

Combining Discipline-specific Introduction to Engineering Courses into a Single Multi-discipline Course to Foster the Entrepreneurial Mindset with Entrepreneurially Minded Learning

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Dr. Robert W Fletcher, Lawrence Technological University

Robert Fletcher joined the faculty of the Mechanical Engineering Department at Lawrence Technological University in the summer of 2003, after two decades of industrial research, and product development experience.

Dr. Fletcher earned his Bachelor of Science Degree in Chemical Engineering from the University of Washington, in Seattle, and the Master of Science and Ph.D. degrees in Chemical Engineering, both from the University of Michigan.

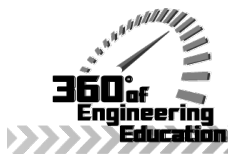
He teaches a number of alternative energy courses at Lawrence Tech. Because of his firm belief that the first experience students have with engineering education is critical and needs to be a challenging, engaging and positive one, Dr. Fletcher in 2004 began actively working with other engineering faculty to reconfigure the Introduction to Engineering courses at LTU.

Dr. Fletcher and his student research team recently concluded a major durability and reliability on multiple PEM fuel cell research used under a wide range of operational conditions for the US Army. Other research efforts include the study of solar concentrators and solar water heaters, as well as temperature effects on solar photovoltaic system performance. He is also establishing an alternative energy laboratory at Lawrence Tech.

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Dr. Meyer directs the Experimental Biomechanics Laboratory (EBL) at LTU with the goal to advance experimental biomechanics understanding. He developed and teaches a number of courses in the Biomedical



Engineering program, including; Introduction to Biomechanics, Biomechanics Lab, Tissue Mechanics, Medical Imaging, Orthopedics, BME Best Practices, Intro to BME, and Fundamentals of Engineering Design Projects. Recently, the EBL has partnered with ME and EE faculty to develop a "Biorobotics" facility that provides practical, hands-on experiences to students focused around the topics of sensing, perception, and control in next generation robotics. He has published 32 peer-reviewed journal articles and was an invited speaker at the IOC World Conference on Prevention of Injury & Illness in Sport in Monte Carlo, Monaco. Dr. Meyer is a member of the American Society of Mechanical Engineering, European Society of Biomechanics, Biomedical Engineering Society, and Tau Beta Pi.

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Abstract

This paper focuses on two initiatives: fostering the entrepreneurial mindset in the first year introduction to engineering course and successfully combining discipline-specific courses into a multi-discipline course.

While most first year introduction to engineering courses focus on design and problem solving, at the same time familiarizing the student with basic technical content, very few also focus on the entrepreneurial mindset – a way of thinking increasingly required of engineers entering the workforce. Skills associated with the entrepreneurial mindset such as effective communication (written, verbal, and graphical), teamwork, ethics and ethical decision-making, customer awareness, persistence, creativity, innovation, time management, critical thinking, global awareness, self-directed research, life-long learning, learning through failure, tolerance for ambiguity, and estimation are as important in the workforce as technical aptitude. In fact, employer feedback has indicated that graduates with these skills are more highly sought than those with an overly technical education since technical engineering skills can be readily obtained on the job; the entrepreneurial mindset takes years of practice/refinement. Although students may eventually begin practicing many entrepreneurial mindset skills in the curriculum especially during a senior project sequence, it is paramount that the importance of the entrepreneurial mindset is stressed in the first year. This paper will include details of how to integrate all of the skills listed here into well-established design projects, homework, and active learning classroom modules in a first year engineering course using entrepreneurially minded learning. Informal interviews with students reveals successful implementation.

As the lines between engineering disciplines are becoming more blurry, employers also covet engineering graduates whose technical skills span a variety of disciplines. Engineers must work on teams that are diverse, and being able to understand and communicate the broad field of engineering is vital to success. Therefore, while completing an engineering degree, students need to become familiar with a multitude of engineering disciplines and work with students from many departments. This is not a new concept and many introduction to engineering courses are interdisciplinary. On the other hand, many colleges still contain only discipline-specific introduction to engineering courses. Over the past year and a half, Lawrence Technological University underwent a successful college-wide transition from many discipline-specific introduction to engineering courses to a multi-discipline course. This paper will outline keys to a successful transition including pitfalls to avoid and working with university administrators, faculty, and staff during the transition.

1. Introduction

Lawrence Technological University has offered engineering students entrepreneurial education programs for many years. Recognizing that graduates entering industry will require business and entrepreneurial skills, the College of Engineering developed an entrepreneurial certificate program and founded the Lear Entrepreneurial Center. The entrepreneurial certificate program develops student skills in communication and business components in the engineering profession and includes a multi-disciplinary capstone design experience for which teams are eligible for student venture grants administered by the institution. Several multi-year grants have strengthened the program through workshops, keynote speakers, faculty curriculum awards, student venture grants, and faculty incentives to work with industry sponsored student teams. Specifically, the College of Engineering received an invitation to participate as part of a larger initiative to develop the Kern Entrepreneurship Education Network (KEEN). The invitation also provided funding to develop and integrate entrepreneurial education across the curriculum. The network is limited to private institutions with ABET accredited engineering programs and is by invitation only.

The goal of KEEN is to make entrepreneurship education opportunities widely available at institutions of higher learning, and to instill an action-oriented entrepreneurial mindset in engineering, science, and technical undergraduates. Some skills often associated with the entrepreneurial mindset are effective communication (written, verbal, and graphical), teamwork, ethics and ethical decision-making, customer awareness, persistence, creativity, innovation, time management, critical thinking, global awareness, self-directed research, life-long learning, learning through failure, tolerance for ambiguity, and estimation.^{1, 2, 3, 4, 5, 6} In 2010, KEEN specifically outlined seven student outcomes pertaining to the entrepreneurial mindset.⁷ A student should be able to:

1. Effectively collaborate in a team setting (teamwork)
2. Apply critical and creative thinking to ambiguous problems (problem solving)
3. Construct and effectively communicate a customer-appropriate value proposition (customer awareness)
4. Persist through and learn from failure to learn what is needed to succeed (persistence)
5. Effectively manage projects and apply the commercialization process within respective disciplines (project management)
6. Demonstrate voluntary social responsibility (social responsibility)
7. Relate personal liberties and free enterprise to entrepreneurship (free enterprise)

In 2013 (while planning for the new first year engineering course was underway), these student outcomes were modified and is best represented in graphic form as shown in the appendix. Use of these student outcomes can be viewed as “entrepreneurially minded learning.” A textual representation is given here (with letter enumeration added for clarity later in the paper):

ENTREPRENEURIAL MINDSET

1. Enterprising Attitude

- a. Exercise curiosity about the surrounding world
- b. Define problems, opportunities, and solutions in terms of value creation
- c. Assess risk
- d. Persist through and learn from failure

- e. Demonstrate resourcefulness
- f. Anticipate technical developments by interpreting surrounding societal and economic trends
- g. Identify new business opportunities

coupled with ENGINEERING THOUGHT AND ACTION

2. Multidimensional Problem Solving

- h. Apply creative thinking to ambiguous problems
- i. Apply systems thinking to complex problems
- j. Examine technical feasibility, economic drivers, and societal and individual needs
- k. Act upon analysis

expressed through PROFESSIONAL SKILLS

3. Productive Collaboration

- l. Collaborate in a team setting
- m. Understand the motivations and perspectives of stakeholders

4. Illuminating Communication

- n. Communicate engineering solutions in economic terms
- o. Substantiate claims with data and facts

and founded on CHARACTER

5. Resolute Integrity

- p. Pursue personal fulfillment as a member of a profession that creates value
- q. Identify personal passions and a plan for professional development
- r. Fulfill commitments in a timely manner
- s. Discern and pursue ethical practices
- t. Contribute to society as an active citizen

These outcomes form an excellent basis for gauging how well the entrepreneurial mindset is being incorporated into student activities within a course, and will therefore be referred to throughout later sections of this paper.

