AC 2012-3830: TEACHING CREATIVITY AND INNOVATION IN THE CLASSROOM

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Teaching Creativity and Innovation in the Classroom

Abstract

Much is being required of engineering graduates that goes well beyond the basic skills traditionally required in engineering. While ABET assessment insures that all programs have the minimum skills and outcomes required for accreditation, it is the responsibility of academic institution to develop "core values" in their students so that the constituents are best served. Feedback from industry highlights the need for students to understand more about the areas of creativity and innovation in the context of the business environment.[1] Innovation and creativity are critical to maintaining an engineering edge in the United States' industrial base.[2] These topics deserve emphasis in classes other than dedicated design classes. This paper will outline what is being done at Baylor University to develop an entrepreneurial/intrapreneurial mindset in our students that emphasizes creativity and innovation through the KEEN Innovator program. This program is enabling faculty to help the students learn to be creative and innovative. Highlighted in the paper will be two examples where modules on creativity and innovation were incorporated into existing classes. Assessment and student response will be addressed.

One course, entitled "Electronic Design", introduced students to the creativity and innovation involved in patent process. Students were given periodic assignments linking the course material to relevant patents associated with the topic under discussion. A major laboratory assignment required the student to design a circuit to accomplish a given function while avoiding infringing on a hypothetical patent for a well-known design. In addition to reporting experimental results, students were required to prepare a patent application for their new design. The patent applications were reviewed by a team of faculty who selected the best application. A second course, entitled "Analysis and Design of Propulsion Systems," had the students learn about creativity and innovation, the Request for Proposal (RFP) process, and then apply what they learned to develop an RFP for a battlefield information gathering system. Their RFP was presented to a panel of faculty who gave feedback on both the mechanics of presentation as well as the practicality of the ideas. A written RFP was also submitted and, based on the two evaluations, a "winner" was recognized. The course went on to use an RFP in the design of a gas turbine engine cycle for a high altitude long endurance aircraft used to gather intelligence. Concepts for innovation and creativity were also evaluated on the course exams.

Introduction

Much of what is included in most current engineering curriculums is very similar. This is usually attributed to the assessment process prescribed by ABET, Inc. In particular, the General Criteria 3, a-k Student Outcomes for an engineering program are usually adopted by the departments as their evaluation outcomes for a program.[3] Many of these student outcomes are rooted in topic areas that are easily found in any engineering program and can be mapped directly to courses that are very similar from program to program.[4] However, the "soft" outcomes raise some interesting questions. These soft skills as stated in the a-k Student Outcomes include:

(d) an ability to function on multidisciplinary teams
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues

These outcomes "challenge" the faculty to examine existing engineering courses to find activities that already exist and illustrate these topics. If none can be found, many times intentional activities are added to existing courses or, as happens quite often, a new course is created to satisfy these outcomes. Some of the outcomes can be found in service courses taught outside the department. The ABET outcomes are intended to be very broad which allows a department to encompass particular educational topics an engineering program might want to emphasize. However, if one examines the mission statement of ABET as well as other professional societies, it might be argued that a-k Student Outcomes are not keeping up with the changing engineering landscape found on both the national and international arena, despite the involvement of the Industry Advisory Council of the ABET Board of Directors.[5] ABET's vision statement reads as follows:

> "Provide world leadership in assuring quality and in stimulating innovation in applied science, computing, engineering, and technology education."[6]

Part of ABET's mission statement declares that ABET should:

> "Anticipate and prepare for the changing environment and the future needs of constituencies."[6]

Nowhere in the a-k Student Outcomes are the words innovation and creativity found. While the one could infer that innovation and creativity could be part of the "soft" criterion listed above, engineering programs should be more intentional about including topics that would develop innovation and creativity. Including these topics leads to the development of the entrepreneurial/intrapreneurial mindset which is a necessity if the United States is to maintain its engineering status in the world today.[7] The Kern Foundation has captured this important emphasis for engineering education and is seeking to change engineering education through the Kern Entrepreneurship Education Network (KEEN)[8]. KEEN desires "to increase the quantity and quality of U.S. engineering talent" not unlike the vision of ABET. The difference is in the emphasis of the organization. KEEN believes that this emphasis on the entrepreneurial/intrapreneurial mindset is increasingly important as the U.S. competes to maintain its economic position in a global marketplace based on innovation. The Department of Mechanical Engineering at Baylor University has even changed its mission and objective statements to reflect this changing engineering environment and is shown below:

