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Innovation to Entrepreneurship in the First Year Engineering Experience

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Abstract

Traditionally first year engineering programs focus on fundamental engineering skills and introduce students to the engineering design process. More recently using the KEEN (Kern Entrepreneurial Engineering Network) philosophy there is momentum to push engineering education further by fostering an entrepreneurial mindset in young engineers. At Western New England University the first year engineering program has been revamped using a combination of elements including entrepreneurially minded learning (EML), Problem Based Learning (PBL), Active Collaborative Learning (ACL) and a design framework based on the "living with the lab" program developed at Louisiana Tech University.

The First Year Engineering program at Western New England University spans four common courses for all engineering majors. This work focuses on two courses, the Introduction to Engineering course, a four credit course offered in the first semester and the Data Acquisition and Processing course, a three credit course offered in the second semester. The framework behind the Introduction to Engineering course is a series four challenges based off of an Arduino robot platform. Including this platform with other basic engineering tools like solid modelling (SolidWorks), traditional skills such as computer aided design (CAD), basic programming, teaming, basic statistics, innovation, the engineering design process, technical writing and oral communications are taught using both ACL and PBL techniques. A degree of EML is presented in this course through artificial budget requirements that are built into the projects.

During the second semester of a students' first year students are guided further in EML concepts in the Data Acquisition and Processing course. In this course a smart design project forms the basis of the EML experience which includes such skills as seeking opportunities using brainstorming, accessing market interest, accessing technical feasibility, designing for manufacturability, and providing a cost analysis of an eventual finalized product.

The entrepreneurial impact of this comprehensive program is assessed through surveys which gage the students' awareness of EML concepts.

This paper will present an overview of the ACL, PBL and EML techniques used in the First Year Engineering Program at Western New England University.

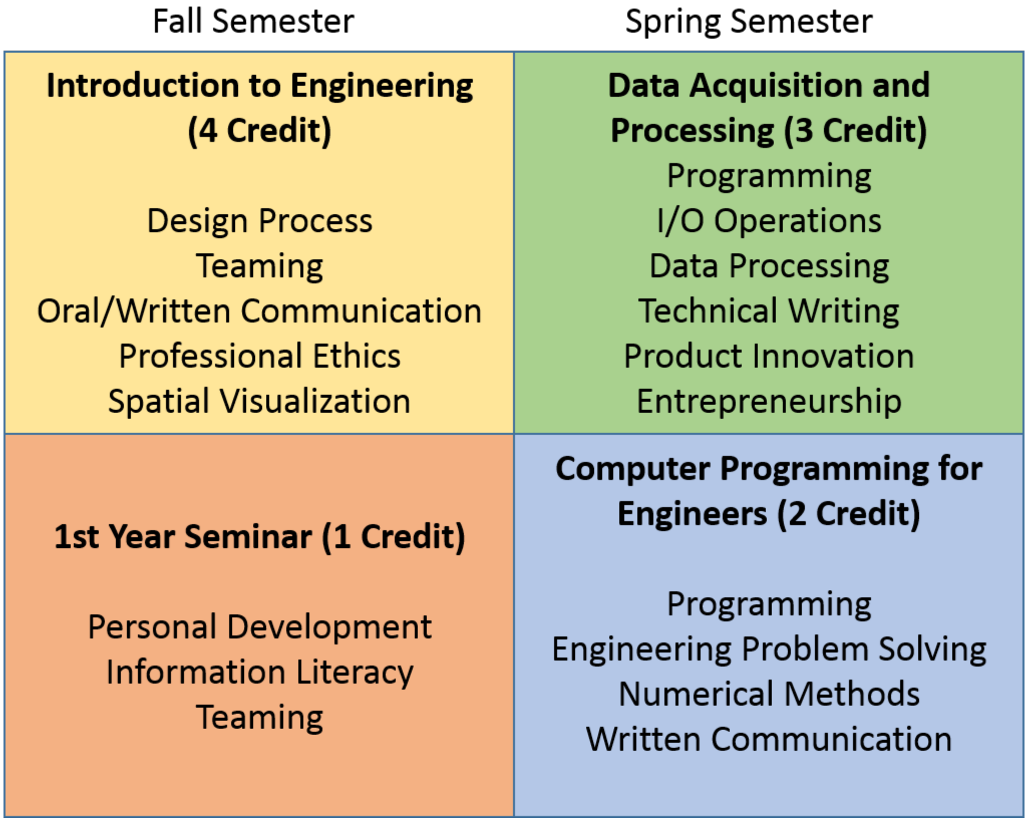
Introduction

This paper outlines a comprehensive first year engineering program that incorporates innovation and entrepreneurship over a two semester span. Innovation and Entrepreneurship skills are delivered to students using Problem Based Learning (PBL), Entrepreneurial Minded Learning (EML) and Active and Collaborative learning (ACL). Students perceived mastery of innovation and entrepreneurial skills were assessed using a set of pre and post-program surveys. Entrepreneurship expertise was further assessed through an independent judging of open ended design projects on such criteria as novelty of opportunity and assessment of market.

Course Structure

The first year engineering program course structure is outlined in Figure 1. The primary course outcomes are listed for each course in the figure. Many of the skills outlined are complimentary amongst the program courses. In the fall semester students take the Introduction to Engineering and the First Year Seminar courses. The courses complement each other in several areas notably in teaming and written communication. Students are presented with teaming strategies in both courses. Notably in the engineering seminar, students are presented with the KGI method of teaming and personal assessment [1]. Students are then able to practice and assess progress on these skills in team-based PBL work in the Introduction to Engineering course. Teams are typically four member teams. The primary PBL event in the Introduction to Engineering course is a series of team based ‘bot design challenges based on the Arduino microcontroller and the BOE-BOT platform [2]. These challenges form the primer to innovation for these students. It should also be noted that a cornerstone of the First Year Engineering Program at Western New England University is the pairing of students with academic advisers who also serve as the student’s instructor in the Introduction to Engineering course.