As of January 2013, KEEN includes nineteen institutions across the U.S. The KEEN program provides access to vital resources for building quality entrepreneurship education programs that engage engineering and technical students including grants, faculty fellowships, capacity building workshops, networking opportunities, and resources. More specifically, KEEN provides financial and developmental resources to grantee institutions for the development of entrepreneurship curricula, modules, and extracurricular activities like business plan competitions, speaker series, student entrepreneurship clubs, and seminars.

In 2010, KEEN established grants for smaller networks within the entire network. These are known as dense networks. Lawrence Tech is part of a dense network known as the Dynamic Compass Network (DCN) along with Boston University, Kettering University, Saint Louis University, and Gonzaga University. As part of the DCN Grant, the universities would collaborate to redesign the First Year Engineering experience at each institution and specifically to introduce the Engineering Grand Challenges.

Introduction to Engineering at Lawrence Tech

For many years leading up to Fall Semester 2013, Lawrence Tech offered five discipline-specific Introduction to Engineering courses – one each from architectural engineering, biomedical engineering, civil engineering, electrical and computer engineering, and mechanical engineering (which includes industrial operations engineering and robotics engineering). These courses were two credit hours each offered in a single semester. While this was convenient from a scheduling standpoint, it posed problems for the students. First, some students switched majors after one or two semesters, and therefore did not receive the specifics from their new discipline's course. Second, students did not experience a wide array of engineering disciplines within the course and therefore may not realize that they chose wrongly “fresh out of high school.” Third, the students did not get to work alongside students from various disciplines as will be expected in the workforce upon graduation. Fourth, the format tended to create barriers for inter-departmental collaboration – not ideal for competition teams (e.g., SAE or ASCE) or senior projects (especially industry sponsored projects). Finally, a single-semester course is not ideal for retention. The first year of an engineering curriculum is filled with non-engineering specific courses (e.g., math, science, and core-course requirements). It is crucial that the students get to experience as much engineering problem-solving and design as possible, so spreading out this experience over the entire first year is important.

In addition to problems for the students, there was a major issue from the faculty viewpoint: how to consistently and effectively incorporate the entrepreneurial mindset into each course. Without a single course or course coordinator, many of the entrepreneurial mindset attributes were overlooked or even misrepresented.

On the other hand, there are advantages to discipline-specific introductory courses, most notably preparing the students for future course work within their disciplines. Therefore it was decided to take the two credits and split them between two semesters (e.g., one credit in the Fall and one credit in the Spring). One credit hour would be devoted to a multi-discipline course and one credit hour would be devoted to discipline-specific courses.

Proposal and General Structuring

First and foremost, a team of faculty is needed that understands the freshmen mindset, has a rapport with underclassmen, understands the needs of first-year students, and are committed to instilling the entrepreneurial mindset. This team was identified roughly one year before the course was conducted and included one faculty member from each of biomedical engineering, civil engineering, electrical engineering, and architectural engineering, and two faculty members from mechanical engineering (the largest of the departments). At the same time, a small team (the two ME professors and one civil engineering professor) formed a proposal to be approved by the Deans and all Department Chairs. (More on this later.) Even before this, the three professors had met several times to establish what broad changes would be needed (e.g., splitting the two credits over two semesters).

The proposal contained many crucial elements. It addressed the reasoning for the changes which were detailed in the previous section, but are also linked to recruitment and retention. Next,

funding was requested to create a dedicated first-year design studio. Also, credit-hour allotment was detailed. Finally the coordination of the course was proposed. The following paragraphs will reveal some details about these elements.

First, the proposal was clear about the main goal of course: for the student to understand what engineering is about (including the various disciplines within engineering) and to practice the engineering design and problem-solving process. In addition the proposal made clear that the students need to learn how to take possession of their engineering education unlike high school where assignments can be “spoon-fed,” less broad, and often non-collaborative. Pertaining to retention, an introductory course should also be exciting, fun, and interactive (i.e., hands-on). Within these broad goals, skills associated with the entrepreneurial mindset can be implemented.

A specific space dedicated to engineering freshmen allows them to take ownership of their engineering work and to bond more to the College of Engineering, a key feature in retention. All of the prior intro to engineering courses were project-based where students design, build, and test multi-component and often large-scale projects. This would continue with the new course so the students needed space to work in teams, be allowed to be “messy,” and also store their works-in-progress. As it were, the students had to transport their projects to and from the engineering building, often damaging the partially-finished product. In addition, the current classrooms did not contain the space necessary nor the proper furnishings for design-based projects. It was proposed that a freshman design studio should be established by Fall 2013. Lawrence Tech had a major advantage; a student project room was being underused. Therefore, we were able to convert this room into a first-year design studio/classroom for relatively low funding. The space was to be modeled on the successful design studios in use at Olin College of Engineering. The studio would be a convertible classroom (all tables and stools are on wheels) with lightweight mobile partition walls to separate teams and plenty of white board space and tack boards. Workbench style tabletops would accommodate teams of 3 to 6 students. Six workstations could be located around the perimeter of the room and still allow for a lecture-style area near the front. An overhead LCD projector, projection screen, and white board were necessary for instructional purposes. Eventually, lockers will also be installed for students to store tools, projects-in-progress, etc. The room can accommodate sections with up to 24 students, so eight sections were needed for Fall 2013. (Two more sections were needed for Spring 2014.)

The proposal included a description of the credit hour allotment. One credit hour was to be allotted for the general multi-disciplinary course which gives an overview of the scope of the profession and the engineer’s role in society in a two hour studio/laboratory-based environment. Much of this was to be accomplished through team-based design experiences. In addition, common focal areas on ethics, teamwork, leadership, problem-solving, communication (oral and written), and general software tools/applications (e.g., PowerPoint, Excel, Word) were to be included. All of these topics could be covered within hands-on projects, especially those that cater to exploring the world’s major social problems (e.g., the Grand Challenges) which have become very popular among incoming engineering freshmen. An additional bonus is the realization of true-multi-disciplinary teams composed of electrical-minded, mechanical-minded, etc. students. Because the course is allotted two hours of studio time per week (much like our laboratory courses), faculty members teaching the course are granted two contact hours.

The second credit hour was proposed to be discipline-specific and will therefore be coordinated by each department. Each department has responsibility for the course content and scheduling. A discipline-specific course will allow the students to begin learning/using the skills they will need for their specific discipline and upper-level courses. So as not to overly burden the student, the discipline-specific courses meet for only one hour per week.

In summary, the students still earn two-credit hours but would have three total classroom hours spread over two semesters to work on projects and “bond” with the College of Engineering. Spreading the course over two semesters allows the students to engage in engineering throughout the academic year when they are otherwise fulfilling only math, science, and core course requirements.

The proposal addressed the coordination of the courses (multi-discipline and discipline-specific) among the Departments of Architectural, Biomedical, Civil, Electrical/Computer, and Mechanical Engineering. One faculty member serves as course coordinator of the multi-discipline course. The responsibilities include the following:

- Ensure that there are an appropriate number of class sections.
- Schedule and lead regular meetings of the intro to engineering curriculum committee / instructors.
- Keep an updated portfolio of course content.
- Ensure that student project materials/supplies are readily available.

The course coordinator is to be granted at least 1.5 credit of release time each Fall and Spring semester.

In addition, a committee oversees the first-year engineering course sequence. It is composed of at least one full-time faculty representative from each department and the course coordinator. The course coordinator has the option to add an additional representative when a department has multiple large degree programs. The committee meets on a regular basis to oversee the multi-discipline course. They develop, evaluate, and implement course content. The committee and instructors are charged to continually add or remove content based on most-recent best practices from the engineering education literature and benchmarking of other institutions.

Finally the proposal stated that each section’s enrollment shall be limited. Twenty-four students per instructor is manageable and divides easily into student teams of 2, 3, 4, or 6 (assuming full sections).