> The Mechanical Engineering Program at Baylor University exists to educate and equip servant-leaders who are:

1. motivated by Christian ideals and a vocational calling to improve people's quality of life worldwide
2. enabled by fundamental technical, communication, and teamwork skills
3. empowered by innovative problem-solving creativity and an entrepreneurial mindset
4. sustained by intellectual curiosity for lifelong learning
5. guided by the highest integrity, professional ethics, and commitment to professional responsibility[9]

It is necessary to define both innovation and creativity for this paper and then show the connection. A definition of creativity is given as:

> "**Creativity** is the ability to produce something new through imaginative skill, whether a new solution to a problem, a new method or device, or a new artistic object or form. The term generally refers to a richness of ideas and originality of thinking. …Studies also show that intelligence has little correlation with creativity; thus, a highly intelligent person may not be very creative. "[10]

The interesting words in this definition are to "produce something new through imaginative skill" and that "intelligence has little correlation with creativity." This seems counterintuitive. As for innovation:

> "**Innovation** . . . is generally understood as the successful introduction of a new thing or method . . . Innovation is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services. "[11]

The key phrase from this definition is the "successful introduction of a new thing or method." From these definitions it follows that innovation and creativity are linked and the following thoughts are given to illustrate this connection:

> "Innovation typically involves creativity, but is not identical to it: innovation involves acting on the creative ideas to make some specific and tangible difference in the domain in which the innovation occurs. "[12]

> "All innovation begins with creative ideas . . . creativity by individuals and teams is a starting point for innovation…"[13]

The authors' involvement in government service and business prior to their academic appointments have provided a background for this new emphasis. Typically, most faculty resist the word "entrepreneur" or any derivative primarily because it is usually associated with starting businesses. Many faculty think that the primary purpose in engineering education is not to develop our students to start small businesses. While engineers have great ideas and do start businesses, the majority of the engineering students who graduate from Baylor University will be working in industry, being a part of a larger corporation. Increasingly organizations are valuing the qualities of innovation and creativity in their new hire engineers, especially in the gas turbine industry. General Electric has an entire webpage dedicated to their "imagination = innovation" slogan.[14] Pratt and Whitney: A United Technologies Company includes innovation as one of its seven core values.[15] The phrase used is “Innovation: Envision new and creative solutions.” Honeywell's vision statement reads “Making our world safer and more secure, more comfortable and energy efficient, and more innovative and productive.”[16]

An experience at the Boeing Company as part the Welliver Faculty Fellowship Program in 2009 also reinforced the necessity of innovation and creativity in engineering education. The Welliver Faculty Fellowship Program is the product of visionary thinkers and much credit should be given to The Boeing Company for taking such a bold step.[17] The program is best summed up from the Boeing website:

> “The approach is to expose a small number of competitively selected professors from U.S. and international universities to key elements and the business realities of industry by enabling them to "look over the shoulder" of working professionals at several levels of the technical, business, and management career paths. They will leave the program with an understanding of Boeing's business including its research needs, with an improved understanding of the practical application of technical and business skills and with a network of contacts within Boeing and among their faculty peers that can form the basis of long-term relationships. There have been 149 university participants since the establishment of the program in 1995.”

The objectives state the purpose of the program very clearly:

“The Boeing Welliver Faculty Fellowship Program objectives are:

- To provide faculty with a better understanding of the practical industry application of engineering, manufacturing, information technology and business skills
- To help faculty enhance the content of undergraduate education in ways that will better prepare tomorrow's graduates for careers in a global environment
- To have faculty observe the Boeing environments, processes, and procedures with "fresh perspectives." Faculty will use their expertise to help identify areas for possible improvements and document their observations at Boeing. “

Essentially, Boeing offers “internships” to faculty members so they can learn about how Boeing operates and, in turn, bring this back to the classroom. Experiences with Boeing were very insightful. One of the authors worked with a research group that was very creative, thinking up new technologies and new ways to apply older, less mature technologies. These ideas had to then compete within Boeing for funding in order to go to the next step of prototyping. Successful testing then generally led to the technology “buying its way on the airplane.” The process was fascinating and the environment very stimulating. Many of the engineers in the research group had multiple patents. Not all jobs at Boeing could claim this type of creative environment however, these experiences at Boeing began the thought process that Baylor University students need to be aware of the environments in which they will be working and learn how to contribute ideas in a positive way for these situations.

