpected pressure sores/ulcers of diabetic neuropathy foot. The device was built and tested by a student team.
The Solar Golf Cart: Regular golf car is redesigned using the solar cells as necessary energy to operate the cart. Two 24-volt rechargeable batteries were used to restore the solar energy for maintaining the required energy to operate the cart.

Low Cost Universal Socket Prostheses: The universal socket was designed and built in 6 pre-made sizes using polypropylene, soft cotton liner, aluminum pipes, and SACH foot to benefit the amputees in the third world countries. The low cost universal socket prostheses were designed as part of “Mercer on Mission to Vietnam” program and the Mercer faculty and student team during the summer of 2009 and 2010 fitted the prostheses for the needed below–knee and above-knee amputees in Vietnam. This project received national recognition and financial commitment from Clinton Global Initiative University. A provisional patent has been obtained for the low cost universal socket and a Mercer faculty team is planning to start a start up venture in Vietnam to provide low cost prostheses to needy patients in Vietnam and other Asian countries.

Design and Fabrication of Automatic Power Switch for Renewable Energy Sources: The goal is to design a switch that must be able to handle up to 240 volts and 200 amps to transfer a modern household from a renewable source of energy to the grid and back again whenever the renewable source is able. The switch is to change between sources (in less than 10 milliseconds) with minimal disruption to normal electrical operations: not to have computers shut off; and electronics such as digital clocks not to lose power long enough to reset.

Infrared Multi-Input System: Two different input devices were constructed that emit infrared light using infrared LEDs that can be detected by the Wii™ remote to interact with the user’s PC. Pushing the button on the LED pen will activate the LED, which is detected as a “left mouse click” when using the software application. The LED gloves use two infrared LEDs on each hand one mounted on the tip of the index finger, and another mounted on the tip of the thumb to do the pinching motion that will cause the system to detect a “left mouse click”.

Design of a Laser Kit for High School Students: A laser kit was designed and developed that would grant students of a high-school level the opportunity to learn basic physics principles using the laser and instruction manual to gauge their understanding by having them complete a demonstration. Other specifications include portability, output power (must be between 2-5mW), and the ability to run off of battery DC power as well as have the option to plug into a wall outlet to convert AC to DC power with a minimum cost.

Retrofitting of Tabletop CNC Lathe: This project describes the infusion of new technology and the resulting extended useful life of an 18 year old computer numerical controlled (CNC) tabletop lathe. Key to the success of the project was the ability to have a low cost, high performance real-time controller that was compatible with the existing electrical components of the lathe. The Enhanced Machine Controller (EMC) Project software installed on a personal computer running a Linux Operating System was the basis of the new controller design. Artifacts were created using G-codes from existing models. The retrofitted lathe is currently being used in the Intelligent Manufacturing Systems Lab at Mercer University for teaching computer aided manufacturing and providing hands-on experience to students taking manufacturing courses (Figure 1).
Affordable Prototyping with the MakerBot Cupcake\textsuperscript{[23]}: The MakerBot Cupcake CNC machine that uses additive manufacturing technology to create objects made of Acrylonitrile Butadiene Styrene (ABS) was assembled and made operational. It converts a 3D model to a usable physical object. Alterations such as reducing idler wheel thickness, using a higher grade material for the insulation between the heater barrel and the rest of the extruder, and fabricating a removable heat source were made to the machine to ease maintenance and improve reliability.

![Figure 1. Tabletop CNC lathe: (a) Retrofitted and functional; (b) Artifact made][22]

The MakerBot consists of a wooden frame, a build platform with X and Y pulleys for movement, and a Z platform on which the extruder sits. The extruder, and the X, Y, and Z stepper motors all have a circuit board which is connected to the Cupcake’s motherboard (Figure 2). Cupcake uses additive technology to form 3-D parts, which is ideal for prototyping and manufacturing a small number of parts. Additive technology allows the capability to print interior structures.

![Figure 2. MakerBot: (a) circuit board details; and (b) assembly.][22]

The following steps were taken to achieve successful operation of MakerBot:

- Downloading software
- Testing motors independently for vibration and backlash
• Testing extruder for idler wheel and heater barrel
• Printing: misprints or successful prints

Using the MakerBot, a whistle was successfully printed as shown in Figure 3. The interior ball did not come free from the bottom wall, and it is possible that this is a complication of the nozzle being too close to the Z platform at the start of the build, or an error in the G-codes. The whistle is a good example to print because of its interior features. The whistle is hollow with an interior ball, which cannot be achieved using a traditional milling machine.