The name of the multi-discipline course was to be “EGE 1001 Fundamentals of Engineering Design Projects.” The discipline-specific course name is at the discretion of each department.

Once the proposal was approved, the prerequisites for the course were determined. While the course does not involve any advanced mathematics, the committee wanted to ensure a standard base education level of each student. We also wanted to ensure that any student in the course was prepared to launch into subsequent engineering courses (e.g., statics or engineering graphics) without a major delay between them. Therefore the student must be in trigonometry or higher. Also the students must be in or have completed English Composition. This is especially

important for the international students where English is not their dominate language; many written assignments are required in the EGE 1001 course.

Planning and Implementation

Throughout the spring semester (before the course went live in the fall), the committee met once per week to determine when the sections should be scheduled, the course learning objectives, and finally the classroom activities and assignments.

To determine the schedule for the sections, we needed to establish when the other required first-year core courses were scheduled. In our case, that includes Calculus 1 or 2, University Chemistry, Principles of Economics, University Seminar, English Composition, World Masterpieces, and Foundations of the American Experience. As one might expect, there were no obvious open times, so we spread the eight sections evenly from Tuesday through Friday between 8 am and 8 pm.

The course learning objectives needed to incorporate engineering problem solving and design while instilling the entrepreneurial mindset. This was accomplished by investigating prior introductory course objectives, ABET outcomes, and the KEEN student learning outcomes. The final learning objectives are as follows:

1. Identify your preferred learning style and explain how you can use information on learning styles.
2. Identify major disciplines of the engineering field and their various areas of focus.
3. Describe the purpose of and practice the major steps of the engineering design process.
4. Analyze the contributors of success and failure during an engineering design project.
5. Function on teams to effectively manage and complete engineering design projects to fulfill an identified need (e.g., customer, client,...).
6. Demonstrate effective oral and written communication skills through design projects and individual assignments on engineering topics.
7. Demonstrate problem solving, critical thinking, and estimating skills.
8. Demonstrate the use and application of important engineering tools, including computers, CAD, word processing, and spreadsheet programs.
9. Explain how global issues such as climate change, emerging economies, natural resource depletion, and sustainable designs are related to the professional practice of engineering.
10. Explain the elements of the *Engineering Grand Challenges*, and discuss the roles of engineers in addressing these opportunities.
11. Describe the basic principles of an engineering code of ethics, such as the NSPE *Code of Ethics*, and apply the provisions of the code to resolve ethical dilemmas.
12. Demonstrate the use of classic ethical theories, such as utilitarianism, duty ethics, rights ethics, and virtue ethics in the resolution of ethical dilemmas.
13. Explain the role of an engineer as leader in an engineering organization and in society in general, and describe the attributes/attitudes that are supportive of the professional practice of engineering.
14. Explain the importance of a broad undergraduate engineering education and post-degree continuing education leading to lifelong learning.

15. List and discuss the benefits of membership in professional engineering societies and explain the role of these societies in promoting, serving, and protecting the engineering profession as well as society.
16. Demonstrate self-directed learning by researching a current topic of interest in a field of engineering.

These course objectives cover six of seven original KEEN student outcomes and elements of all five new KEEN student outcomes. More specifically, they touch 18 of the 20 “sub” KEEN outcomes. As it turned out, all 20 KEEN outcomes were integrated into course content as will be elaborated in later sections.

Next, potential content (i.e., classroom activities and assignments) was identified that would cater to these objectives. The content was divided into in-class active collaborative learning (ACL) modules, individual homework, team projects, and classroom presentations. The most effective means for determining suitable content was to establish a spreadsheet matrix with one objective in each row, and potential activities for each column. Each activity was assessed for its objectives and marked accordingly. Most activities could be “recycled” from those in use in the old discipline-specific courses, but a few were newly created or adapted from other institutions. The final matrix is shown in the appendix.

The final course entailed six team projects (design/build/test), five individual homework assignments, seven ACL modules, and four presentations. While this later proved to be somewhat overwhelming for the students, they handled it well and appreciated the value received for the cost of a single credit hour. We ensured that the due dates were spread out evenly when some assignment work overlapped.

The major themes running throughout the course are the engineering design process and customer-appropriate value (or customer awareness). Admittedly, there are many variations to the engineering design process (a review has been completed by Schubert et al.⁸), with some steps possibly occurring in parallel, and with some others being skipped altogether. The basic flow block diagram in Figure 1, however, outlines the fundamental sequence that is distributed to and discussed with the EGE 1001 students within the first few class meetings. In addition to the block diagram, some notes are also given to the students that explain what the process is, what purpose it serves, why it is useful, when to use it, where to use it, and briefly how to use it.

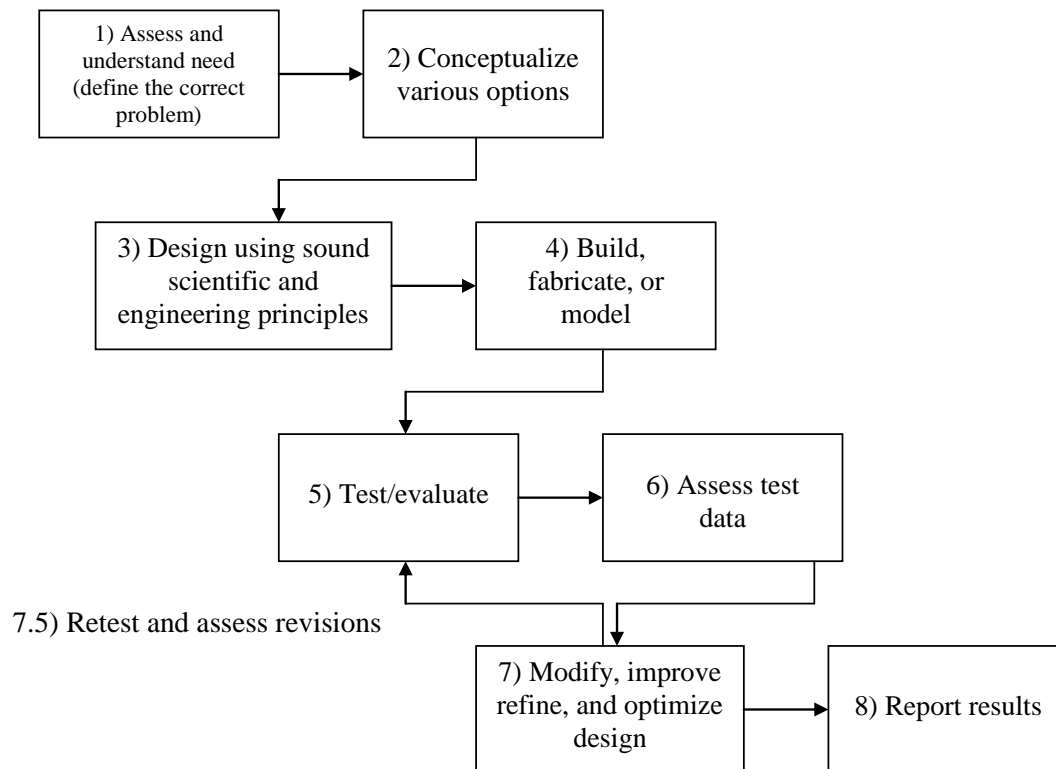


Figure 1. The Engineering Design Process used in EGE 1001 Fundamentals of Engineering Design Projects

Team Projects

The first few collaborative projects are intended to slowly/progressively introduce the student to problem-solving and design, and incrementally increase in magnitude/difficulty. The first project is accomplished in pairs and involves designing a package for priceless Faberge Eggs which are on a museum tour. Constraints are tight (ten sheets of paper, one half of a file folder, and translucent tape) and customer requirements are the focus. Teams often over-focus on the drop testing (20 feet with a raw egg) and forget the package must survive vibration and rough handling as well. The team must also provide written instructions for loading and unloading an egg within the package in less than 90 seconds. During testing, the instructor must follow these written directions without verbal input. Details can be found in reference 4 and examples are shown in Figure 2. This initial project preliminarily covers KEEN outcomes b, c, d, e, h, k, l, m, and r. Pertaining to c (Assess risk), just prior to testing, each team is given the following risk vs. reward choice with one minute to announce their decision:

There are a total of 10 points possible for the egg drop testing portion of the project.
There are two alternatives:

- 1) Students can choose to have the package dropped from the 20 foot level. You will receive 10 points if unbroken and 6 points if cracked but intact. If it fully breaks – zero points. Maximum Possible Points = 10.