In the spring semester first year, engineering students take the Data Acquisition and Processing and the Computer Programming for Engineers courses (Figure 1). In the Data Acquisition and Processing course students learn the graphical-based dataflow programming language, LabView and concurrently develop team-based open-ended smart design projects. Arduino targets are used in both data acquisition lab assignments and in the production of the smart projects. The primary entrepreneurship component of the first year engineering experience at Western New England University is the smart design projects. The Computer Programming for Engineers course is based on a MatLab platform. The focus of the course is programming and numerical methods. These courses complement each other and the Introduction to Engineering course primarily in the areas of programming and written communications. For example, programming is taught in all three courses using three different platforms, C using the Arduino IDE in the Introduction to Engineering Course, LabView in the Data Acquisition and Processing Course and MatLab in the Computer Programming for Engineers Course. Written communications are stressed in all four first year engineering courses. This paper will focus on the Introduction to Engineering and Data Acquisition and Processing courses as these courses present the majority of the Innovation and Entrepreneurship content in first year engineering at Western New England University.



Fall Semester	Spring Semester
Introduction to Engineering (4 Credit) Design Process Teaming Oral/Written Communication Professional Ethics Spatial Visualization	**Data Acquisition and Processing (3 Credit)** Programming I/O Operations Data Processing Technical Writing Product Innovation Entrepreneurship
1st Year Seminar (1 Credit) Personal Development Information Literacy Teaming	**Computer Programming for Engineers (2 Credit)** Programming Engineering Problem Solving Numerical Methods Written Communication

Figure 1: Outline of the course structure of the First Year Engineering Program at Western New England University. Below each course title the primary course outcomes for each course are listed. Many of the skills taught in one course complement practice in one or more of the other courses.

Introduction to Engineering: Innovation

Innovation at Western New England University starts for students on the first day in the Introduction to Engineering course. Four person teams compete in a series of four autonomous ‘bot challenges. The ‘bot platform used is the Parallax BOE-BOT [2] controlled with an Arduino microcontroller. This platform was chosen after seeing the success of the “living with the lab” program at Louisiana Tech University [2]. The ‘bot challenges parallel lesson plans in computer aided design (CAD), programming (C in the Arduino IDE environment), the design process, fabrication methods and electronics which the students require to complete the design projects. Active and Collaborative Learning (ACL) methodologies are used throughout this instruction. Think-Pair-Sharing is a common ACL method used in teaching these lessons [3]. As this is a design challenge the PBL instruction is primarily a design-build [4]. A major course outcome of the Introduction to Engineering course is the ability to apply an engineering design process. The engineering design process used in the course (Figure 2) was developed from Holtzapple and Reece [5]. The design process is taught through direct application of the process while students design ‘bots for four separate design challenges. Initially instructors provide intensive facilitation of the design process. By the fourth design challenge students are able to implement the design process with little coaching. Ideation techniques such as brainsketching, flipping and Debono’s Six Thinking Hats method are used in the design process [6]. The ‘bot challenges are altered each year. Partnering with the University Army R.O.T.C.

Battalion, the most recent challenges were given an Army Engineering flavor and included an A) Race ‘Bot, B) Tractor ‘Bot, C) IED ‘Bot and D) Minesweeper ‘Bot. The ‘bots were also judged by the customer (Army R.O.T.C. Instructor/Officer) on aesthetics.

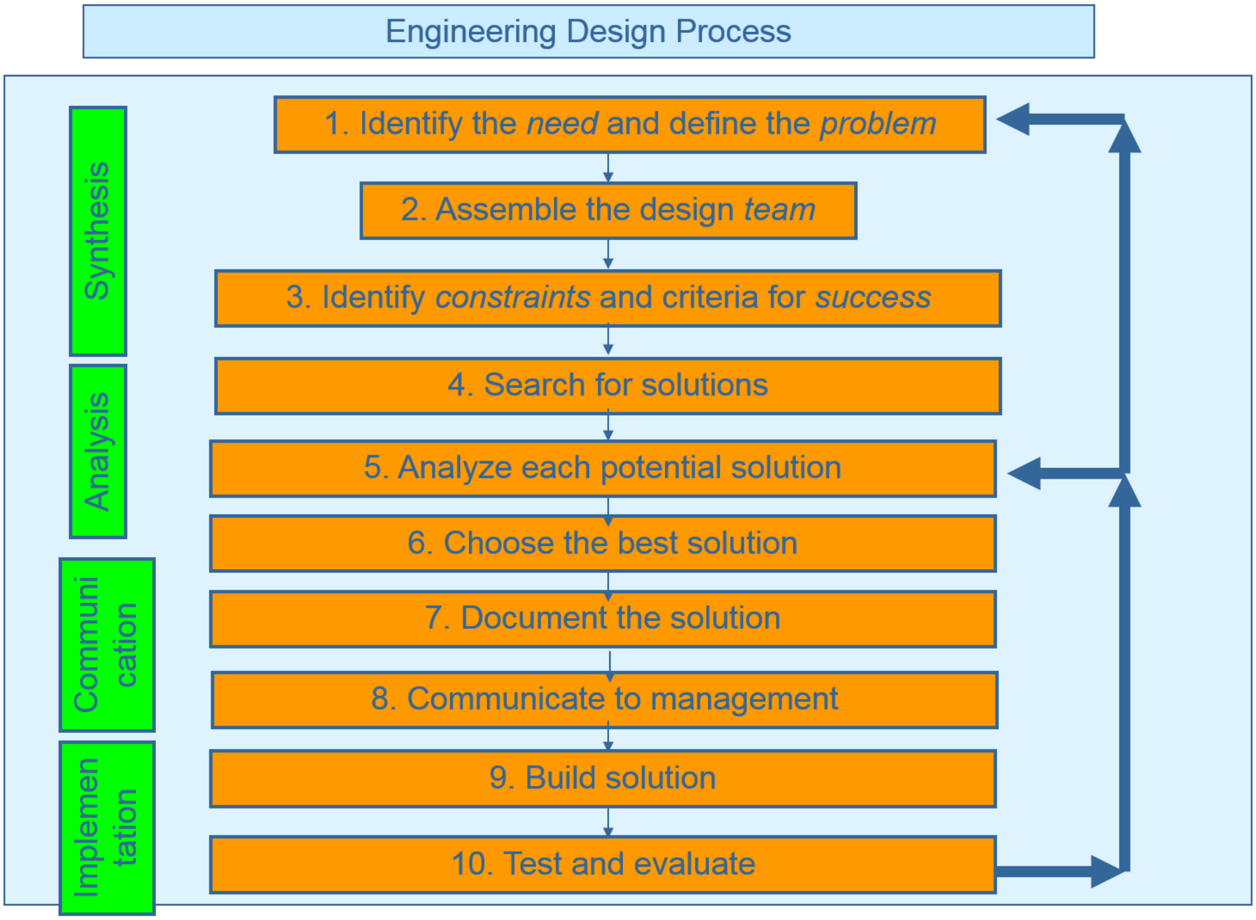


Figure 2: Schematic of the engineering design process taught in the Introduction to Engineering course. This process is derived from Holtzapple and Reese [5].

