AC 2011-2443: INCORPORATING ENTREPRENEURSHIP INTO MECHANICAL ENGINEERING AUTOMOTIVE COURSES: TWO CASE STUDIES

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Dr. Craig J. Hoff is a Professor of Mechanical Engineering at Kettering University. He teaches in the areas of thermal design, mechanical design, and automotive engineering. His research focuses on sustainable mobility technologies including alternative fuels, fuel cells and hybrid electric vehicles. He is actively involved in the Society of Automotive Engineers and is the faculty advisor for Kettering's Formula SAE race team. Dr. Hoff is a registered Professional Engineer in the State of Michigan.

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Professor Riffe has been a member of the Kettering University faculty since 1985, teaching courses in manufacturing processes, sheet metal forming, composite manufacturing, and problem solving. In 1988, he developed a class called "Engineering Creativity" that was designed to bring out the creative side of engineering and business students. Well over 1000 students passed through this course. Because of this background, he was selected to be part of a team to teach the "Innovations and New Ventures" class on entrepreneurship that began in the summer of 2006, with him concentrating on the innovation side of the course. To date, over one hundred and eighty students have learned how to develop a product and put together a basic business plan. He led a team to develop "Entrepreneurship Across the Curriculum" at Kettering University where faculty members attended workshops designed to help put innovation projects into their classrooms. This effort resulted in Kettering University receiving the "Best in Class" award from the granting foundation. His current efforts are to help extend the entrepreneurship program across the entire institute to include all faculty and appropriate staff people.

Incorporating Entrepreneurship into Mechanical Engineering Automotive Courses: Two Case Studies

Abstract

Engineering programs are often criticized for focusing solely on technical education while ignoring industry and business needs. In order to address this situation, entrepreneurial ideas were incorporated directly into existing engineering classes. Because many faculty members are not well versed in the "entrepreneurial mindset," Kettering University offers a series of entrepreneurship/innovation classes over the course of a term to faculty from all disciplines and departments. Armed with their newfound confidence and knowledge, these faculty members are then expected to incorporate these concepts and projects into existing courses.

This paper provides information on the training and entrepreneurial techniques taught to the faculty and then on the incorporation of entrepreneurial ideas and assignments into two automotive courses offered in the Mechanical Engineering Department. The techniques used to convey the entrepreneurial ideas primarily come from the "Need-Approach-Benefits-Competition" or NABC approach espoused by Carlson and Wilmot.[1] The successes and failures of the approaches are discussed. Examples are provided to illustrate how these ideas have been used to enhance the undergraduate learning experience. Since the university has a strong automotive focus, many of the examples cited pertain to that industry, but the concepts can be easily applied to other fields such as aerospace, power production, and alternative energy.

In addition to enhancing undergraduate education, there are significant other benefits to this approach. For students, these ideas can be much more engaging than traditional classroom material and the exposure to the ideas of the "entrepreneurial mindset" helps to prepare them for careers in the fast paced society in which we live.

Introduction

It has often been stated that there is a large gap between what universities are teaching and what engineers are expected to know in industry. Engineering programs are criticized for focusing solely on technical education while ignoring industry and business needs. In response, many programs have added dedicated courses in leadership or entrepreneurship into the curriculum. The problem with this approach is that, often, students do not find that it is connected to their studies in a meaningful way. Further, it is extremely difficult to add an extra course into an existing program; therefore, this sort of class is usually offered as an elective, reaching a relatively small audience. Recently, authors increasingly argue that teaching an entrepreneurial mindset requires an integrated approach.[2,3,4]

Kettering University has adopted this approach by trying to incorporate entrepreneurial ideas directly into existing classes. This can be difficult to accomplish for several reasons. First, engineering professors find it difficult to make room in the course syllabus for an entrepreneurial education. Further, many faculty have not been exposed to the "entrepreneurial mindset" and thus do not feel prepared to broach the subject in class. Kettering University has developed what

we believe to be an effective approach to resolve these issues by offering a series of entrepreneurship/innovation classes over the term to faculty from all disciplines and departments. Armed with their newfound confidence and knowledge, these faculty members are then expected to incorporate entrepreneurial concepts and projects into existing courses.

