Proposal-Based Learning for Freshman Introduction to Engineering

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With more than thirty years’ experience in the education profession, Dr. Carpenter has a track record of managing the development of high quality, revenue impacting, blended curriculum. A seasoned professor and corporate trainer, she has delivered valuable learning experiences to students who range in age and ability from Head Start preschoolers to doctoral candidates at one of America’s oldest universities. As a certified Instructional Designer, she has held leadership and instructional design positions at Fortune 500 Companies where she has leveraged strong program management and communication skills, knowledge of various MLSs, and the ability to lead and collaborate with IT professionals, subject matter experts, and content developers to create and maintain revenue generating learning experiences.

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Logan Micher was born in Southery, England, in 1996. He earned an IB Diploma in May 2012, and is currently working towards his Bachelor of Engineering degree. Logan recently developed a low-cost, programmable robot designed for intermediary robotics instruction, and held classes in which he walked students through design, prototyping, revision, manufacturing, and assembly processes. Since 2010, Logan has worked as a private tutor; most recently he has moved from small in-person tutoring into electronic classroom learning as a consultant for an online tutoring service. In previous semesters, he has aided the teaching of introductory design and modeling classes at Florida Polytechnic University. As the operator of the Florida Polytechnic University Robotics Laboratory, he trains students to use fabrication machinery, 2D and 3D design software, and analytic methods to aid in student and research projects. Logan also provides 3D modeling, prototyping, and 2D design services to various local companies, and hopes to earn certifications for 3D design in the coming months.

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Prior to Florida Polytechnic, Dr. Drake was a Senior Research Engineer at Lockheed Martin Missiles and Fire Control, a post she held since 2008. Prior to that, she was a Nanotechnology Research Engineer at Lockheed Martin. She started and co-chaired the Lockheed Martin Nano-Bio working group and is the nanotechnology editor for the Industrial Biotechnology Journal. Her research interests cover novel materials and sensors based on metamaterial approaches; low-cost imagers and sensors; and biologically inspired or incorporated sensors and platforms.

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Abstract

Creation and Implementation of Proposal-Based Learning in a freshman introductory engineering course is described. The course introduces project-defining skills for use in a sequence of engineering design courses taken later in the undergraduate program. Proposal-Based Learning is similar to Project-Based Learning, and is comprised of the following elements: 1) requires a response to an open-ended challenge; 2) creates a need to understand the important elements of an engineering proposal, such as technical details, schedule of tasks and deliverables, and estimating costs associated with the proposed tasks; 3) requires inquiry to learn and/or create something new; 4) requires critical thinking and problem-solving; 5) requires identifying patentable aspects of the proposed solution; 6) results in a publicly presented performance; and 7) requires interpretation of customer requirements based on sparse information. This last element was given particular emphasis, as it is often overlooked in undergraduate engineering programs, yet frequently leads to unsuccessful proposal submissions due to misreading or poor internalization of customer needs.

Each student group of two to five members was required to generate a unique technical proposal in response to a Request For Proposal (RFP) or Broad Agency Announcement (BAA) supplied by the instructor. The format selected for the RFP or BAA is widely used in the engineering profession. The proposal topic choices were guided by the need to: stimulate the interest of students pursuing a variety of engineering disciplines; provide deliberately vague design constraints to introduce students to the challenge of interpreting the intentions of the RFP or BAA; encourage individual creative content in the proposed solution; and adjust the technical challenge to be accessible to students with no previous engineering courses. A preliminary design review with peers and the instructor provided valuable feedback to each group, with sufficient time allotted for design changes.
The learning outcomes were assessed using proposal quality, compliance with RFP or BAA specifications, judging by an outside panel of engineering and technology professionals, and student surveys. Several patentable concepts resulted from a total of 53 proposals responding to three RFP’s and one BAA. The challenges of implementing the instructional framework are discussed, along with recommendations for improvements.

Introduction

Describing ‘engineering’ to freshmen undergraduates usually begins with a working definition of engineering. Sheppard¹ suggests that engineers “scope, generate, evaluate and realize ideas.” Dym et al.² states “design is the central or distinguishing activity of engineering.” Hyman³, in his operational definition of design as “a proposed solution to a problem,” states that “the design itself is a value added proposition, meaning there is a business value in the solution, or else why bother designing it?” One of the ongoing challenges facing engineering programs is how to provide freshmen with an engaging, budget-aware introduction to engineering that enhances program retention and provides the student with skills that are applicable throughout their education and careers.