The first challenge (the Race ‘Bot) was given in the first week of classes and included the following PBL “Hook Statement”:

> “Cyberdyne Systems, inc (makers of skynet) is developing a multipurpose robot for the US Army Engineers. Your job is to build the fastest possible robot (with the given parts). Oh, and here’s a catch the course has a turn at the end so it’s not completely straight. The bot should also include its own on-board starting signal. Cyberdyne systems cares about its product looks and budget is always an issue.”

An image of the ‘Bot course is shown in Figure 3. Photogate sensors wired to an Arduino microcontroller with an LCD display were used to accurately display the ‘bots race time. The photosensors were fitted to stands so that the beam height was 3 inches from the base (Figure 4). Students showed high degrees on innovation and ingenuity on this design challenge. Examples included ‘bots with swinging arms to trigger the final photogate, ‘bots with trailers to trigger the starting gate after the ‘bot was nearly at the finish and ‘bots which jumped the starting line followed by follow-on trailer ‘bots which simultaneously triggered that start and finish sensors (Figure 4).

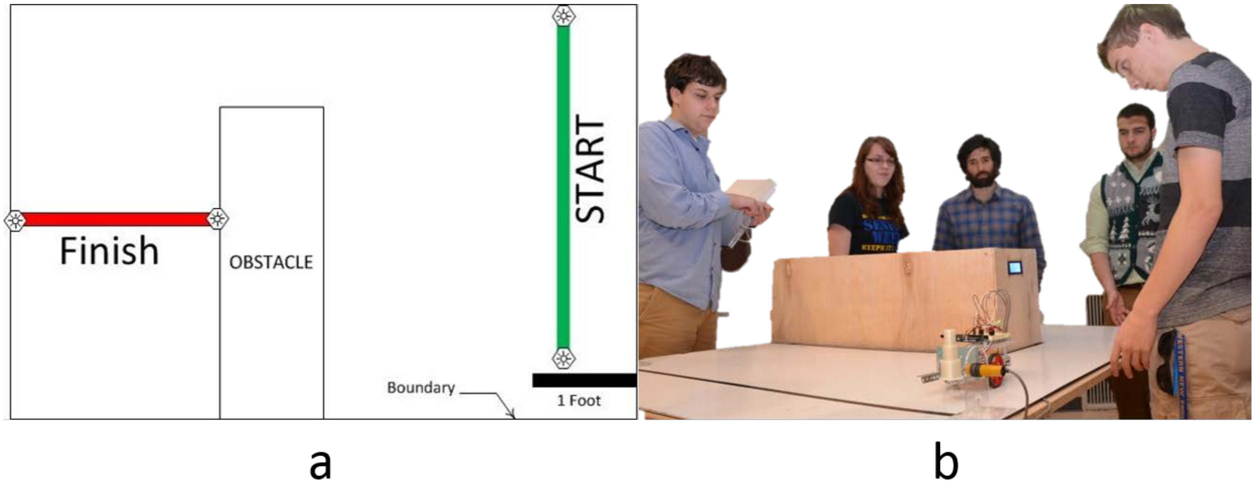


Figure 3:Race 'Bot challenge course a) schematic and b) action photo. The start (green line) and finish (red line) were fitted with photosensors wired to an arduino controller with a LCD display in order to accurately display the race timing. The obstacle was a rectangular prism one foot in height, three feet long and one foot in width.

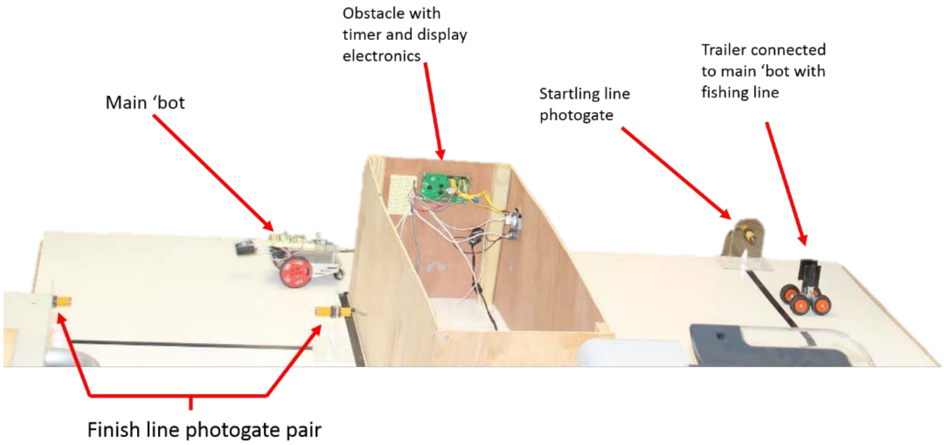


Figure 4: The race ‘bot course along with an innovative student design. This 'bot was designed to travel under the photogate not triggering it until a follow on trailer connected with fishing line tripped the sensor when the lead 'bot was nearly at the finish sensor.

The second design challenge given to students, the “tractor ‘bot” involved moving a cylindrical mass a set distance of four feet while expending the least amount of electrical energy (Figure 5). Most teams simply pushed or pulled the mass over the distance. Some innovative teams rotated the mass on its side allowing the ‘bot to roll the mass expending less energy than other designs.