![Printed part - different views of the whistle.](image)

Figure 3. Printed part - different views of the whistle.

Single and double gears were printed that have a hollow honeycomb interior, which reduces use of unnecessary ABS filament. This can be seen in the interior of the gear. Both the single and double gears were printed and different views of the gears are shown in Figure 4.

![Different views of gear.](image)

(b)

Figure 4. Different views of (a) single gear and (b) double gear.

The 3D printer is currently being used in the Center for Innovation and Entrepreneurship for teaching the concept of additive manufacturing and rapid prototyping to undergraduate students.
in engineering. The printer has already been used by a number of student teams working on their senior design/research projects to print their parts and prototypes.

Student teams of all the projects discussed in this section participated in the annual business plan/entrepreneurial senior design project competitions held at MUSE. Some of the projects were presented in the BME, ASEE, KEEN, NCIIA, IEMS, and ICMES conferences and published in the conference proceedings.

Program Assessment

The effectiveness of Mercer entrepreneurship program has been critically assessed and evaluated during 2007-2009 using:

- the comprehensive evaluation plan already in place recommended by KEEN advisory team to assess entrepreneurial mindset;
- assessment plan (rubrics) developed for all the entrepreneurship courses offered;
- the factors such as number of entrepreneurship courses taught, number of student enrollment, number of entrepreneurial design projects in the program, number of faculty and alumni participation in the program, support from administration, number of internal and external grants obtained, number of student entrepreneurship club activities, and number of students participation in national and regional competitions as well as conferences;
- exit interview from seniors graduating from Entrepreneurship General Education Program, Mercer on Mission to Vietnam Program, and other programs developed through the Center for Innovation and Entrepreneurship;
- faculty/alumni teams to advise and evaluate the entrepreneurial senior design projects; and
- Georgia based entrepreneurs to serve as advisors/mentors to student project design teams as well as judges for entrepreneurial senior design and business plan competitions.

During 2010-2012, the KEEN–TTI assessment tools were used in assessing freshmen through seniors as well as the Entrepreneurially Minded Engineers (EMEs) by administering the KEEN–TTI performance DNA [24-25]. More than two hundred students and EMEs took the survey and the results are being analyzed by the assessment team.

The KEEN program seeks to produce EMEs. Principles of KEEN are codified in the KEEN pyramid (Fig. 5) which emphasizes Technical Knowledge and Skills, Business Acumen, Customer Awareness and Societal Values and the KEEN Student Outcomes (KSOs). A KEEN student should be able to:

1. Effectively collaborate in a team setting
2. Apply critical & creative thinking to ambiguous problems
3. Construct & effectively communicate a customer-appropriate value proposition
4. Persist through, and learn from failure (to understand what is needed to succeed)
5. Effectively manage projects through to commercialization or final product delivery
6. Demonstrate voluntary social responsibility
7. Relate personal liberties and free enterprise to entrepreneurship
The KEEN schools are developing methods to achieve the KSOs and the assessment instruments needed to verify that the KSOs are being satisfied.

**Sustainability**

Other faculty members across the Mercer Campus are being encouraged to participate in the entrepreneurship program. Currently, faculty from engineering, business, medical, liberal arts, and law schools as well as more than 100 active engineering and non-engineering students are participating, promoting and enhancing entrepreneurship activities across the Mercer campus.

Mercer’s entrepreneurship faculty team is actively seeking funds from government funding agencies, private foundations, local industries and Mercer alumni. So far the team has received funding from NCIIA in addition to Kern Family Foundation grants. Kern Family Foundation has approved additional funding required until 2012 in order to expand the entrepreneurship program across the Mercer campus. In addition, through AIM funds, the Mercer Center for Innovation and Entrepreneurship has been developed.

Mercer’s entrepreneurship program is actively developing network of outside financial support: from Mercer alumni, local industries, successful entrepreneurs, state and local governments, Angel Investors Group etc. Some of Mercer’s alumni have already come forward to actively participate and contribute financially to senior design projects. Participating faculty members are planning to seek additional funding for the program by submitting proposals to other extra mural funding agencies.