The learning outcomes of engineering programs have evolved over the past century. In the 1800’s, programs promoted “the application of sciences to the common purposes of life,” with the goal of training employees for the rapidly expanding economy. The Wickenden Report⁵ (1930) recommended design projects for sophomores and juniors, and the Grinter Report⁶ (1955) recommended engineering programs contain both technical (including design) and social (general education, social sciences) goals. Credit hour caps reduced or eliminated courses such as shop, design and manufacturing technology by the 1960’s. Reconsideration of these changes began in earnest by the late 1980’s. For example, a 1997 National Science Foundation report Systemic Engineering Educational Reform- An Action Agenda⁷ listed teamwork, project-based learning and industry interactions as important areas of emphasis. In addition to the creation of senior year capstone design classes, existing freshman introductory classes were modified to
improve student retention by having freshmen experience some aspects of engineering taught by engineering faculty.\textsuperscript{2}

Motivation for Proposal based learning

The role of an engineer increasingly involves defining and writing a technical response to a customer’s Request For Proposal (RFP) or Broad Agency Announcement (BAA). The proposal often requires the design or creation of a solution to the customer’s problem as interpreted by the proposal team. As stated by Jerry Jenkins, CEO of Texas Instruments- “most engineering jobs involve design and practice, not theory and research.”\textsuperscript{8} The report \textit{Educating the Engineer of 2020}\textsuperscript{9} contends that, in addition to an emphasis on real-world problem solving and teamwork, schools need to prepare students for more than their first job. Hart Research Associates 2013 survey\textsuperscript{10} found that 93\% of 318 surveyed employers said that when filling a position, critical thinking, clear communications and complex problem solving were more important than the engineering major studied. The natural arc of an engineer’s career eventually leads to significant participatory and/or leadership roles in successfully interpreting and responding to a customer’s stated and implied requirements. Awareness and development of this skill early in a student’s career has clear long-term benefits for the student, the employer, and the customer.

Unfortunately, engineers commonly think of engineering design as just the realization portion of Sheppard’s design\textsuperscript{1} that tends towards a hobbyist approach to design as opposed to an engineering approach to design. Although engineering programs continue to teach the technical competencies necessary for this exercise, many new engineers lack the mental discipline to perform a thoughtful evaluation of their proposed solution, or a careful interpretation of the customer’s needs, some of which may not be clearly defined. We believe that there is a need to introduce this skill as early as possible into an engineering program, and provide a vehicle for its deployment in a cornerstone class.

The ability to build confidence in engineering “thinking” should not be overlooked in the freshman year. One definition of engineering thinking published in 2014 by the Royal Academy of Engineering\textsuperscript{11} is described as Engineering Habits of Mind (EHoM) and includes systems
thinking, problem-finding, visualizing, improving, creative problem-solving, and adapting. Engineering thinking has two very important functions: 1) Female students often lack confidence in STEM and building early confidence in thinking like an engineer may help retention rates for females in STEM; and 2) Non-traditional engineering students and those populations with lower persistence in STEM get an early glimpse (and potentially improve learning gains) into what the process of being an engineer is like. While at first glance that may seem minor, this gives students the opportunity in their freshmen year to truly imagine themselves as an engineer in the future and have an understanding of what that looks like. We believe this will help with persistence in their program and give students an increased passion and motivation to stick out “tough courses.”

For student learning gains to be meaningful, the vast majority of students need a way to “cement” the knowledge in their minds. It has been demonstrated that real design examples and reasoning through conclusions is an effective way to get young students to higher learning gains. An often overlooked but extremely effective component of student engagement is the ‘fun factor” as summarized nicely by: “What everyone wants is a little excitement each day about going to class, a little reminder of why students chose engineering, through fun and challenging experiences that prepare students for their future.” Students always show interest in things (proposals) that are related to personal benefits and/or career aspirations (i.e. what am I going to do with this?). Since most engineering curricula in the first 2 years are not necessarily engineering or design based (ABET curriculum requirements call for one year combination of basic math and sciences plus a general education component), freshmen cornerstone classes such as ours are a way to weave the larger story of being an engineer into the first year student experience and perhaps even help with learning gains (and motivation) in those courses.

Teaching Frameworks

A number of teaching frameworks for engineering courses have been described elsewhere and include:
1) Project-Based Learning (PBL)- projects with student-supplied creative component;
2) Inquiry-Based Learning- students create knowledge rather than receiving knowledge, and the professor guides class discussion following a script;
3) Design Competitions- increased motivation for students, for example in junior electronics courses, and impromptu contests where challenge is assigned and completed in one class period;
4) Case Study modules- applied to open-ended, ill-defined problems, for example, the invention and design course at Univ. of Virginia\textsuperscript{17} given to engineering and non-engineering students and includes prototyping for a hands-on experience;
5) Reverse Engineering- also known as mechanical dissection, involves disassembly, analysis, and re-design of a device or apparatus; and
6) Design Based Learning- design used to teach engineering science, mostly used with middle school students, e.g. Georgia Tech program,\textsuperscript{18} but not common in undergraduate programs.