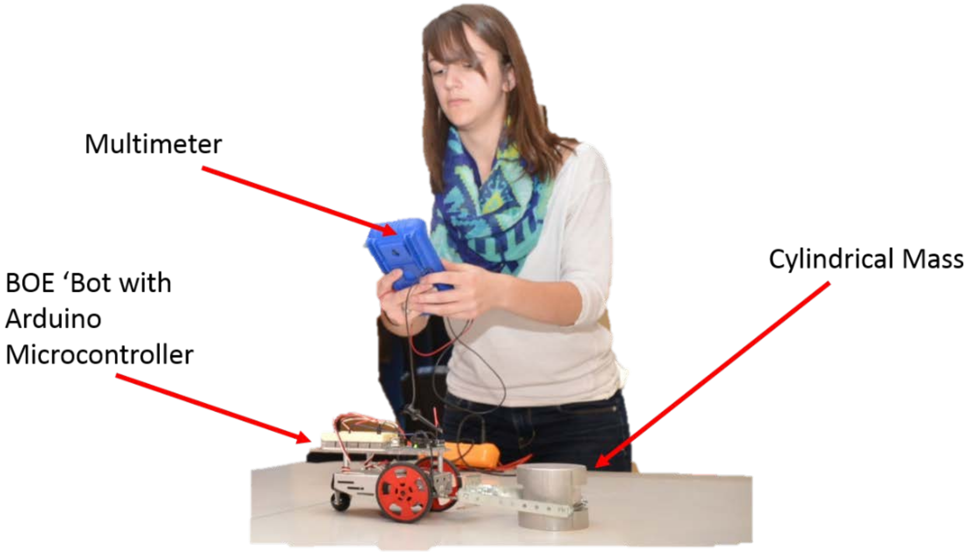
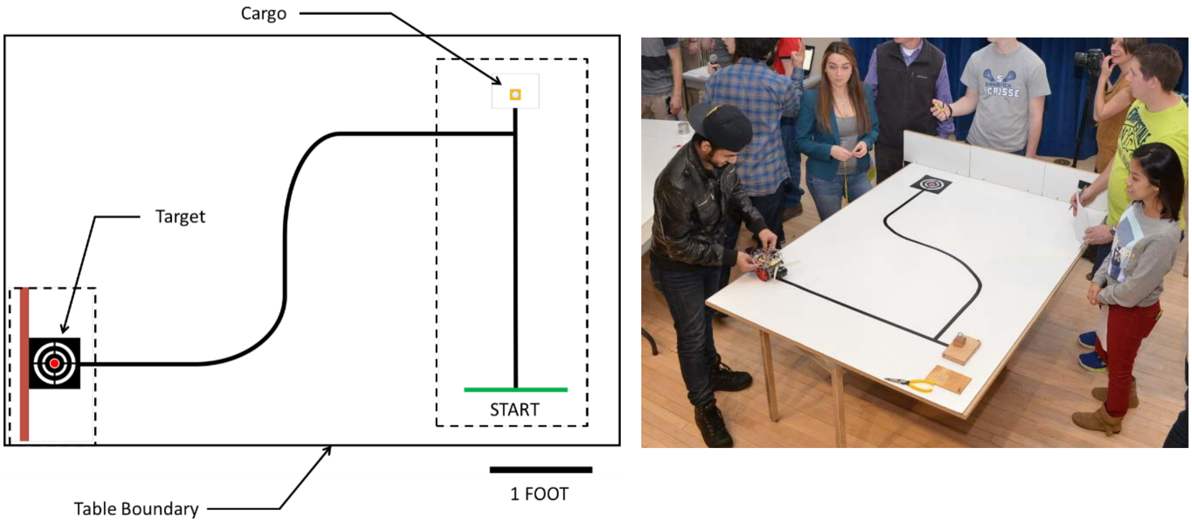


Figure 5: A student measures electrical current using a multimeter as a ‘bot moves a cylindrical mass across a 4 foot span.

The fourth and fifth design challenges were given to student teams simultaneously in the 9th week of a 15 week semester. At this stage student teams were well versed in the application of an engineering design process and student teams needed less coaching. These projects however have a much higher degree of difficulty in terms of programming. The first two design challenges given could be completed using open-loop programming without the use of sensors. The last two challenges however necessitate the use of sensors and more advanced closed-loop programming. The forth challenge given was called an “IED ‘bot”. The task given was for the ‘bot to find, grab and deliver an fake improvised explosive device (IED) to a target and then back up a given distance. The PBL hook statement follows:

> “Cyberdyne Systems, inc (makers of skynet) is developing a multipurpose robot for the US Army Engineers. Your job in this task is to build a robot that can carefully pick up an IED and deliver it to a safe target area. These IED’s are ‘hot’ so the ‘BOT needs to deliver the payload to the target as quickly, as accurately and as safely as possible. To demonstrate feasibility the payload location will remain constant. Cyberdyne Systems cares about its product looks and budget is always an issue.”

The course layout was given to students for the design process (Figure 6). The layout was given such that the ‘bot would be required to use sensors with closed-loop programming approaches. Line tracking was a major part of the design.

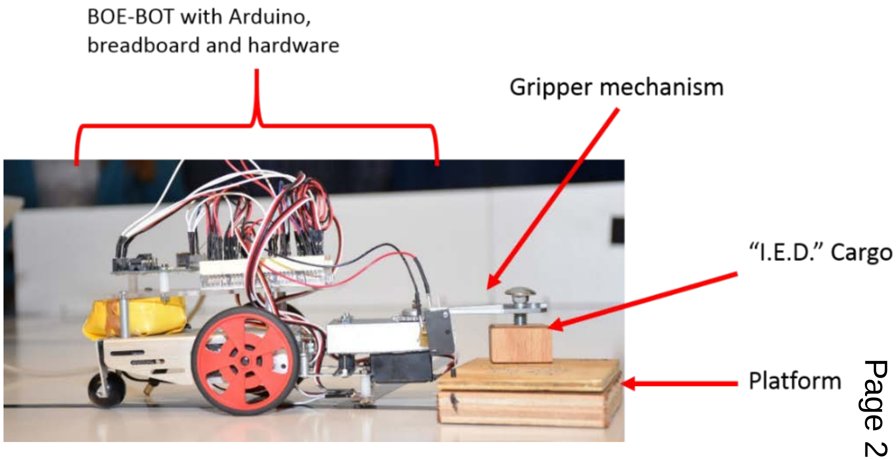


a b

Figure 6: The IED ‘bot course a) schematic and b) action photo. The dashed lines on the schematic represent areas that were designated to not change from the time of the problem definition to the competition. The path between cargo and drop target therefore could change necessitating students to develop a sensor-based closed-loop programming approach. The black line represents a line that the ‘bot could follow using line tracking methodologies.