2) Students can choose to have the package dropped from the 10 ft level first. You will receive 5 points if unbroken and 3 points if cracked but intact. If it fully breaks – zero points. If it survives the 10 ft drop, the package will be dropped from 20 ft for 3 more points if it survives unbroken for a total of 8. Maximum Possible Points = 8.



Figure 2. Examples of students' egg packages.

For the second project, teams of three or four students design and test a prototype bridge for a remote South Pacific island population. Some details can be found in reference 4 although this project has been recently modified to include a customer-value proposition. In the problem scenario, the islanders traditional vine bridges traversing the hilly terrain have been attacked by a fungus and degrade faster than they can be replaced. The concept of vine bridges, and only vine bridges have become integrated into their culture, and thus they believe their vine bridges are the only safe material to use to make their bridges. Each team must initially consider alternatives for

replacement island bridges. After some initial consideration, bamboo and natural binding material surface is the best alternative, but now the teams must convince the islanders of the bridge design's strength. They are tasked to build and demonstrate a scale model prototype which spans 22 inches. The teams can only use 100 (or less) plastic drinking straws (representing bamboo) and one roll of translucent tape (representing indigenous binding material). The bridge must support at least one brick and minimization of material use is rewarded in the points structure. An example of a student team's bridge is shown in Figure 3. A written report is also required. (This project has a "secret" reveal at its conclusion that the students typically overlook and reinforces proper problem definition and innovation.) This project allows practice of the following KEEN outcomes: a, b, d, e, f, h, i, j, k, l, m, o, p, r, t. Due to the nature of the scenario, the students are especially attentive to "solutions in terms of value creation," "anticipating technical development by interpreting societal trends" (albeit in a low tech society), "examining societal needs," "understanding the motivations and perspectives of stakeholders," and "contributing to society as an active citizen."

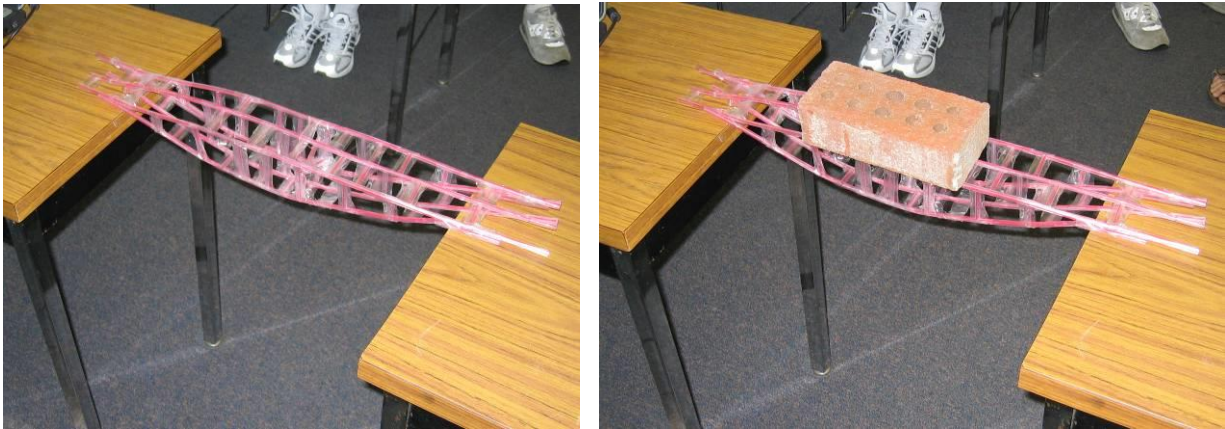


Figure 3. Example of students' plastic drinking straws and tape bridges. Note that no bridge anchoring to the tabletop is allowed; the bridge is resting freely on the table.

Following the bridge project, each student team of four or five are given a different list of several engineering disciplines and must develop and deliver a formal presentation on their topics. With this format, approximately 22 engineering disciplines can be explored within an hour. Also, the students get practice with team presentations and creating visual aids (e.g., PowerPoint). This project indirectly ties to only one KEEN student outcome: identify personal passions and a plan for professional development. It is the key assignment for the student to understand the various forms of engineering and where their enthusiasm lies. In addition, the assignment directly emphasizes the entrepreneurial mindset attribute of communication.

At this point, the students are better prepared for a larger-scale multi-component project. The students were tasked to develop a small car that operated on a finite amount of "rainwater" (employing potential to kinetic energy). The project ties in one of the Engineering Grand Challenges (clean water), as well as the importance of alternative forms of energy. As stated in the student assignment hand-out, "The potential energy of 1 inch of rainfall on the average single-story house, if captured at the roof height provides approximately 120 kJ of energy, and even more if the rain can be captured while in motion. Devices to convert and store this energy could be created, utilizing an untapped and readily available energy source. In addition, the

rainwater itself could be harvested and stored for a variety of everyday uses thereby conserving energy and precious fresh drinking water sources.” The vehicle must be no longer than 18” and 12” wide. They can use 0.5 liter of water with 60 cm height. The water must be captured and drainable (i.e., no water spills), and the student teams are only allowed to use repurposed materials (i.e., nothing bought new). Examples of rainwater cars are shown in Figure 4. The student teams are given four weeks for completion; this timeline allows the students to focus on each step of the engineering design process, and points are awarded for interim testing a week before final testing. This turned out to be an important aspect toward “persist through and learn from failure,” “act upon analysis,” and “apply systems thinking to complex problems.” In general, most teams did not appreciate these outcomes during this project, but realized by the final project how important they are. This was clearly reflected in the scoring results difference between the rainwater car and final projects, details of which are related in the conclusions section. In other words, the students were much better prepared for interim and final testing during the final project. The students’ car projects are judged on two tests. For the first test, the car is to obtain maximum distance; for the second test, the car must land on a specified mark ranging from 5 to 8 meters from the starting line (with the distance unknown until the test date). In the written report, the students must clearly define the repurposed materials that were used so that the design can be replicated. This project emphasizes KEEN student outcomes a, b, d, e, g, h, i, j, k, l, n, o, r, with major emphasis on demonstrating resourcefulness.



Figure 4. Examples of students’ rainwater cars and a test run.