At Baylor University, the Board of Advocates for the School of Engineering and Computer Science have repeatedly suggested that engineering students have more business acumen and along with that, the innovation and creativity being sought by industry. This, coupled with the emphasis from professional societies, leads to the importance of incorporating both innovation and creativity into the engineering curriculum thereby anticipating the changing environment and needs of industry. Dr. Victoria Rockwell, 130th President of ASME, on numerous occasions has championed the need for innovation and creativity. In a letter to the U. S. Senate concerning STEM education initiatives, she (and ASME) "…strongly support the bill's focus on innovation through a variety of best practices such as hands-on engineering competitions, STEM Master Teachers, and innovative professional development models."[18] For these reasons the KEEN Innovator program was developed at Baylor University.

KEEN Innovators

The Kern Family Foundation, located in Waukesha, Wisconsin, was created in 1998 through a generous gift from Robert and Patricia Kern, the co-founders of Generac Power Systems. The primary mission of the foundation is to improve lives by promoting strong pastoral leadership, educational excellence and high quality, innovative engineering talent. The Kern Entrepreneurship Education Network (KEEN), one of the Foundation's programs, "supports Mr. Kern's passionate desire to instill an entrepreneurial mindset in engineering students."[19]

The mission of the KEEN is to graduate engineers equipped with an action-oriented entrepreneurial mindset who will contribute to business success and transform the U.S. workforce. "The [KEEN] program attempts to increase the availability of entrepreneurship education at selected U.S. colleges and universities by supporting the creation of entrepreneurial initiatives within engineering programs."[20]

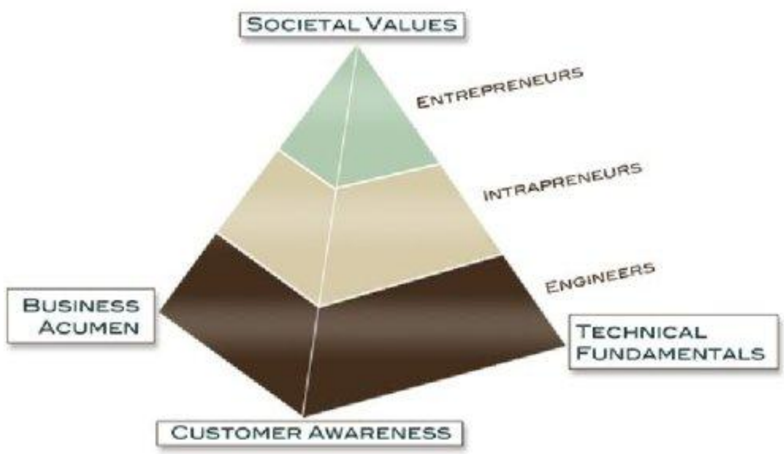

Figure 1: The KEEN Pyramid (http://www.keennetwork.com/about-keen/theory-of-change/)

As part of the third cohort of schools invited to participate in the KEEN, Baylor University was awarded a series of grants which included a major objective of encouraging the integration of entrepreneurial concepts and skills into the engineering and computer science curricula by awarding a stipend to an Engineering & Computer Science (ECS) faculty member who develops an innovative plan for fostering the entrepreneurial mindset within the course(s) they teach.[21] A Request for Proposal (RFP) was sent to all ECS faculty explaining the purpose of the Innovators program, as well as outlining the requirements for selection as a KEEN Innovator. These requirements include:

- Attend a one-day workshop presented by a KEEN Fellow to introduce the Innovators to ideation and the use of case studies in a workshop (i.e., "hands on") setting,
- Attend one of the various other KEEN faculty workshops available through the network,
- Administration of the KEEN-TTI Performance DNA assessment instrument to the

students and to themselves, and
- Publish the results of the implementation and assessment of their proposals.

In the first year of KEEN Innovator awards, the goal was to maximize the exposure of the entrepreneurial mindset to ECS students in design courses. The first two Innovators taught the freshmen, junior, and senior design courses. In the freshman design course various elements of the ideation process were introduced, along with the importance of intellectual property protection. In the junior and senior design courses, case studies were used to illustrate various elements of design such as design for prototype versus design for manufacture and mass production, emphasizing the professional skills needed in working with a design team.