In addition to the base ‘bot, students were given a set of sensors including an IR distance sensor (GP2Y0A21YK0F, Sharp), a bump sensor (snap action switch , Pololu) and two line tracking reflectance sensors (QTR-1A, pololu). The IED challenge required a major mechanical design in the mechanism used to grab the IED cargo (Figure 7). A key component of the course content was to instruct and guide students in designing for fabrication and manufacturability. Students designed gripper mechanisms using the Solidworks computer aided design (CAD) software package (Figure 8). With manufacturability in mind students had the option of building mechanisms using 3D printing (Maker-bot replicator) or laser cut plastics (Trotec Speedy 100). Teams were also given a standard set of erector set parts (multi model 15, Erector). These tools are part of a Freshmen Fabrication Lab which also includes soldering tools, electronic wiring tools, hand drills, standard tools sets, a scroll saw, belt sander and drill press (Figure 9).

Figure 7: IED ‘Bot gripping the “IED” cargo with the gripping mechanism. The IE.D cargo was placed on a platform 1 inch from the table.



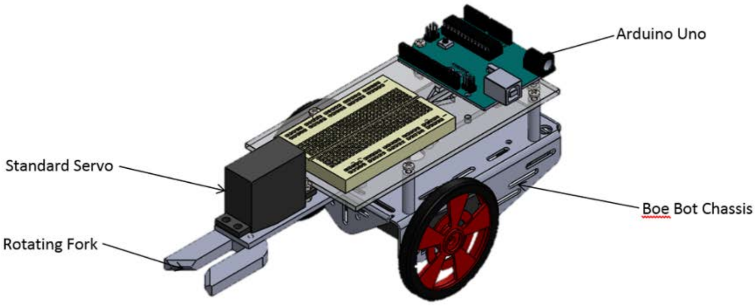


Figure 8: Example of student SolidWorks solid model assembly of an IED 'Bot design.

Figure 9: Photographs of students working in the Freshmen Fabrication Lab.

The final design challenge presented to students was the "minesweeper" challenge. In this challenge, students were tasked with clearing as many "mines" off of a table in 60 seconds as possible. The PBL "hook" statement read:

> "The Army also wants Cyberdyne systems to build a robot that can push mines off of building roofs and cliff tops. Your job is to build a robot that can push as many mines off of a 6' x 4' table as possible in 60 seconds. The robot must start the challenge with a size under 9"x6"x6" and cannot fall off of the table during the challenge. Cyberdyne systems cares about its product looks and budget is always an issue."

This final challenge required students to use the design for fabrication and closed-loop programming techniques learned through challenge three, the IED 'bot challenge. This challenge produced many innovative designs (Figure 10). The primary innovation was in designing systems to push as many “mines” off of the table while still meeting the size parameter and designing closed loop systems to prevent falling off the table and stopping at 60 seconds.

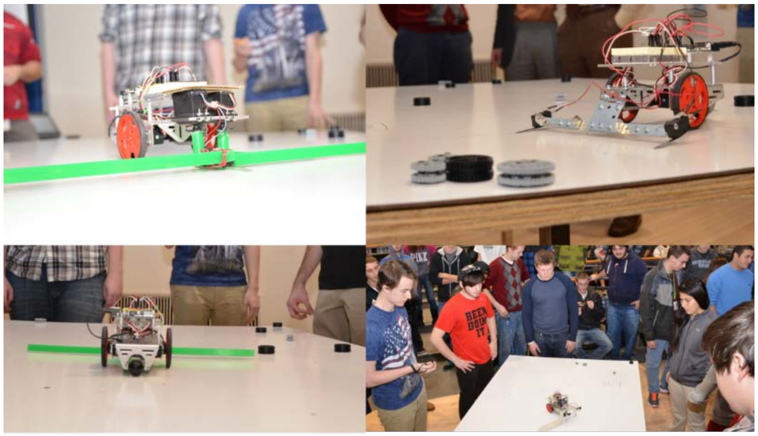


Figure 10: Photographs of “minesweeper ‘Bots” in action clearing “mines”.

While innovation and the design process was the focus of the Introduction to Engineering course a degree of entrepreneurial minded learning (EML) was introduced through the introduction of artificial monetary constraints on the project (Table 1). One of the “Criteria for Success” teams used in the design process was to minimize cost. Teams therefore were required to communicate engineering solutions in economic terms, one of the KEEN complimentary entrepreneurship skills [7].

Table 1: ‘Bot challenge component cost breakdown. This cost structure was implemented in order to include a degree of EML in the project.

Design Project Cost Structure
\$5.00 per in^3 of 3D print
\$1.00 per in^2 of laser-cut acrylic
\$2.00 per each individual erector set part
\$25.00 per each continuous rotation servo
\$30.00 per each standard servo
\$15.00 for the standard servo acrylic mount
\$0.50 for each erector set nut/bolt
\$20.00 per permanent magnet
\$0.50 electromagnet wire per foot
\$1,000,000 for a 1”x1” piece of tape (duct or otherwise)

The introduction to Engineering course culminated in a design competition in which all first year engineering students competed in the four ‘bot challenges plus an aesthetic criteria judged by a Captain from the University ROTC battalion. This aesthetic judging was important in teaching students the “voice of the customer”. Lessons from Don Carpenter’s “House of Cards” PBL were directly incorporated in this aspect of the competition [8].

Spring Semester: Smart Product Design

In the spring semester, the freshmen continue their first-year sequence with a course titled “Data Acquisition and Processing”. Half of this course focuses on introducing students to the LabView environment, while the other half continues to focus on engineering design through PBL, EML and ACL. The class sizes remain the same, at about 24 students; however, they have entirely new compositions as a result of a new academic scheduling cycle.