This effort has been developed and aided by the contributions from the Kern Family Foundation, beginning in 2006. Kettering University is part of the Kern Entrepreneurship Education Network (KEEN). Through this effort, Kettering University began an initiative to integrate the entrepreneurial mindset across the curriculum.

Kern Entrepreneurship Education Network (KEEN)

The Kern Entrepreneurship Education Network (KEEN) was started by the Kern Family Foundation in 2005 as a collegiate initiative to complement programs that they had developed at the K-12 level to increase the quantity and quality of U.S. engineering talent. The Kern Family strongly believes that instilling an entrepreneurial attitude and skill-set is key to helping the United States maintaining its economic position in the increasingly competitive global market place. *KEEN's mission 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 aims to fulfill this mission by supporting the creation of programs that develop technical leaders with strong skills and an entrepreneurial mindset in undergraduate engineering programs at select private U.S. colleges and universities.*[5]

A depiction of KEEN program vision is shown in Figure 1. It shows that Societal Values can be achieved by the efforts of Entrepreneurs, Intraprenuers, and Engineers starting from a strong base in the areas of: Business Acumen, Customer Needs, and Technical Fundamentals. The Kern Family recognized that engineering programs in the U.S. excelled in the teaching technical fundamentals, but were woefully inadequate at providing engineers with the necessary background in the areas of business acumen and identifying customer needs.

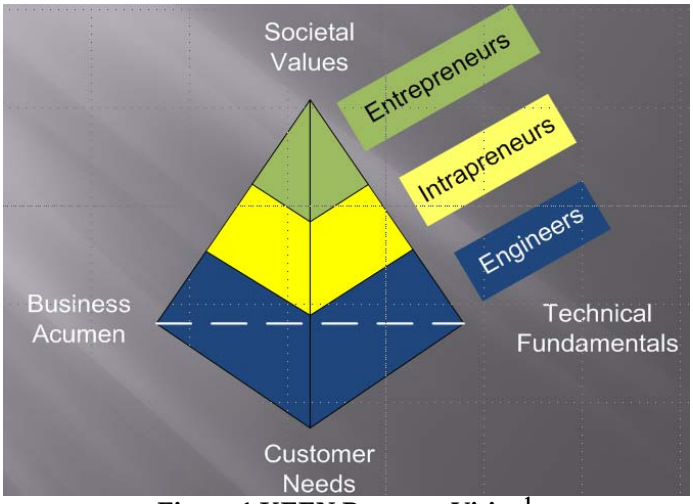

Figure 1 KEEN Program Vision[1]

Kettering University Entrepreneurship Across the Curriculum (EAC) Faculty Educational Program

The EAC program at Kettering University is designed to expose faculty from all disciplines and departments to the ideas of an entrepreneurial mindset. This program is an eight week program, conducted once a week during the evening. Because this occurs while faculty members are busily engaged in teaching their courses and conducting research, a monetary stipend is provided to those completing the course. The course itself is taught in a casual seminar format. Faculty members are required to complete outside assignments as part of this course. All EAC faculty are provided workbook materials and copies of the text, "Innovation: The Five Disciplines for Creating What Customers Want," by Carlson and Wilmot. Live guest lecturers and videos of lectures as well as guided discussions are conducted throughout the workshop. Time is spent educating the faculty about entrepreneurship and different strategies to employ these concepts into existing courses. To further entice faculty to take the next step--incorporating the entrepreneur ideas into their course--an additional stipend is offered when faculty complete a course project and report on their experience.

This effort has been quite well received by the faculty. Currently, more than 60% of the faculty members have taken the workshop. To date, over 1700 "student touches" have occurred. A "touch" is defined as one student accomplishing an assigned "entrepreneurial mindset" task. Some students may have more than one encounter. This continues to grow as more faculty are educated, adding to the pool of courses. Interestingly, more than 50% of prior workshop participants voluntarily took an additional, unremunerated, training program. Some of the seminar topics and discussions are briefly provided below.

Entrepreneurship and Intrapreneurship

The characteristics of an entrepreneur are difficult to define, but there is general agreement that, through the years, entrepreneurs have been responsible for "job creation, improved productivity, increased prosperity, and a high quality of life."[6] An entrepreneur may be defined as a person who undertakes the creation of a business that has the chance of being sustainable. Entrepreneurs choose a level of personal, professional or financial risk to pursue opportunity. They tend to identify a market opportunity and exploit it by organizing their resources effectively to accomplish an outcome that changes existing interactions within a given sector. In a similar manner, *intrapreneurs* act like entrepreneurs, except within a larger organization; both are strongly focused on creating new customer value.