In the second year, the goal was to extend the exposure to students by awarding two Innovators who taught in discipline-specific, upper-level design courses. In an “Analysis and Design of Propulsion Systems” course, new modules were incorporated on creativity in conceptual design and the students developed a Request for Proposals (RFP) for a battlefield intelligence platform. In an “Electronic Design” course students were introduced to the patent process, including the basic elements of a patent search as well as the development of a patent application for their circuit designs. The current paper summarizes the efforts of this second year participants.

In the third year, our funding was renewed which allowed the award of seven KEEN Innovators, expanding into computer science as well as engineering. The results of these KEEN Innovators course design innovations led, in part, to a large grant request from the Kern Family Foundation which continues the momentum gained in the Innovators program.

Highlighting the second round of KEEN Innovators, this paper will discuss the description of project (original motivation), the aims/objectives of project, the assessment of student grade, the assessment of objectives/usefulness of the projects, and the feedback and change for subsequent offerings of the courses in question.

Electronic Design

A critical aspect of capitalizing on creativity and innovation as an engineer is learning to effectively document and communicate important new ideas, methods, or designs in compelling and efficient ways. The patenting process is one such means of communication, as well as means of providing a tangible measure of the economic value of a given innovation.

The goal of the project has been to introduce students to the role of patents in the day to day life of an engineer and to give them an appreciation for economic value of the intellectual property produced by engineers. In their early course work students have minimal exposure to the historical and business impact of the various topics that are routinely covered from the technical side. For example, students in Electronic Design learn to analyze the electrical behavior of an operational amplifier integrated circuit or a Widlar current source, but they are typically not made aware of the work of Jack Kilby[22] or Bob Widlar[23] and how such pioneering inventive work is both protected and ultimately made available to others through the patent process.

A second goal of the project was to give engineering students a first exposure to the overall patent process and introduce them to the various players involved in the successful prosecution of a patent application. In particular, the students were surprised to learn of the necessarily adversarial role of the patent office and the role of legal precedence in shaping the way in which inventions are described and claims are crafted. As they gained understanding of these aspects of engineering, the students were challenged to sharpen their communication skills in terms of precision of description for the benefit of the patent examiner and their legal counsel as well as in the need to have power of persuasion and clarity in convincing a non-technical audience of the value of their invention.

Clearly, in a course as densely packed with content as Electronic Design, it was not possible to provide more than a basic introduction and motivation of these topics. However, the students were able to accomplish the following tasks without hampering their assimilation of the primary course content:

1. Searched for and retrieved patents within a given field
2. Learned the functions and purposes of the various sections of information in a patent
3. Learned the difference in importance between inventor and assignee
4. Developed an appreciation for the distinction between the specification of the invention and the claims
5. Developed an awareness of the time and money often expended in obtaining a typical patent.

While these exercises do not necessarily foster an increase in creativity and innovation in the thinking process of the student, they do foster an understanding of value of creativity and an appreciation for the infrastructure that has been put in place to capture and record the results of that creativity for the benefit of all. Anecdotal feedback from the several of students seems to confirm the students have recognized the benefits that have accrued from this opportunity to explore the patenting process.

To limit the grading burden for the course some of the early and easy assignments were checked only for completion. For example, the first assignment was to find a recent patent addressing the topic of amplifier impedance. The students were simply required to turn in an electronic copy of such. Selected new topics in the course required a similar search for a related patent. To encourage prompt completion of these simple tasks, a few students were chosen at random to give a one-minute description of the patent that they had submitted. To facilitate equity in this process names were selected sequentially from a randomized list made at the start of the semester. The students were unaware of this list and that they would not likely be called upon more than once during the semester.

The primary assignment called for the submission of a patent application for an improved half wave rectifier. A laboratory experiment involved comparing a simple resistor-diode half wave rectifier with a design incorporating an operational amplifier that eliminated the diode turn-on threshold effects in the half wave output at low signal levels. The operational amplifier design was such that it purposely exhibited other undesirable output behavior at high signal levels and high frequency. The experiment teaches the students how to test and evaluate the performance of circuits for various conditions of signal level, frequency of operation, and output loading. The task is then given for them to design an improved circuit that mitigates the defects in performance that they have identified.