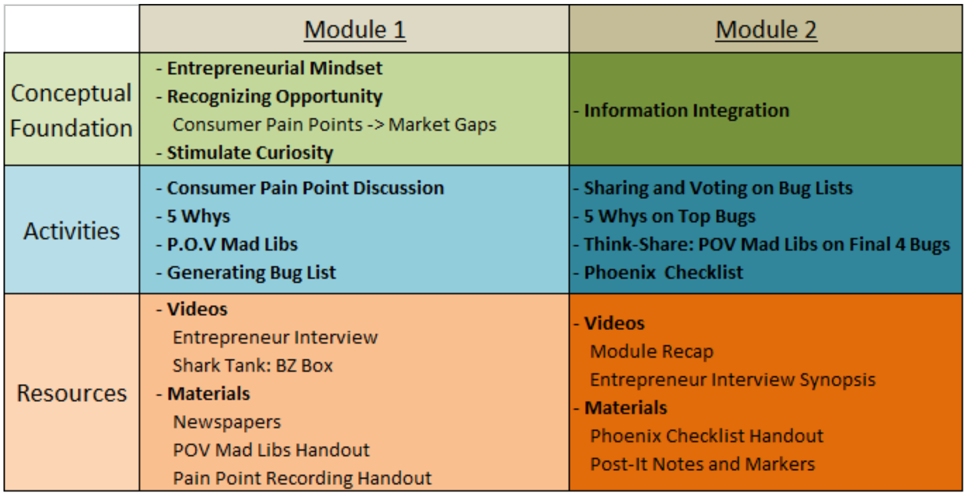
The design portion of this course takes a different approach than in the fall semester. Instead of providing the students with specific prescribed tasks, we let the students formulate their own need and problem statements, and apply the Engineering Design Process in order to produce and demonstrate a working prototype of a “smart” product. To qualify as “smart”, the end product must involve some combination of sensors, actuators and programmable functionality. At the end of the semester, there is an “Expo” event where each team of 3 or 4 students shows their working prototype alongside a poster and accompanied by a well-rehearsed 30-second elevator pitch. This event is locally advertised and well-attended by local high schools as well as business owners and entrepreneurs, several of which are asked ahead of time to serve as judges.

One of the most important and defining steps in the Engineering Design Process is obtaining a good need and problem statement. This is also a step which students tend to rush through if not carefully guided. Often, students have “pet” projects which they are eager to pursue, but which tend to bypass need and problem formulation as well as some other key steps in the Engineering Design Process. It is therefore best (both in terms of meeting the course objectives and increasing the quality of the projects) for students to approach the need, problem and concept generation portion with an open mind. This is also essential for a more successful and rewarding experience of the entrepreneurial process, since it can make students more likely to recognize and address big-picture societal and/or market needs.

In the past 2 years, the formulation of need and problem statements has been approached by instructing each team of students (3-4 per team) to generate a “bug list”. This is essentially a list of problems, annoyances, or inconveniences that they encounter on a day-to-day basis and which could potentially be addressed with an engineering solution. Then, they vote as a team to select the most compelling “bug” and write an open-ended need and problem statement. After this, the teams brainstorm to identify reasonable constraints, set attainable criteria for success, generate several diverse solution concepts, and screen the concepts in order to select, design and produce the most viable option.

This year, about half of the sections of this course (3 out of 7) tried a different approach for generating need and problem statements. Instead of simply assigning a “bug list”, a much more in-depth approach was designed and implemented which carefully guided students through entrepreneurial-based problem identification. This approach consisted on two modules, each executed during a full 80-minute class. These modules, outlined in Table 2, focused on explicitly introducing the entrepreneurial mindset. Students were guided through various activities to recognize opportunity, stimulate curiosity and integrate information. In the beginning of Module 1, the students were shown a video excerpt from the ABC show *Shark Tank*, where a young woman pitched the "BZBox": a collapsible storage box that is easier to fold and re-use than conventional cardboard boxes. After watching the video, the students were instructed to conduct a team discussion of the pain points (i.e., bugs) that this product addressed. Then, they set out to find the root of the problem and formulate a suitable problem statement via the "5 Whys" and "POV Mad Libs" methods. These methods are taken from Stamford d.school's Bootcamp Bootleg document, which is an open compilation of several such *Design Thinking* tools [9]. Specifically, the "5 Whys" method consists of starting with the statement of the recently identified pain point and asking *why*; then, formulate an answer and then again ask *why*, and so on. The idea is that after 5 iterations, the students find themselves much closer to the heart of the problem. Subsequently, the "POV Mad Lib" method aims to formulate problem statements by filling the blanks in this sentence: "[*user*] needs to [*user's need*] because [*surprising insight*]". After Module 1, the students were assigned individually to compile a list of 15 bugs, pain points, and/or societal needs, which would become the starting point to generating one problem statement (as a team) from which to begin the engineering design process. The students were assigned to generate these bugs via 2 separate activities. The first one was to interview people (non-students) asking them to list things that "bug" them. The second one was to read through newspaper and magazine articles (newspapers and magazines provided by the instructor) and identify articles relating to specific societal needs.

Table 2: Advanced Modules for Need and Problem Formulation



	Module 1	Module 2
Conceptual Foundation	- **Entrepreneurial Mindset** - **Recognizing Opportunity** Consumer Pain Points -> Market Gaps - **Stimulate Curiosity**	- **Information Integration**
Activities	- **Consumer Pain Point Discussion** - **5 Whys** - **P.O.V Mad Libs** - **Generating Bug List**	- **Sharing and Voting on Bug Lists** - **5 Whys on Top Bugs** - **Think-Share: POV Mad Libs on Final 4 Bugs** - **Phoenix Checklist**
Resources	- **Videos** Entrepreneur Interview Shark Tank: BZ Box - **Materials** Newspapers POV Mad Libs Handout Pain Point Recording Handout	- **Videos** Module Recap Entrepreneur Interview Synopsis - **Materials** Phoenix Checklist Handout Post-It Notes and Markers

When the students returned for Module 2, they each came with a list of 15 "bugs". This gave each team of 4 a list of up to 60 bugs which would become the starting point for this module. Most of this module consisted on refining their bug list through an iterative process of voting and applying the "5 Whys" exercise. This process is described in Table 3. After each team whittled their list down to 4 “bugs”, they applied the “POV Mad Libs” method to each, refining them in order to obtain 4 good problem statements. Then, the students were introduced to the “Phoenix Checklist” method for integrating information. This method, developed by the CIA in the early 90s, offers a thorough way to look at a problem from various angles, in effect broadening the scope and providing big-picture context to the problem at hand [10]. This is a great way for students to really get a grasp for the implications of addressing one particular problem statement. After applying this method to each of their 4 final “bugs”, it should become clear to each team which of these 4 bugs is worth addressing given the resources available and time constraints.

Table 3: Module 2 Session Plan – Constructing a Problem Statement

ACTIVITY	TIME
Team share on the large list (48+) of “bugs” from homework	5 min.
Team vote on the 48 “bugs”. Vote has no “criteria”, each team member gets 24 votes and can put as many “votes” as they want on each “bug”. This can be done with stickers or marking pens etc. on a whiteboard or wall. The top 12 bugs move on to the next stage.	2 min.
Team: perform the “5 whys” on the remaining 12 “bugs”	12 min.
Team vote on the remaining 12 “bugs”. Each team member now gets 8 votes and the top 4 bugs move on.	2 min.
Individual “Think”: write down a P.O.V. mad lib for each of the remaining 4 “bugs” then as a team refine and combine to get 4 solid P.O.V. statements	9 min.
Review the ”Integrate Information” mindset	2 min.
Introduce the Phoenix Checklist	5 min.
Pair-Team using the Phoenix Checklist	12 min.
Introduce the homework assignment	1 min.