**Future Work**

The MCIE and MEEEP will concentrate on educational as well as scholarly activities. The educational opportunities will be focused on developing and offering a minor in entrepreneurship across the Mercer campus covering all aspects of invention, innovation, creativity, and entrepreneurship. The courses will focus on project/case-based teaching and learning. The scholarly activities will initially focus on the development of low-cost rapid prototyping and smart product design facilities. There will be opportunities for innovative interdisciplinary initiatives by the faculty and students from all participating schools and colleges. Findings from
the research conducted at the center will be presented at national and international conferences and published in journals and conference proceedings.

The MCIE will (1) provide stipend for engaging undergraduate and graduate students in interdisciplinary research; (2) train the faculty and students in the development of an entrepreneurial mindset through workshops and seminars; (3) provide funds for participation in KEEN and NCIIA conferences; and (4) purchase machines and equipment for research in manufacturing, biomedical, and energy systems.

The products that will be produced from the MCIE activities include but are not limited to: development of low-cost facilities and devices for rapid prototyping, production of alternate energy, and smart product design; presentation of research results in regional/national/international conferences; publications in journals and conference proceedings; students taking entrepreneurship minor/elective courses; curricula, instructional materials, tools and techniques, patents, protocols, resource manuals, project reports, training sessions/workshops, and conferences; increases in undergraduate/graduate student enrollment; collaboration between KEEN schools, and development of national and international collaborative studies/projects through networking.

**Results and Conclusions**

The entrepreneurship certificate program established in 2007 is expanding and achieved a number of mile stones: Engineering, Business, Medical, Liberal Arts, and Law faculty members are actively engaged in promoting entrepreneurship program across the Mercer campus through the Mercer Center for Innovation and Entrepreneurship; both graduate and undergraduate students are attracted to the entrepreneurship related courses; a number of entrepreneurial senior design projects were funded and the student teams participated in the “Business Plan Competitions” as well as presented their design projects in regional, national, and international conferences. Some of the design projects received regional and national recognitions/awards during the period 2007-2011. The entrepreneurship program and assessment results are summarized in Table 2.

Some of the entrepreneurial design projects discussed in this paper are shared among KEEN schools. The learning objectives defined for these projects were successfully accomplished by the student teams and written instructions are available for most of the projects.

The challenges encountered in the early stages of the entrepreneurship program at MUSE include but not limited to the following:

- involving the upper administration for promoting the entrepreneurship program;
- recruiting students and faculty for the program;
- promoting entrepreneurial mindset among students interested in entrepreneurial program;
- seeking additional funding for the long term program sustainability;
- developing a network of outside support (mentors, judges, and advisors for the student projects); and
- engaging engineering faculty to teach courses related to entrepreneurship program.
### Table 2: Entrepreneurship program results

<table>
<thead>
<tr>
<th>Program Outcome</th>
<th>Year 2007-08</th>
<th>Year 2008-09</th>
<th>Year 2009-10</th>
<th>Year 2010-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students impacted (courses/modules)</td>
<td>30%</td>
<td>60%</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>Entrepreneurial senior design projects funded</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Students participated in business plan/innovation chase competitions</td>
<td>-</td>
<td>22</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Recognition and awards to student projects</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Students participated in meetings/conferences</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Student participation in entrepreneurship club activities</td>
<td>30</td>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Faculty participation in meetings/conferences</td>
<td>7</td>
<td>15</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Proposals submitted for funding</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Faculty participation in workshop and training</td>
<td>4</td>
<td>5</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Regional meetings/conferences participated and/or organized</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>International conferences organized/participated</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Papers presented in conferences</td>
<td>6</td>
<td>10</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Invited speakers</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Fundraising events</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Graduates working as intrapreneurs</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Commercial products developed</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Patents applied</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

The entrepreneurship courses and modules help to instill entrepreneurial mindset among engineering students and graduates. Extracurricular activities such as business plan competitions, Mercer innovation chase competitions, participation in meetings/conferences, invited speakers/seminars promote innovation and creativity among students. Students’ learning outcomes are assessed using KEEN-TTI assessment tools.

### Acknowledgments

The author wishes to express his sincere thanks to Kern Family Foundation for the initial grant during 2007-09 and the expansion grant during 2009-11 to promote invention, innovation, and entrepreneurship in engineering education at MUSE.

### References