In previous semesters, before the introduction of the patent content, this particular lab assignment involved an extensive report tailored to both technical and non-technical audiences. With the introduction of the patent content, the reporting component of the assignment was change to require a patent application for the new design. The improved designs did not have to be original for the assignment. For those students who found improved designs in the literature, the patent application was prepared as if they acting for the "inventor" in preparing the application.

While graduate teaching assistants often grade laboratory assignments, the grading task for the patent applications were reserved for the course instructor. To give the students ample time to complete the patent application the due date for the assignment was set for the end of the semester. However, to assure ample feedback and to make provision for improvement in writing style, each student was required to submit drafts of the various sections prior to a team submission of the final product. The early draft sections were marked with severity for both form and content, but no grade was assigned. The final submissions were submitted to a team of "patent examiners" comprising volunteer faculty members who ranked the submissions. The winning teams were given small prizes in recognition of their success.

The fall 2011 semester, reported here, represented the second offering of the patent project within the course. Anecdotal comments from the students who participated in the first offering in the fall of 2010 were generally quite favorable. Since Electronic Design is offered in the first semester of the junior year, there has not yet been opportunity to assess the value of the learning opportunity for graduates entering the profession.

Analysis and Design of Propulsion Systems

The idea for this application came out of a workshop held a Baylor University in the summer of 2010. The speaker, Jonathan Weaver of the University of Detroit Mercy, was introducing the faculty to innovation and creativity. The initial intention was to place aspects of creativity and business sense into the class. The class is mainly a gas turbine propulsion course which uses a three part design project. The design project was typically centered on a Request for Proposal (RFP) and was a very successful part of the course. Student teams designed an engine cycle and then "competed" their engine design against each other at the end of the course. Each team had to "sell" their engine to the "customer". While this project already had some sense of developing a company, it really was more like the Boeing model. Each team could be considered a separate conceptual design team within a single company that had to make the case that their design was better at satisfying the RFP than the competitor. In the end, Jonathan's discussions led to the plan of developing a session on creativity and then having the student teams develop an RFP for a perceived need, in this case the need for battlefield intelligence.

As a result, the project proposed for this course had two objectives. First, the students needed to see the importance creativity and innovation in the design process. Second, the students needed to understand the Request For Proposal (RFP) development process and apply creativity in writing an RFP.

Adding material to a course is very difficult, especially when the course is already full. Upon reflecting on the syllabus, three lessons (out of 42) were devoted to addressing the innovation and creativity/RFPs. Lesson 1 was entitled Innovation and Creativity and a PowerPoint presentation was developed to illustrate these topics. The presentation started by having the students define creativity and innovation. The link between the two was discussed. Next, two articles on creativity (Brain Drain (high school students joining Israeli think tanks)[24] and Aerospace Must Revive Its Spirit (a new company, SpaceX, capturing the enthusiasm seen in NASA during the 1960s)[25]) along with the experiences learned at Boeing underscored the need for creativity in the workplace. Next student teams were asked to improve on a basic bicycle design. About eight minutes were given to this task. After hearing student solutions, many of which were the "obvious" such as gears, suspension, etc., several additional ideas were offered in the PPT, many of which were not discussed by the students, such as bicycles for other functions like mowing the grass or bicycles as art. Students were then exposed to Biomimicry (using nature to inspire design) and Bosociation (pairing two seemingly unrelated functions into a product) to show how design can be inspired from many different sources. Lastly, students were exposed to an anti-creativity checklist[26] as well as creative thinking tips and Teamwork-brainstorming. The homework assignment was to brainstorm as a team (two to three students per team) for 30-45 minutes many new and different ways to use gas turbine engines. Again, minimal guidance was given so as not to prejudice the developed ideas. While this 50 minute lesson seems rather "busy" it actually flowed quite well and the students were engaged the whole 50 minutes.