As described earlier, only three out of seven tried this advanced methodology for problem formulation. The other four sections simply asked the teams to come up with a list of “bugs” and vote on them as a team, without performing any of the module activities outlined in Table 2: Advanced Modules for Need and Problem Formulation. The main intent is to compare the outcomes of the section with the problem formulation modules to those without and determine if there are any statistically significant improvements in project quality, entrepreneurial merit and/or overall level of entrepreneurial awareness.

Assessment

Evaluation of project quality and entrepreneurial merit will be done via surveys administered to the visiting judges during the end-of-semester Expo, while evaluation of entrepreneurial awareness was done via comparison of “pre” and “post” surveys given to the students themselves. Table 4 shows a list of the questions in these surveys, all of which were answered by circling an integer between 0 (low) and 4 (high). The pre- and post-surveys were anonymous, however they were paired so that net change could be evaluated on an individual basis. A total of 140 students completed pre- and post-surveys. A total of 68 students across three sections were exposed to the opportunity recognition modules. The remaining 72 students did not receive the additional opportunity recognition modules.

Table 4: Pre/Post Survey Questionnaire

Please rate your current level of knowledge/ability regarding...	
Q1	*identifying an opportunity.*
Q2	*investigating a Market.*
Q3	*creating a preliminary business model.*
Q4	*examining technical feasibility, customer value, societal benefits and economic viability.*
Q5	*customer engagement.*
Q6	*assessing policy and regulatory issues.*
Q7	*determining design requirements.*
Q8	*performing technical design.*
Q9	*analyzing design solutions.*
Q10	*creating models and prototypes.*
Q11	*validating designs.*
Q12	*communicating engineering solutions in economic terms.*
Q13	*communicating engineering solutions in terms of societal benefits.*
Q14	*validating market interest.*
Q15	*developing partnerships and building a team.*
Q16	*identifying supply chains and distribution methods.*
Q17	*protecting intellectual property.*

The overall results from the pre-survey and post-surveys are shown in Figures 11 and 12, respectively. These are shown along with their standard deviations (error bars). The orange columns show the responses from the sections which did not perform the advanced modules for problem formulation, whereas the blue columns show the responses from those sections which did.

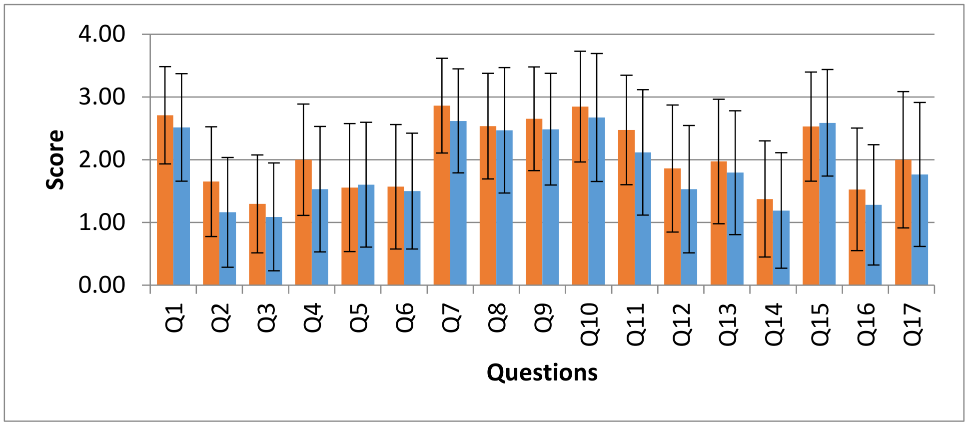


Figure 11: Pre-Survey Results. The orange columns represent the mean value of responses of students in the standard sections. The blue columns represent the mean response values for students in the group that was exposed to the extra opportunity identification modules. Error bars represent standard deviation.

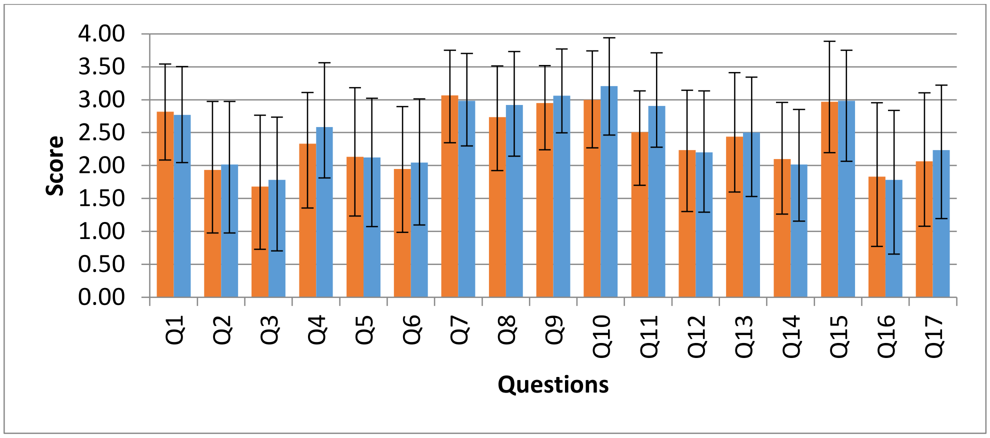


Figure 12: Post-Survey Results. As in the Pre-survey data, orange columns represent the mean value responses of students in the standard sections and blue columns represent the mean response values for students in sections exposed to the extra entrepreneurial modules. Error bars represent standard deviation.

Figure 13 shows the net gain from pre- to post-surveys. It can be seen from this figure that while all sections saw net gains across all questions, the sections in the control group (that is, those which underwent the advanced modules for problem formulation) showed consistently higher gains in most questions. It is particularly reassuring that some of the most pronounced contrasts can be seen in Q2, Q4, Q10 and Q11, which are perhaps the 4 questions most relevant to the advanced modules.