Characteristics of Successful Entrepreneurs/Intrapreneurs

Attempts to define the characteristics of successful entrepreneurs in the seminars proved to be elusive; everyone seems to have a different opinion. The moderators of the seminar presented a study from Timmons-Spinelli[7] that seemed to capture many of the complex characteristics. A brief summary of these characteristics are:

1. Commitment and Determination – Entrepreneurs are tenacious and decisive, able to commit/recommit quickly.

2. Courage – Entrepreneurs are fearless experimenters and are not stopped by fear of conflict/failures.
3. Leadership – Entrepreneurs are team builders and inspire others.
4. Opportunity Obsession – Entrepreneurs have intimate knowledge of customer wants and needs and are market driven.
5. Tolerance of Risk, Ambiguity, and Uncertainty – Entrepreneurs take *calculated* risks but avoid *unnecessary* risks. They tolerate ambiguity, uncertainty, and stress well.
6. Creativity, Self-reliance, and Adaptability – Entrepreneurs tend to be nonconventional, open-minded, lateral thinkers restless with the status quo.
7. Motivation to Excel – Entrepreneurs set high goals for themselves and are driven to achieve these goals.

Although not all of the above characteristics can be taught in the classroom, techniques can be taught which will aid in assessing and acting on an idea. One such technique is the Need-Approach-Benefit-Competition (NABC) analysis espoused by Carlson and Wilmot.[1]

NABC Analysis

The NABC analysis provides one with a tool to help recognize an opportunity and to determine the risk and potential rewards of acting on the opportunity. This analysis is flexible enough to be employed in a variety of situations. For example, it could be used to assess the value in launching a new entrepreneurial venture or it could be used to evaluate a new product idea in an existing company, helping the intrapreneur to move the company forward. One exercise that was used to practice the NABC technique was to create an 'elevator pitch,' or a brief presentation of a value proposition. The scenario for the exercise is that you find yourself in an elevator with the CEO (or other influential person) and you have just 90seconds to pitch your idea. In that short time you need to be able to convey the following:

- **N**eed: What is the important customer and market *need*?
- **A**pproach: What is the unique *approach* for addressing this need?
- **B**enefits: What are the important *benefits per cost* that results from this approach?
- **C**ompetition: How are these benefits per cost superior to the alternative solutions of the competition

These concepts (and others) from the seminars were the basis for the authors adding entrepreneurial activities to two automotive elective courses. The rest of the paper will discuss these attempts and the resulting feedback.

MECH 544-Introduction to Automotive Powertrains

The Introduction to Automotive Powertrain class is a senior/graduate student elective course offered in the Mechanical Engineering program. Upon completing the course, students should be familiar with the technical operation of common automotive powertrain components and be able to predict the acceleration and fuel economy performance of a vehicle. In an attempt to go beyond the technical issues and to introduce entrepreneurial concepts into the course, many of the homework projects were rewritten to use the Kettering University Formula SAE (FSAE)

vehicle as the focus for the problem. The FSAE *vehicle* was the target for the technical problem being asked (such as to determine appropriate gear ratios or to calculate acceleration capability), and the FSAE *team* was used to discuss the entrepreneurial aspects of the competition (see Figure 2). It was noted that members of the team tend to display and practice all seven of the key characteristics of entrepreneurs. Examples were provided to illustrate how the teams ability to tolerate risk, find creative solutions, etc., was necessary to successfully develop the vehicle.

Figure 2 Kettering's FSAE vehicle and team.

In addition to FSAE related activities, the students were asked to complete an intrapreneurial term project. Specifically, the following innovation scenario was provided.

> Scenario
> You are working for an automotive OEM or supplier. You have developed an idea for improving either acceleration performance or fuel economy performance. (As a student you'll have to do research to find a good idea). You are then to prepare a short NABC analysis (one or two pages + attachments) to convince the management to fund the development of your product.
>
> Examples for ideas:
> - Use of an alternative materials to reduce weight
> - Use of alternate engine technology
> - Use of alternate transmission system
> - Use of an alternate fuel (to replace scarce oil reserves)
> - Use of fuel additives or lubricants
> - Use of aerodynamic aides to reduce drag losses
> - Use of energy recovery systems

To aid the students in their research for innovative technologies the students were introduced to the Society of Automotive Engineers (SAE) Digital Library and industry publications such as SAE's *Automotive Engineering International*.