Lesson 2 was about RFPs. This presentation started by discussing the homework assignment from the previous class, that of find new and different ways to use gas turbines. The lists of gas turbine applications were collected and then distributed to different teams. Each team had to evaluate the other team's solutions. From the list determine 1) the most promising idea and 2) the most imaginative. Next they were to take the most promising idea and to make it better by suggesting changes or additional applications. This exercise in the classroom was enjoyed by all and the students were very engaged. After this exercise, which took approximately 20 minutes, the PPT presentation on RFPs began with a definition of an RFP and a discussion of an RFP in both a civilian and government (DOD) context. The KC-X was used as an RFP case study. The need was defined however, the RFP process and procedure for the KC-X was not well executed. An outline of how to write an RFP, as well as elements to include in an RFP, were discussed next. Lastly, the students were given the task of developing an RFP to satisfy the need, in this case a battlefield intelligence gathering system. The RFP had to be descriptive enough so a company could develop the technology to satisfy the RFP but not so prescriptive to eliminate creative solutions. A presentation was to be made the next class lesson with a written RFP submitted two lessons later.

Lesson 3 was an RFP Panel Session. The students presented their RFP to a panel of three professors. Each team was given a time slot during the class with maximum time of up to 10 minutes. Other teams were not present to hear the "competition." The desire was to create as much of a business atmosphere as possible. Teams were evaluated on elements discussed in the RFP lesson. Professionalism in the presentation and slides were also graded. The panel deliberated on the presented RFPs and decided on a "winner" which was announced the next class period.

This sequence was offered twice to a limited student audience since this was an elective course. The first offering was to a section of 10 students and the second time to an offering of only five students. The total was six teams over the two years. The first lesson on innovation and creativity was well received by the students. It was a topic that had not been addressed in any other class that the students had in the past. Clearly, some students were able to handle the open-endedness of the creativity exercise better than others. Here is where team dynamics were very important and, when forming teams, care should be given to including creative people on each team. Students enjoyed the "anti-creativity" checklist and saw this was an interesting technique to talk about innovation and creativity. The homework exercise due in the second lesson was very enlightening. One team had 54 uses for a gas turbine engine and another team only had six (this was a team of students who did not do as well in the classroom exercise). Changing lists and having the teams see another team's work was something for which the students were not prepared. It took them by surprise but kept them engaged. The Panel Session on the third lesson went well. Some teams used their full time period of 10 minutes and some did not. Most teams were able to address the necessary components for the RFP however, some teams clearly put more thought into the details. Assessment evaluations usually fell into two categories in final grading. If creativity was more heavily weighted, then clearly one team would "win". If one were to evaluate on whether the system could actually be developed, then another would "win". In the end, the panel emphasized creativity. The written RFP was graded by the author and grading was similar to the categories used in the presentation, only now the teams were judged on how well they communicated their ideas. The design project RFP for the course provided some ideas to be incorporated into the course RFP for the design project.

Grading for the RFP project included 25 points for the presentation and 25 points for the written RFP out of 1000 points for the course. The three part design project included interpretation of an RFP and incorporated ideas of teamwork around a company theme. The total for the design project was 350 points. The first exam in the course had one multiple choice questions worth three points out of 100. The final exam also had two multiple choice questions worth 10 points out of 250.

For the six teams that participated in this exercise, the average score for the combined written and presented RFP was 89.6% which equated to 44.8/50 points. On exam one, 15 students took the exam over the two semesters with 100% score on the single multiple choice question. For the final exam, again 15 students took the exam. On the first question 6/15 scored correct for a 40% and on the second question 7/15 scored correct with a 46.7%. Clearly the innovation and creativity lesson occurred early in the semester and were not studied as much by the students for the final. With this limited set of data it is difficult to assess the success of the module in the course and no changes have been made over the two semesters. No student comments were made on the course critiques however anecdotally, the students were challenged by a different type of thinking required for this module. More information will be gathered and additional changes made to the design project to make it more competitive from a business perspective.

Conclusion

At Baylor University, steps are being taken to intentionally expose the students to the concepts of innovation and creativity in the context of the business environment. This contributes to the KEEN objective to graduate engineers equipped with an action-oriented entrepreneurial mindset who will contribute to business success and transform the U.S. workforce. While a course could be developed in the curriculum to accomplish this task, it is more desirable to include portions of these important topics in courses across the curriculum. This exposes the students to these topics several times throughout their academic career. A broader outreach will require involving more faculty in the KEEN Innovators program which will then include more courses with exposure to these topics. Students will eventually see the importance of these topics and, as the students graduate and begin their work experience, then Baylor University will be able to determine the impact of having a business acumen and exposing students to innovation and creativity. Of course this entire effort must be supported by both the administration and the faculty in order for it to be successful. The administration at Baylor University is fully supportive of this new emphasis and the faculty are beginning the journey by participating in the KEEN Innovators program. Currently about 1/3 of the faculty have participated.