Early in the semester, the students were required to participate in orientation sessions for our metal shop, wood shop, electronics lab, and library resources. Many of the first-year engineering students do not realize until their third or fourth years that they can use these resources anytime during their education at Lawrence Tech. The required orientation sessions introduces these early, and then the student teams must put them to use for the following project. With Lawrence Tech as the client, teams of four are required to design and fabricate an example scale model of a possible aesthetic display kiosk or centerpiece/focal point that features one of two areas of Lawrence Tech: 1) Lawrence Tech Athletics, or 2) the new Lawrence Tech College of Engineering Building. Fabrication of the product must include a distinct set of metalworking operations and woodworking techniques. It also must include multi-color graphics, lighting, and at least one additional electronic component. Examples are shown in Figure 5. Just prior to this assignment, the students completed an in-class ACL that emphasizes customer awareness (described later as “Cards to the Sky”). Therefore the students should be prepared to inquire about the customer requirements. They are encouraged to speak with Lawrence Tech stakeholders as well as the course instructor. Once their models have been produced, each team is given a minute to pitch or “sell” their final model via a presentation to the instructor. An additional requirement for each team is to provide final detailed (computer generated) sketches of each and every component fabricated with their full scale dimensions along with a final assembly drawing of the design (emphasizing communication with the stakeholders). Note that prior to this assignment, students participated in an in-class ACL emphasizing communication with a customer which will be described later. In other words, as with “Cards to the Sky” and the communication ACL, classroom activities are deployed “just in time” to emphasize one or more of the entrepreneurial mindset attributes for future projects. The kiosk project emphasized KEEN student outcomes a, b, e, g, h, i, j, k, l, m, and r with prominent emphasis on value creation and understanding the motivation and perspectives of stakeholders. Of special note, the students were informally polled at the conclusion of the semester which team project was their favorite. The kiosk project ranked as the top choice (along with the final project). The authors have speculated that this is because of the creativity allowed and artistic nature of the project. All of the other team projects have a specific task to accomplish (e.g., protect an egg, support a brick, reach a target). The kiosk project allowed freedom. There seems to be an innate entrepreneurial spirit in the first-year students.



Figure 5. Examples of students' kiosk displays.

The final team project involves a scenario involving the Fukushima nuclear facility disaster following the March 2011 Tohoku earthquake and tsunami. The students are presented with the need to design and build a small, remotely-controlled repair device. The purpose of the device is to navigate using remote control to specified locations and complete a series of tasks. This will protect human operators from absorbing a high dose of radioactive contamination. The repair device will operate in confined spaces with potential unknown barriers and will provide video feedback that could inform the operators so that they may avert an accident or begin repairs. Students are provided a USB connected endoscope. Their mission is to design, build, and test a remotely-controlled, proof-of-concept device capable of negotiating through a four inch diameter pipe “maze,” perform a series of tasks, and return the device back to the pipe entrance. The tasks occur at various locations in the pipe and include; flipping a switch to turn on an electronic system (a light), dislodging an object (a ball) that is blocking a section of pipe, navigate over unstable terrain (gravel), remote recording of the reading on a digital display (clock time) and collecting a small sensor (a ball bearing). The pipe maze is shown in Figure 6. Teams must complete interim deliverables before final testing. The team must report on future plans to improve the design prototype and to produce a commercial device. They must also report the cost to produce the proof-of-concept device. The pipe maze project emphasized KEEN student outcomes a, b, c, d, e, g, h, i, j, k, l, m, n, o, and r with prominent emphasis on “examining technical feasibility and societal needs” and “apply systems thinking to complex problems.”



Figure 6. Top view of final project maze. Entry point is on the bottom left of the image. The light switch is in the first lateral at the bottom of image. A ball obstructs the path before the first tee on the right. The bucket is filled with loose gravel. A digital clock is placed at the left, and the metal ball bearing is on a ledge inside the final tee.

Individual Assignments

Individual assignments included creating a semester-long, specifically-organized binder, as well as an examination and reflection of their personal learning styles (see <http://www.engr.ncsu.edu/learningstyles/ilsweb.html>). These assignments do not relate specifically to the KEEN student outcomes nor the attributes associated with the entrepreneurial mindset and are therefore not elaborated here. They are, however, important to teach the students organization skills, note taking, and how they can succeed in courses with various formats and delivery styles.

Another individual assignment requires each student to write a paper on ethics involving electronic waste. This is completed after an in-class ACL on responsibility and ethics (described later). For the paper, the student reflects on a series of videos:

www.youtube.com/watch?v=LEmOsq7aWD8&feature=relmfu

www.youtube.com/watch?v=wU3k6gJtGtY

http://www.livestream.com/thebby/video?clipId=flv_4647d133-b208-4ba9-97dd-f4b25877f284

Specifically, the students relate the material to the National Society of Professional Engineer's "Code of Ethics for Engineers" and also a code related to their engineering discipline. They must then list, describe, and elaborate upon three other areas they believe that engineers should be involved with, or are already involved with, to make a positive ethical impact on society. This assignment strongly relates to the KEEN student outcomes "discern and pursue ethical practices" and "contribute to society as an active citizen."

One of the individual assignments was a long term project. Each student was required to make a beam from paper and white school glue. The students spend two months fabricating their beam to ensure that the glue is dry. The completed beams are tested on an actual tensile/compression machine. Beam testing and post-test examples are shown in Figure 7. Well-constructed beams will withstand loads between 700 to 1000 pounds with the highest loads over 1350 pounds. While this project is not directly related to the entrepreneurial mindset, the student must decide on paper orientation and use the test data to establish stress-strain plots, reinforcing "substantiate claims with data and facts" and potentially relating to "identifying personal passions and a plan for professional development."

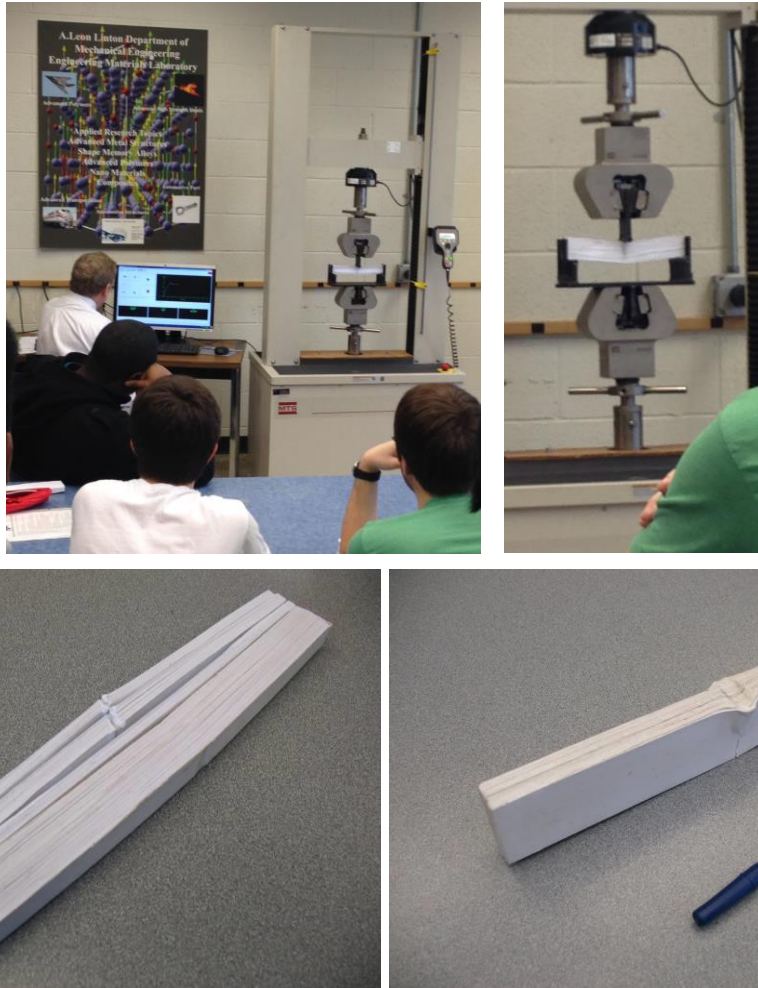


Figure 7. Beam testing and two types of student designs of paper beams after testing. Bottom left image shows a leaf spring style with the paper stacked perpendicular to the applied load. Bottom right image has the paper stacked parallel to the applied load.

While student teams are completing the rainwater car project, each individual student must also choose one of the Engineering Grand Challenges, research it, and complete a written paper.