Project-Based Learning (PBL) was identified as the most effective teaching framework for engineering design. Carefully implemented PBL forces students to adopt both divergent thinking (open-ended questions with multiple solutions that may not hold any truth) and convergent thinking (questions whose answers hold truth, typically found in the engineering curriculum).

We define Proposal-Based Learning (which encourages similar divergent thinking, provided the proposed solutions have sufficient creative content) to be comprised of the following:

1) requires a response to an open-ended challenge;
2) results in a public presentation;
3) requires inquiry to learn and/or create something new;
4) requires critical thinking and problem solving;
5) requires identifying patentable aspects of the proposed solution;
6) introduces engineering proposal elements such as technical details, schedule of tasks and deliverables, and estimating costs; and
7) requires interpretation of customer requirements based on sparse information.
Items 5, 6 and 7 are particular features that distinguish PrBL from PBL. In a sense, PrBL and PBL each can encompass the complete engineering design process, but PBL typically focuses efforts on the build/test/operate portions of engineering design. PrBL focuses on the idea creation, evaluation, planning, and decision making portions of engineering design. By having a two-semester sequence consisting of Introduction to Engineering with PrBL, followed by Introduction to Engineering Design with PBL (where the projects are not the same between semesters), the freshman student acquires a complete introduction to engineering design. The authors are not proposing to replace PBL with PrBL. Rather, the authors propose PrBL as a useful addition to the toolbox of methods previously described.

The resource requirements for PrBL can be met with library and web access from student-owned devices, and are therefore minimal compared with the hardware and software tools, fabrication space and consumables associated with the projects in PBL. In addition, the need for safety protocols, equipment training and scheduling access to specialty equipment such as laser cutters, CNC machining or 3D printing are not required for PrBL. Because of these important differences, PrBL is much more readily scaled to large numbers of students. Note that the pilot test of PrBL described here was accomplished with over 200 students working in teams of 2 to 5 students. A significant resource investment by the institution would be required to support a similar number of students in a class employing PBL.

ABET requirements

Under ABET Criterion 3 (Student Outcomes) for Engineering programs, the student outcomes relevant for our Introduction to Engineering class are:

- (a) an ability to apply knowledge of mathematics, science and engineering:
The students are required to provide technical analysis of their proposed solution using math and science skills they learned prior to the course (usually high school).
- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability:
The RFP and BAA provides a list of constraints with which the student proposal must be in compliance.

- (f) an understanding of professional and ethical responsibility:
Although this was covered in class, it was not explicitly part of the PrBL framework used.

- (g) an ability to communicate effectively (orally and written):
The proposal generated by the student team and its summary using a standard quad chart format met the written portion. The presentation of the proposed idea in class and at an industry review met the oral portion.

- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice:
This included the design of an engineering solution, as well as the creation of the structural elements that comprise a professional technical proposal.

Course Logistics

Proposal Based Learning (PrBL) was implemented in the inaugural semester of a three credit hour freshman undergraduate course Introduction to Engineering. The objectives included:

1) improve student engagement and retention;
2) introduce students to aspects of engineering design;
3) acquire teamwork skills;
4) learn engineering communications tools.
Achievement of these objectives was assessed using proposal quality, compliance with RFP or BAA specifications, judging by an outside panel of engineering and IP professionals, and student course assessment.

The RFP/BAA

The challenges regarding selecting appropriate RFP or BAA topics and structures for PrBL are similar to the challenges associated with selecting hardware or software projects in PBL. For example, assessment of an Introduction to Engineering course at Arizona State University found that three projects selected from the National Academy of Engineering grand challenges list (solar tracking device, water transport and filtration device, educational toy or exhibit) had a negative impact on student interest in the engineering program. Another important consideration is the need to keep the attention of students from different engineering concentrations, as well as (in our case) a significant population of students enrolled in the College of Information & Technology. The latter group of students may have minimal interest or curiosity regarding engineering, and represent a challenge to win over their engagement in the class.

There needs to be a balance between narrowing the scope of the assigned problem sufficiently to avoid students being unable to find a way forward, but having a sufficiently open-ended nature that it reflects a real-world experience of responding to an RFP or BAA, which are often deliberately vague and open-ended. The proposal generation process strengthens the student’s ability to make decisions about a path with little information; the true focus of PrBL is on the thought process of design, not just the end product, prototype or artifact.