Student Response to the Project
All Kettering students participate in cooperative education and most of the students in the class had co-op employers in the automotive industry; consequently many of the term projects focused on technologies that were appropriate for the students' co-op employers. About 25% of the students embraced the true nature of the project. They researched the technical aspects of their innovation and also did at least some economic analysis, so that they could justify the investment in their concept. The remaining students did a good job at researching the technical aspects of their innovation idea, but failed to consider any economic impacts. Everyone demonstrated that they understood the idea of the NABC analysis; although the lack of economic analysis indicates that most of the students (75%) were much more comfortable with the technical problem and hadn't made the connection to the importance of creating customer value.

Subjective responses from the students were decidedly mixed. About half of the students responded that they felt the entrepreneurial discussion and activities were useful; the other half felt that they were a waste of time. Several of those with negative responses indicated their co-op work experience was a better way to learn about these concepts than any activities that could be done in a classroom setting.

Project Assessment
There was concern at the beginning of the project about having sufficient time to add entrepreneurial content to the course; but by wrapping the new material around the existing homework projects very little additional class time was needed. Overall the innovation activities and term project worked well in this course; although more emphasis needs to be put on the importance of covering the economic issues (customer value) in the NABC analysis. Another improvement in the future would be to free up time in class for the students to present their NABC analysis orally as an 'elevator pitch.'

MECH541-Advanced Power Systems

This course is a senior/graduate level course in which students study contemporary issues affecting automotive power systems. Students learn how to develop advanced engine models, and how to collect and analyze engine performance data. As part of this course, students are exposed to contemporary engine modeling software and expected to gain a basic understanding of the use of this software. This last task can be a rather dry exercise for the students. In order to change this, students were directed to focus their efforts on the solution of a real world problem-improving the fuel economy performance of an existing engine. The software is simply a tool to be used in helping to analyze proposed solutions to this problem.

Project Scenario
For this project, a mythical consulting firm was setup. This "firm" consists of two real University Alumni who are currently employed in the field with small engineering firms. This consulting firm has been hired to help a company improve the operating efficiency of its four

cylinder engine. The company cannot afford to redesign this engine completely, but it must meet elevated fuel economy standards in the near-term. The consulting firm is the students' customer.

Here is a synopsis of the information that was provided to the students at the project outset:

> Improving the Efficiency of an Existing Engine
>
> Need:
> For this project, a consulting firm has been hired to help a company improve the operating efficiency of its four cylinder engine. The company cannot afford to redesign this engine completely, but it must meet elevated fuel economy standards in the near-term. The engine has variable valve timing capability, but the calibration engineers have not had time to optimize it. The company may also be willing to invest in new camshafts, or turbocharging as well. The consulting firm has hired you due to your ability to use simulation tools such as GTPower, and your access to the SAE database through the library.
>
> The consulting firm, your **customer**, is operated by the following two Kettering University Alumni: (names not provided for technical paper)
>
> In order to facilitate communication, I have set up a group site. Each group will get a discussion area to be used as the primary means of communication.
>
> Approach:
> - You are required to team up in groups of 2-3 students per project team.
> - Each team will use the SI engine model:
>   - Tutorial;GTPower;04-4cylSI-final
> - Details of this model must be conveyed to your customer!
> - You must first generate a baseline performance profile using this engine: i.e. BSFC Power for various throttle openings.
> - You must conduct a brief literature search to determine the state-of-the-art in engine efficiency.
> - Your customer will require a brief synopsis of your research including the actual articles. This must be provided within 2 weeks of commencing the project.
> - Each team will then propose their **Approach** to improving the fuel economy, identifying the approaches used by **Competitors**. Please provide specific reasons why your approach is better or similar to that used by the competition. These reasons will be drawn from your research and must be documented! This report is due to your customers 4 weeks of commencing the project.
> - After negotiating with your clients, you will then quantify the **Benefits** of your approach by using the GTPower modeling software and base engine. All of this must be documented in a final report that is due no later than the 9th week Friday.