Elements of the paper included:

- Motivation (why is the EGC important to solve?)
- Background and Technical Issues
 - Current status of the problem
 - Limitations of existing technologies, processes, etc.
 - Ultimate technical goal
 - Proposed engineering solutions and obstacles
- Identification of which engineering disciplines could contribute to the solution and how they can each contribute
- Identification of how their declared or likely engineering major discipline could contribute to the solution

- Personal reflection on the challenge selected including why it was selected, the motivation for selection, how they hope to contribute to the solution, and their feelings about this challenge and this assignment.
- References

As covered by the required paper elements, this is a key assignment for the following KEEN student outcomes: Pursue personal fulfillment as a member of a profession that creates value, identify personal passions and a plan for professional development, and contribute to society as an active citizen.

In-class Active Collaborative Learning

As noted earlier, ACLs are delivered “just in time” as reinforcement for attributes that should be used to succeed on projects and assignments. During the first or second class period, each student team of four or five are presented the same riddle. Each group can ask the instructor only “yes” or “no” type questions. The riddle is intended to lead the students to make initial assumptions about the solution. The activity emphasizes the importance of steps 1 and 2 of the engineering design process especially defining the correct problem (based on customer input). The activity does a very good job of enlightening students about asking questions regarding every aspect or concern. It is also an early method to emphasize KEEN student outcomes, “exercise curiosity about the surrounding world,” “persist through and learn from failure,” “apply creative thinking to ambiguous problems,” and “substantiate claims with data and facts.” Being an entrepreneurially minded engineer must begin early in the curriculum.

The next ACL occurs in the second class period to emphasize effective collaboration. The ACL is a rank order exercise involving inventions (e.g., light bulb, gasoline engine, laser, etc.), and the goal is to rank the inventions from earliest to latest. First students rank the inventions individually. Next students pair up and must come to an agreement to rank the inventions. Finally, students are placed in fours and must all agree on their rankings of the inventions. Once all the groups are finished, the instructor reveals the answers, and each student can calculate their differences from the actual rank for each of the three iterations: individual, pairs, and teams. Once the data is collected and displayed, the mean differences make a very clear statement about the collective knowledge and synergy of teams. Pairs score better than individuals, and teams score better than pairs. At the conclusion of the exercise, a debriefing concerning some of the individual anomalies can discuss personality types on teams and team behavior. Roles and responsibilities can also be discussed. This exercise sets the stage for the KEEN outcome “productive collaboration.”

A week prior to the third team project (rainwater car), the students participate in an ACL focused on communicating with customers and stakeholders. Engineers and engineering students in particular focus much of their interest and attention on solving the technical issues of problem-solving or design. Often the customer needs are inadvertently abandoned or never fully understood. In other cases, the engineer is speaking in different terms than a non-engineer customer. A breakdown in communication between the engineer and customer (or stakeholder) can lead to the unnecessary use of extra resources such as time and money. Therefore, it is very important that the first-year engineering student learns and practices the art of effective communication with a customer. During the exercise students learn the importance of asking the

right questions and clarifying expectations. They will also learn that a common standard/foundation must be set at the beginning of communication so that the ideas and concepts expressed will be readily understood. The basic premise of the ACL is that students must exactly replicate a set of geometric shapes drawn on a piece of paper with only verbal communication from one other student. No visual input is allowed. To begin the activity, the students are split into two groups: Team A and Team B. Team A will pick one person to be their communicator. The communicator is given a copy of a drawing containing three simple geometric shapes which could be triangles, rectangles, and polygons. The communicator turns his back toward Team A. Team B will be observing only so they will be given copies of the drawing. Team A can only ask “yes” or “no” questions as the communicator explains the drawing; Team A attempts to sketch exactly what is on the communicator’s page. After the communicator has finished, the solution is distributed to Team A and the drawings are compared. The outcome is very poor. At this point the entire class should discuss strengths, shortcomings, and methods for Team B to perform better. Next, Team B begins with their chosen communicator working from the new (second) drawing which includes slightly more difficult to draw shapes such as angled parallel lines or a set of arcs. The procedure is the same as before, but now Team A has copies of the drawing and observes only. After completion, more discussion entails. Even though the drawing was more difficult, the new techniques from the class discussion should produce slightly better results, although not by much. At this point, the instructor can claim that nearly perfect results are possible. The whole class now attempts a new (third) drawing while the instructor describes. The first step is setting up a common foundation for communication. The instructor has the students fold their blank paper multiple time lengthwise and widthwise. Unfolded, the paper now contains a grid which can be numbered to produce coordinates. Once the coordinates are spoken, students simply connect the dots. Not only does this ensure nearly perfect replication of the drawing, it also speeds up the communication; very few if any questions are asked by the students. The excellent result is surprising enough to the student that the lessons learned are retained. During discussion, the instructor explains the importance of understanding the audience and setting-up a common foundation. Analogies and examples from the workplace generally help emphasize the importance of three basic components of communication: hearing, responding, understanding. While this ACL does not necessarily teach the student when and how to communicate with the customer concerning their motivations, it does emphasize “understanding the perspectives of stakeholders.” Understanding their motivations is covered in a subsequent ACL described below as “Cards to the Sky.”

Another ACL is focused explicitly on critical thinking and estimation. Implicitly the KEEN student outcomes “apply systems thinking to complex problems” and “examine technical feasibility, economic drivers, and societal and individual needs” are also covered. At the beginning of the activity, teams of four or five students are asked to estimate in 60 seconds the number of ping pong balls that will fit in the room. After recording all the answers (on the board), the teams are given five minutes to determine a second estimate while documenting their process. After recording the answers, a group discussion focuses on the processes used by the teams. This discussion includes estimating, resources, assumptions, documentation, etc. Now the teams are given another five minutes to refine their answers by estimating boundaries which would bracket the “correct” answer. (There may not be a correct answer depending on how the team defines the boundary conditions such as whether the room contains tables, whether the drop

ceiling is included or removed, etc.) Finally, the class compares how different or similar the three answers from each team were. The instructor can then discuss a key point; sometimes you can get by with the “\$1000 solution,” and other times the “\$100,000 solution” is required. Economic drivers and/or customer needs will help to dictate the appropriate solution.

By week seven (of 15), the students have experienced customer awareness through the egg package and straw bridge projects, but only mildly. An ACL is used to punctuate customer awareness and specifically “understanding the motivations and perspectives of stakeholders.” The ACL is called “Cards to the Sky.” The basic premise is that teams of students are asked to create a tower built from playing cards to customer specifications. Each team is provided the design challenge with the following scenario: “Your engineering firm (Great Lakes Engineering, Inc.) has a contract with the Things of Yesterday Society (TOYS) to design and build the community’s first portable elevated viewing platform to give the TOYS a great view of Lake Michigan.” Students are also provided a list of customer design requirements which include items such as “the top of the structure must have a platform at least 12 inches above ground level that will allow two TOYS to look around at the views of the region”, “the structure must remain standing in high winds (created by a fan at close proximity) primarily blowing from the west”, and the “structure must be aesthetically attractive.” Each team is provided one box of standard playing cards, one roll of translucent tape, a ruler (provided as a temporary resource but may not be used in the final structure), and a pair of scissors. The students are then instructed to construct the tower with the playing cards and transport the tower to the testing area in 30 minutes. Towers not delivered in the set timeframe are disqualified. Small plastic army figures are used for the TOYS, and a small desktop fan is used to test the towers to determine if the structures are structurally sound and safe. Testing of a design is shown in Figure 8.

A second optional document is provided to each team (typically 5 to 10 minutes into the challenge) titled the “Great Lakes Engineering Design Process Guidelines” which represents their engineering firm’s process for conducting design. The guidelines include statements such as “vague requirements should be clarified as the project progresses; conduct mid-project reviews with the customers to confirm their position” and “safety cannot be compromised; make sure the customer is informed of safety features and liability concerns.” Finally, the students are informed their corporate design guidelines are proprietary and confidential (i.e., do not share information with other teams). If students follow the design process guidelines and ask questions of the customer (simulated by the instructor), they determine that several of the original customer specifications are incomplete. There are additional design specifications such as maximum tower height, number of TOYS that can access tower, variable wind direction, and what is deemed aesthetically pleasing by the customer. This last point is very important; the aesthetics are only relevant to the customer (the students’ client) and will only be determined by asking questions. There are several deployment options to this challenge which will not be elaborated here.