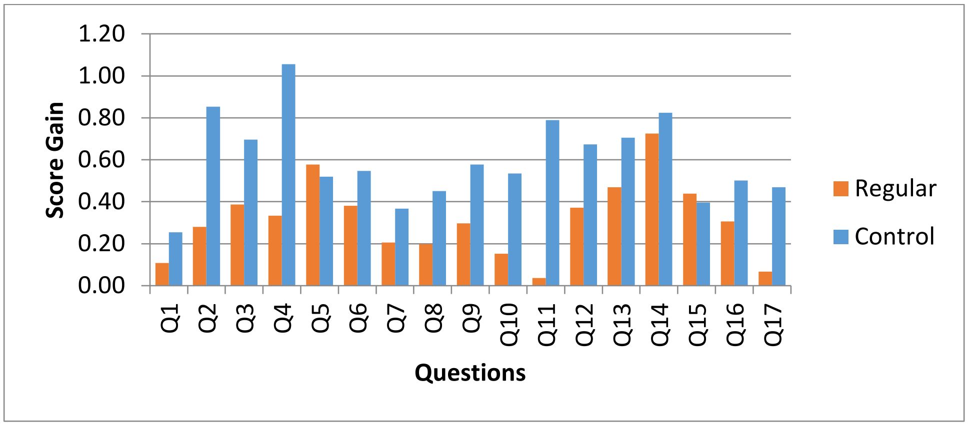


Figure 13: Net Gain Comparisons. These data represent the net gains between the pre- and post- surveys. The orange bars represent the gains made by students in the standard sections while the blue bars represent the gains made by students in the sections which were exposed to the opportunity identification modules.

Emerging Engineers Exhibition

At the end of the spring semester, a show-and-tell event dubbed the “Emerging Engineers Exhibition” is held on campus to showcase the freshmen’s Smart Product designs. The event is open to everyone, and well-attended by the campus population as well as visitors from the local community, including high school students and local business owners and entrepreneurs. Members of this latter group also serve as anonymous judges, and awards are given to the top 3 teams. The 3 deliverables from each team for this event are a poster, a 90-second elevator pitch, and a working prototype of their Smart Product design. Figure 14 shows a sample poster setup from the 2014 event, and Figure 15 shows two sample Smart Product designs.

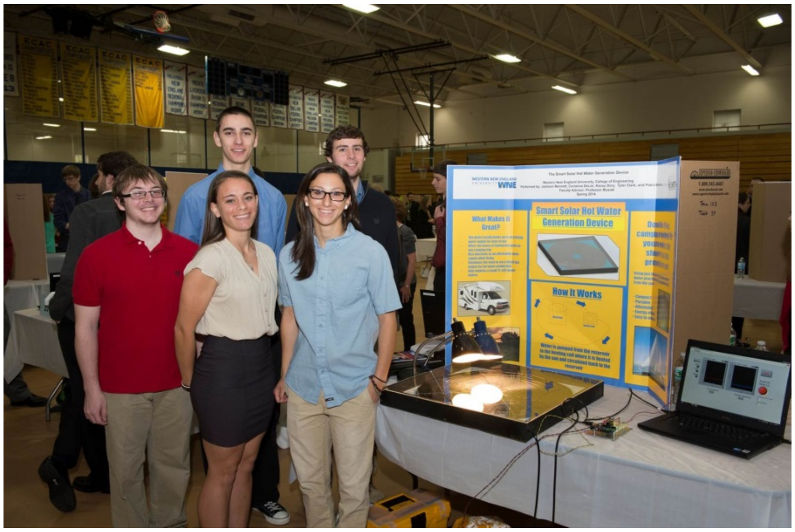


Figure 12: Team “Smart Solar Water Heater” posing for a group photo during the 2014 Emerging Engineers Exhibition

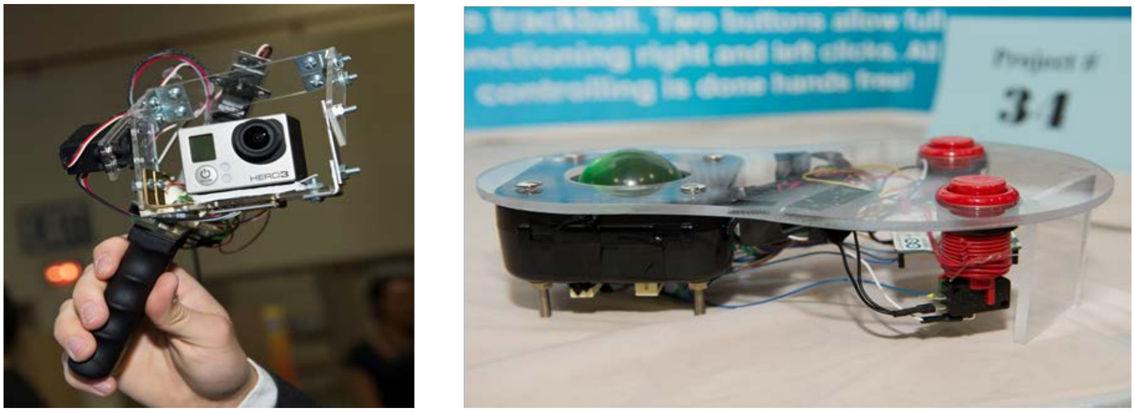


Figure *13: Sample Smart Projects from Spring 2014*
Left: “The Gimball Buddy” – a device to maintain desired camera orientation
Right: “The Foot Mouse” – enabling normal computing to arm amputees

Conclusions

This paper presented an overview of the entrepreneurial toolset utilized in the First Year Engineering program at Western New England University, particularly related to elements of entrepreneurially minded learning (EML), problem based learning (PBL), and active collaborative learning (ACL). These tools are specifically channeled through a 2-semester course thread. In the fall semester, students work in teams to address 4 specific challenges using an Arduino-based platform. The problem statements for these challenges are prescribed and discussed in the classroom. In the spring semester, the students (also in teams) develop their own "smart product" designs, starting by formulating their own unique problem statements. This year, three out of the seven sections added two in-depth EML-based modules aimed to inject a deeper entrepreneurial breadth to the problem statements and by extension to the overall smart projects. The success of these modules was assessed via "pre" and "post" entrepreneurial surveys completed by the students, as well as by the overall quality and entrepreneurial merit of the smart project designs, judged by local entrepreneurs. The survey results showed that those students exposed to the modules had a more significant increase in their scores (from pre to post), which suggests that the more advanced EML activities in the Smart Design project yielded an increase in perceived knowledge in these areas by students.

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