Each of the student teams completed the following reports: Background/Literature Search Report, Approach Report, and Final Consulting Report.

Student Response to the Project

Overall, student response to the project was positive, 75% of the students agreed that this project forced them to think more broadly, focusing on their customer's needs. They were especially motivated by the fact that they were working directly with practicing engineers who were themselves, Kettering graduates. An excerpt from one design report demonstrates how the students were able to incorporate the NABC concept into their project:

> **Need:**
>
> To improve the operating efficiency of an inline-4 cylinder 4-stroke spark ignited engine to meet future fuel economy standards.
>
> **Approach:**
>
> To improve the operating efficiency of this engine we will explore the benefits of increasing the compression ratio, tuning intake manifold runner length for the operating range of this engine, and to optimize the variable valve timing. If time permits, variable intake runner length will be explored as well. Simulation will be done with GT Power to estimate gains in efficiency of each alteration. Attached are the abstracts from three SAE papers that will be utilized to improve the efficiency of this engine.
>
> **Benefit:**
>
> The benefit of our approach is minimal cost of redesign. If gains in efficiency through simulation of increased compression ratio or different intake manifold geometry proves beneficial, the cost of redesigning these parts will be minimal compared to adding more components to the system.
>
> **Competition:**
>
> Some strategies that competitors might explore are the introduction of direct fuel injection, stratified charge operation, forced induction, combustion phasing, and cylinder deactivation. All of these strategies require addition of components or significant redesign in engine architecture.

As is shown above, the NABC approach provides a simple tool for students to use which helps them to organize their approach to solving a technical problem. Further, this tool helps the students to broaden their approach by requiring them to research solutions to similar problems that have been proposed by others.

Additionally, the NABC approach requires students to communicate with their customers. Students were a bit nervous about this communication, indicating that they were feeling pushed beyond their comfort zone. Learning to effectively communicate their ideas with real practicing engineers is important.

Unfortunately, about 25% of the students did not embrace the openness of the project, preferring, instead, a more structured and focused assignment. These same students did not push themselves to better understand the use of the software and did not effectively communicate with their customers.

Project Assessment

Overall, the project went well for a first attempt. In order to assess the project, a conference call was held with the two consulting "partners." The results of this call are summarized below.

1. The “give and take” feedback from the practicing engineers to the student teams was impressive. This really enhanced the learning experience.
2. Some of the students did not take enough initiative to solve their own problems. They sometimes relied too heavily on getting the answers from the practicing engineers! More problems will be “bounced” back at the teams in the future.
3. Setting up the Group site on Google proved to cause some problems, delaying the communication. It was ultimately abandoned. Email was the real solution! Email will continue to be used.
4. This project really forced the students to look at other approaches and evaluate these alternatives. This helped them to improve in this regard.
5. Students did not meet all of the project milestones in a timely fashion. Part of this was due to the delays encountered when trying to use the group site, but some blame also falls on the students themselves. The project will start earlier in the term in the future.
6. Try to get a narrower topic that is of more vital interest to the “partners”. Working with the students takes time. We could get more support by turning the current consulting “partners” into real customers. We are looking for ways to try this out in the future project iteration.

Item 6 is of considerable importance in sustaining this type of project. A direct linkage needs to be established between the assignment and a current problem of interest for the partners. This will encourage more timely feedback and a livelier online discussion between the students and their clients. Additionally, an extra effort will be made to engage all of the students in discussions earlier in the term by scheduling conference calls/online meetings at critical intervals.

Conclusions

Overall, the authors see real value in integrating entrepreneurial concepts into the classroom. The NABC approach provides a template to help in achieving this goal. This approach is flexible enough that it can be used in a variety of ways. Importantly for the instructor, the NABC template does not significantly add to the course development time. Existing projects and assignments can easily be modified using this approach.

Feedback from the students has been positive, and the instructors at Kettering who have tried to integrate the entrepreneurial ideas into the classroom have generally continued in subsequent terms. Overall, technical students need a stronger “push” to fully consider the economic impacts of their technical decisions; therefore, the instructor needs to emphasize this consideration of the NABC approach.

A more quantitative and comprehensive assessment process of the program is being developed. This will provide more data about student perceptions regarding entrepreneurial concepts both before and after the experience. Additionally, overall perceptions of the project value can be made.

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