Approximately 10% to 20% of teams do not complete the challenge in the allotted time (another learning opportunity). Of the towers completed in the allotted time, only about 50% of those survive testing. Finally, after customer requirements are considered, there is usually a clear winning design, and why other designs “failed” or did not live up to expectations is discussed as part of the concluding discussion. The concluding discussion includes reflection on knowledge

gained and its relevance in the field of engineering. The objectives of the exercise (customer awareness, asking questions, clarifying design expectations, teamwork, prototyping, and learning from failure) are all discussed.



Figure 8. Cards to the Sky testing.

The final ACL occurs just before an ethics discussion (covering different types of ethics) and an ethics homework assignment (on electronic waste). In teams of four or five, students are given five minutes to list five responsibilities professors have to their students. Randomly calling teams, these are listed on the board. Next the teams are given five minutes to list five responsibilities students have to their professors. Again, these are listed on the board. Next teams are given five minutes to list four responsibilities students have to their peers. These are listed on the board. Finally, teams are given five minutes to list three responsibilities students have to society. These are listed on the board. Once this activity is completed (and most students are not sure why it is being done), the instructor will ask the students what we have created. The answer is a Code of Conduct for the course or a Code of Ethics. This is a good time to clarify that the list does not contain laws or morals, but ethics. The ACL sets the students minds about the definition of ethics for an ensuing lecture or discussion. Importantly this sets the stage for pursuing the KEEN student outcomes of “discerning and pursuing ethical practices” and especially “contributing to society as an active citizen.”

Presentations

To round out the curriculum, a few special presentations are included in the curriculum. One involves describing the student sections of professional engineering societies available on campus. This not only promotes early participation in these societies' activities, it also emphasizes the KEEN student outcomes "pursue personal fulfillment as a member of a profession that creates value" and "identify personal passions and a plan for professional development."

Another presentation conveys effective methods of using visuals for oral presentations.⁹ This is delivered a week before the group presentations on engineering disciplines.

Finally, near the end of the semester, senior co-op students and staff from the Office of Career services discuss co-ops and internships. At Lawrence Tech, students that choose to pursue a co-op must present their work during their third and final semester of employment. EGE 1001 creates an audience for these presentations while also showcasing what engineering work entails for the first-year students. These presentations not only emphasize "pursue personal fulfillment as a member of a profession that creates value" and "identify personal passions and a plan for professional development," they also highlight "illuminating communication." In other words, without fail, the majority of a senior co-op student's presentation revolves around how he was always "communicating engineering solutions in economic terms" and "substantiating claims with data and facts."

Curriculum Summary

The projects, assignments, ACLs, and presentations cover all attributes of the entrepreneurial mindset as well as all of the KEEN student outcomes. As it turns out, first-year design and problem-solving courses are excellent vehicles for entrepreneurially minded learning. Upon analysis, one particular KEEN student outcome was least covered: "Identify new business opportunities." This outcome is implicit throughout the course, but never explicit. The outcome can be viewed as rather advanced for the first-year students who are still gaining an understanding/appreciation of what engineering is and whether or not they are pursuing their appropriate career.

Execution and Avoiding Pitfalls (when creating a multi-discipline introduction to engineering course)

As stated earlier, a committee of six faculty members from five departments, representing nine degree programs, developed the curriculum for the new multi-discipline introduction to engineering course. Five of these six faculty members had previously taught the now-defunct two-credit hour discipline specific introductory courses. (Recall that the new discipline-specific courses are one-credit hour.) Therefore when planning projects, assignments, and classroom activities, each faculty member brought several ideas with them. Many of these were favorites and all of them successful. Thus, the initial list of potential content was very large and cutting ideas was not easy. Deciding on the final list required hours of constructive debate. In the end, when the course was ready to deploy, all of the chosen content fit neatly into a 15 week schedule,

but this was “on paper.” The committee had a vague feeling that we had too much content for a one-credit course, but reached an impasse when attempting to cut anything; there was always a well-reasoned argument for keeping everything. Midway through the fall semester, it was blatantly obvious that the students were stressed. While all the due dates were spread apart (i.e., no major projects were due on the same day), at the midpoint of the semester, students were working on five different assignments simultaneously. The instructors were lenient and fair while continually reminding the students how to spread their workload and not to worry. In the end, the students pulled through wonderfully. The project work was very well executed and the individual assignments in general were very good. Final student grades were also quite good. Only a few of the 180 students switched to a non-engineering major, but this is to be expected in the first semester, and only one of those students changed because of the workload. Nonetheless, the course content will need to be reduced, and no one on the course committee wants to give up their “pet projects.” This will be a major item to address in the Spring semester.

Incidentally, it should be noted that every faculty member on the planning committee was also an instructor for the course. We had one additional instructor that joined us as the planning committee morphed into the instructor committee.

Decisions on creating student teams was contentious. Teams can be formed by the instructor or self-selected by the students. Teams can be kept intact from the beginning to the end of the semester or could be mixed from project-to-project. There are reasonable arguments for any of these options. Instructor-formed teams allows for a mix of majors on each team and/or can be accomplished systematically allowing for similarity of schedules among team members. Lawrence Tech has a very mixed student population of residential and commuting students. We also have a mix of students with jobs and those that do not. Finally we have a mix of students that are traditional (ages 18-22) and non-traditional. All of these factors can be taken into account by surveying the students and using the data to form teams appropriately. On the other hand, if there is a conflict that develops within these instructor-formed teams, it becomes the instructor’s burden. Self-selected teams for the most part bear their own burden for conflict resolution. Keeping the same team composition intact for the entire semester allows a rapport to grow and time management is much easier when multiple projects overlap. On the other hand, by mixing up team composition between projects, the first-year students are given an opportunity to meet many different students and form a bond they may have never otherwise formed. It also allows the students to experience a variety of different team dynamics, which can be very valuable for their future education and work experience. In the end, we were compelled to use a mix of team formation. The first two projects (egg package and straw bridge) were small-scale projects and thus required only two and three member teams respectively. Subsequent projects required four to five members. In other words, we could not keep the same teams throughout the semester. We also wanted instructor-formed teams early in the semester. This way we could ensure that many students met each other, and we could evenly distribute the majors throughout the teams. By the fourth project through the sixth, we allowed the students to form their own teams. Surprisingly, the students mixed themselves up between majors (i.e., no team was dominated by a single major) – a pleasant happenstance. They had also, in general, figured out whose schedules worked well together and who lived on- or off-campus.

Since each section of the course only meets once per week, when selecting days of the week for each section, we had to be careful not to have a section on Monday. At Lawrence Tech, there are only 14 Mondays, while every other day has 15 meeting times.

When developing the course authorization form for official registrar entry into the course catalog, we had every engineering department chair sign for approval. This was done for four reasons. First, instructors were to receive two contact hours for this one-credit hour course. Second, we needed their support to expend a faculty member's time to participate on the curriculum committee. Third, course flowcharts and scheduling needed to be altered. These alterations proved to be slightly difficult as credit hours are relatively equally distributed over all semesters. Splitting two credits in one semester into one credit over two semesters slightly upset the balance. Fourth, every chairs' approval generally guarantees that the new format has been discussed and approved by all the engineering faculty. Besides the chairs' approval, it was also necessary to keep the coordinator of core curriculum courses (math, science, humanities, etc.) well informed of the changes to the first-year engineering curriculum. Because of the prerequisites of the course and newly created scheduling conflicts, "bottlenecks" can be created. For example, some students need full-time student status (12 or more credit hours) for loans and/or scholarships. During Fall semester student advising, this needed close monitoring.