References

1. "Engineering Graduates for Industry," The Royal Academy of Engineering, February 2010, last accessed March 8, 2012, http://www.raeng.org.uk/education/scet/pdf/Engineering_graduates_for_industry_report.pdf
2. "Grand Challenges for Engineering," National Academy of Engineering of the National Academies, The Summit Series on the Grand Challenges, last accessed January 8, 2012, http://www.engineeringchallenges.org/
3. http://www.abet.org/engineering-criteria-2012-2013/ accessed on January 8, 2012.
4. Jordan, W., Fry, C., "Assessing a Dense Network of Entrepreneurially Minded Engineering Programs," ASEE 2012 Annual Conference & Exposition, San Antonio, TX, June 10-13, 2012
5. 2011 ABET Annual Report, Industry Advisory Council, last accessed March 8, 2012, http://www.abet.org/2011-annual-report-industry-advisory-council/
6. http://www.abet.org/vision-mission/ accessed on January 8, 2012.
7. "Summit Series on the Grand Challenges," National Academy of Engineering of the National Academies, last accessed January 8, 2012, http://www.engineeringchallenges.org/
8. http://kffdn.org/default.asp?L1=InnovationPrograms&L2=KEEN accessed on January 8, 2012.
9. http://www.ecs.baylor.edu/mechanicalengineering/index.php?id=62490 accessed on January 11, 2012.
10. http://www.answers.com/topic/creativity accessed on January, 11, 2012.
11. Luecke, R. and Katz, R. (2003). *Managing creativity and innovation.* Boston, MA: Harvard Business School Press
12. http://www.wikipedia.org/ accessed on January 11, 2012.
13. Amabile, T. et al., "Assessing the work environment for creativity," Academy of Management Journal, October 1996, Volume 39, Issue 5, pp 1154-1184
14. http://www.ge.com/innovation/archive.html accessed on January 12, 2012.
15. http://www.pw.utc.com/about_us/company_values.asp accessed on January 12, 2012.
16. http://honeywell.com/About/Pages/our-company.aspx accessed on January 12, 2012.
17. http://www.boeing.com/educationrelations/index.html accessed on January 8, 2012.
18. http://files.asme.org/asmeorg/NewsPublicPolicy/GovRelations/PositionStatements/30470.pdf accessed on January 8, 2012.
19. The Kern Family Foundation, http://www.kffdn.org/default.asp?CID=AboutUs accessed on January 8, 2012.
20. *"Instilling the Entrepreneurial Mindset into Engineering Undergraduates,"* Timothy J. Kriewall and Kristen

Mekemson, Journal of Engineering Education, Volume 1, No. 1, July 2010, 5-19 (http://www.jeenonline.com/Vol1/Num1/Vol1No1P1.pdf)
21. Fry, C., Jordan, W., Leman, G., Garner, B., and Thomas, B., 2010, "Bringing Innovation and the Entrepreneurial Mindset (Back) into Engineering: The Keen Innovators Program," AC2010-2218, ASEE 2010 Annual Conference & Exposition, Louisville, KY, June 20-23, 2010.
22. Kilby, J. S., "Miniature Semiconductor Integrated Circuit," U.S. Patent 3,115,581, December, 1963.
23. Widlar, R. J., "Low-Value Current Source for Integrated Circuits", U.S. Patent 3,320,439, May, 1967.
24. Fulghum, David A., "Brain Gain: Israeli program grabs top 18-year-olds for key problem-solving work," Aviation Week & Space Technology, August 2, 2010, p65.
25. Aerospace Must Revive Its Spirit, Aviation Week & Space Technology, August 16, 2010, http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=space&id=news/awst/2010/08/16/AW_08_16_2010_p58-245003.xml&headline=Aerospace%20Must%20Revive%20Its%20Spirit accessed on January 11, 2012.
26. Moon, Youngeme, The Anti-Creativity Checklist, http://blogs.hbr.org/cs/2010/03/the_anticreativity_checklist.html accessed on January 11, 2012.