With our prior two-credit hour discipline-specific introduction to engineering courses, two-credit hours meant two meeting hours per week. Now only one-credit hour meets for two hours per week. This created some conflict with instructor course loads, which in turn creates some difficulty in having enough instructors for all sections. The problem becomes worse when we have simultaneous one hour discipline-specific courses and two hour multi-discipline courses. We have the fortune of employing many adjunct professors with several years of Lawrence Tech experience and a high regard from the students. Among this pool of adjunct professors, we have been able to identify at least three instructors comfortable with these open-ended and non-traditional freshmen courses. Be aware that any adjunct professors must be able to spend significant time on campus as the students will use office hours regularly. There is also significant on-campus prep-time for each class period every semester, compared to traditional lecture-style courses.

The workload for developing projects and assignments was relatively evenly split between four of the instructors. This entailed developing handouts and presentations and/or gathering supplies for each project or assignment. This requires a tremendous amount of time the first time the course is deployed, so we tried to insure that one instructor was preparing one project at a time. The ACLs had all been employed prior to the new course, so the most experienced instructor for each taught the remainder how it is deployed.

Funding for expendable supplies is necessary. To ensure consistency of resources between teams, materials for many of the projects must be supplied by the university. For example, with the straw bridge project, all teams must be using the same brand of straws and tape; an important part of the project is structure design, not material selection. Another similar example occurs with the playing cards supplied for "Cards to the Sky." Thus, we charged a lab fee for the course. Lab fees at a university often go into a general pool of funds, so we made sure that some of that money was put into the Engineering Dean's account specifically for EGE 1001. This is

especially optimal when a faculty member needs reimbursement for personally purchased supplies. (Since we do not have any college-wide laboratories, we do not have a dedicated staff member to handle a college-wide design studio...yet.)

Consistency between sections is a must, both in delivery of content and grading. With seven instructors and eight sections, communication was key. Admittedly, we were only able to stay one to two weeks ahead of deployment for ACLs and assignments. Therefore we met regularly each week. Typically the meetings covered three major items. 1) How to present and deploy content (especially an ACL that was new to many of us). There was typically one to three “experts” on the content that could walk through the content with the remainder. 2) Review and distribution of newly prepared handouts or PowerPoint presentations. This was aided by having an instructor-only Blackboard website organization. All content was separated by week and further divided between instructor resources and student handouts. 3) How to grade an assignment, both for consistency and points allotment. Rubrics were the key for consistency. While an individual instructor may be responsible for project development, rubric develop for the project/assignment was typically a committee effort. For points allotment, the committee could quickly decide, for example, that 10 points of 50 was for interim reports, 30 points would be for final testing, and 20 points would be for the final report. When there was a split decision, the course coordinator made the final decision.

Many of the assignments and in-class presentations have intriguing and/or surprising reveals at their conclusion. The riddle for example has a single solution. The straw bridge project has an interesting special solution that the students usually do not discover during their design process. Cards to the Sky has some key points for success. All of these are best experienced first-hand (i.e., live) by the students. The surprise associated with the experience creates the highest impact resulting in excellent retention. The instructors must be clear in telling the students to keep the reveals to themselves – not to spoil the experience for others. They must also ask if anyone knows the reveal before showing it and remind the student or two to please keep the answer to themselves. Surprisingly, the students did a fantastic job. Another potential problem arises when a few of the projects, such as the rainwater car and pipe maze have an innate best design. Many ideas will work; some work better (or are at least easier to construct and test). In the long run, we *do* want the students to benchmark and research before settling on a final design. Working with students from other sections should be encouraged for open-ended design projects. On the other hand, we will need a rotating repertoire of projects to choose from so that, for example, the rainwater car is not overdesigned by the third year of implementation. (Freshmen talk to sophomores and juniors who have taken the course as well.)

Finally, a debriefing meeting of all the instructors must take place immediately at the conclusion of the semester, before any semester break. Issues, necessary changes, and ideas are still fresh. In addition, one section may have experienced an issue that another one did not, so this issue can be noted for future sections.

As mentioned in the Proposal section, a few other items must be addressed to implement the multi-discipline course and will be mentioned here again for reference; a convertible classroom must be established, a coordinator must oversee all operations, and appropriate course prerequisites must be set.

Conclusions

Many individual two-credit hour discipline specific courses were combined into a one-credit hour multi-discipline course and a one-credit hour discipline-specific course. This allows the student to experience a variety of engineering disciplines and consistent entrepreneurially minded learning, while still being able to gain a base of information within their chosen discipline.

Each instructor conducted informal group and individual interviews with their section of students. All of the students agreed that the one-credit course required too much work. On the other hand, they realized the value of everything that was accomplished; in essence, there was not a single assignment that stood out that should be cut. The students did request that more studio time (i.e., time to work on projects in class) should be allotted. However, they also requested that more ACLs are incorporated which of course takes away studio time. Upon reflection, this is probably an indication that we achieved the appropriate middle-ground of class-time use. We are currently unsure if the first-year students will actually use extra studio time earlier in the semester if it is given. By mid-semester, they have yet to realize its importance. For example, in weeks 7 and 8 when there was some time to refine their rainwater car, almost every student simply left class early and did not use the second hour. By week 12, 13, and 14 (after realizing that their rainwater car could have been better with more time devotion), nearly every team was using the second hour for refining their pipe maze device. This was reflected in the scoring differences (i.e., grade difference) between the two projects. Out of 40 teams, very few teams were able to reach their goals for the rainwater car assignment. On the other hand, 39 or 40 teams achieved 45 of 45 testing points with many also accomplishing goals for bonus points.

During the interviews, the students expressed their opinion concerning which projects they found most meaningful. The display kiosk and the pipe maze device were the clear winners. The display kiosk allowed them to express the most creativity because of its extraordinary open-endedness. The pipe maze may have been so meaningful, because it served as a capstone. In other words, by the end of the semester, the students had gained an understanding of the necessary actions to be successful.

For the ACLs, the riddle and Cards to the Sky were attested to be most meaningful. Both of these revealed brand new insights that the students had never before considered, namely problem definition and customer awareness. It also helps that they are immensely fun.

In summary, a first-year survey course can teach problem-solving and design while instilling the entrepreneurial mindset and developing useful “tools” (from electronics experience to creating visual aids). Each of the KEEN student outcomes were (at least) experienced, albeit at a first-year level.

Future work for the course includes developing a rotating repertoire of projects which meet the same outcomes as its replacement. Also both indirect and direct assessment data will be collected and analyzed to quantify the effects of the course. Preliminary data was collected in the first offering of Fall 2013 and will be processed with subsequent data.

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Fostering an Entrepreneurial Mindset



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Entrepreneurially Minded Learning

Objective vs. course activity matrix

	Project					Individual Assignments/Homework					Active & Collaborative (in-class) Learning					presentations						
	package/egg drop	straw bridge	Disciplines presentation	Rainwater car	Metal/wood Shop Kiosk display	Maze	binders and cover page	Learning Styles	paper beam	E-waste (ethics)	EGC paper	Learning styles	Cabin Riddle	Inventions rank order/teaming	Cards to the Sky	oral communication - listening/sketch	Estimation (ping pong)	Ethics / Responsibilities	Student societies	Using PowerPoint effectively	Co-op and career services	Fab Lab, Wood shop, Electronics, Library
Objective																						
1. Learning style																						
2. Disciplines																						
3. Steps of EDP																						
4. success and failure of project																						
5. Teams, manage, fulfill need																						
6. communication																						
7. prob. solv., critical think., estimating																						
8. Tools																						
9. Global/social issues																						
10. Eng. Grand Challenges																						
11. Ethics codes and application																						
12. ethical theories																						
13. engineer in work/society																						
14. broad UG eng. ed. and lifelong learning																						
15. Professional Eng. societies																						
16. self-directed learning, research current topic																						

KEY
Explicit to activity
objective mildly met
not an objective of activity