An important but often overlooked consideration for project selection should be that online and library resources for potential solutions should exist but they should not be too saturated. This avoids leaving the student with the feeling that “everything has already been invented.” The objective is to encourage divergent thinking to inject creative content into each student group’s proposed solution.
In all cases, the content of the RFP or BAA must not fall too far outside of the zone of proximal development or knowledge frontier of the student cohort, or student frustration and loss of engagement can occur. As Rabb et al. commented; “A students’ view that they could accomplish the work in a class was a greater factor in a students’ effort and in the critical thinking that they did in a class, than was their general academic skill.” A similar loss of engagement (due to boredom) will occur if the technical demands lie too far inside the student cohort’s knowledge frontier. There was some indication of this in the student responses to the open-ended survey questions. These are discussed later in the paper.

Finally, the students need to come to the conclusion that the new information has intrinsic value for follow-on courses and throughout their careers. The knowledge, therefore, needs to be decoupled from the technical specifics of the RFP or BAA. That is, the learning outcomes must be agnostic to the technical details of the proposals, and focused instead on the processes involved in creating the proposal in a team environment.

A total of three RFP’s and one BAA were created for approximately 220 students (over 90% of whom were true freshmen) in the inaugural semester of the class, having the following topics:

1) RFP- Acoustic noise in office space;
2) RFP- Controlling Wi-Fi access in an office or dorm space;
3) RFP- Energy harvesting for a hiker;
4) BAA- Harsh environment sensor/electronics enclosure.

The selection of topics was based on the desire to make them relevant to student experiences on campus, potential future projects on campus, and hobbies such as backpacking. It was also necessary to tailor proposal expectations to make creative solutions accessible for students with little or no engineering coursework completed.

The acoustic noise RFP was looking for ways to reduce the noise levels in faculty offices, which were designed without ceilings. The RFP was also relevant for a means of reducing the noise coupling between floors in a campus dormitory building. The RFP on Wi-Fi access was looking
for ways to prevent access to a Wi-Fi network in particular spaces or regions of a building. The RFP on energy harvesting was looking for innovative ways that allow a hiker to harvest and utilize energy from the environment or from the hiker’s own movements. The BAA was requesting proposals for electronics enclosures that could survive underwater, exposure in environmental temperature extremes, and abuse by wildlife such as alligators, while supporting a variety of sensors that may require electrical or similar ports that penetrate through the enclosure walls.

The RFP’s and BAA included a list of technical specifications that needed to be met, along with a budget ceiling (in three RFP’s, but open-ended in the BAA), a strict deadline, and document formatting requirements that are typically found in an RFP or BAA issued by a government agency. In all cases, the submitted proposals required all of the elements normally found in a professional engineering proposal, including:

1) A narrative describing the state of the art or prior approaches, along with references;
2) A summary of the proposed approach, including technical discussions;
3) A detailed description of tasks;
4) A schedule of tasks in the form of a Gantt chart;
5) A detailed budget sheet that includes materials, personnel types and salaries, travel, indirect costs, overhead, profit, etc.
6) Identification of any potentially patentable content.

Course Structure

Each student group of two to five members was required to generate a unique technical proposal. Three milestones were identified as PR1 (Project Review 1), PR2, and PR3. The first milestone, PR1, required each project team to select an RFP or BAA, restate the problem, perform a prior art search, and write a narrative summarizing the relevant prior art. PR2, the second milestone, required each team to submit a narrative describing their solution and why it is an improvement, a detailed discussion of the technical approach, a draft time schedule, Bill of Materials (BOM) and budget sheet. The final milestone, PR3, was the complete proposal in final form with a
detailed schedule. The workload was weighted to the first two-thirds of the semester to allow
groups time to recover from missing or incorrect submissions prior to submitting the final
proposal.

Additional classroom activities included the following:

-Skills for group work.
Six Thinking Hats\textsuperscript{20} is a tool to collect ideas and work towards a best answer, a compromise or
consensus. According to Rittel,\textsuperscript{21} the early stages of engineering design are inherently
argumentative among team members and require negotiated decisions, making Six Hats an ideal
tool for engineering design. As reported by Stanford Design Program Professor Faste, “some of
the best ideas were initially labeled ‘stupid’.”\textsuperscript{22} Six Thinking Hats is a tool that can help identify
the best ideas that otherwise might be discarded.

-Back of the envelope estimation.
Dym et al\textsuperscript{2} found that undergraduates tested for estimation skills gave answers that varied by 3 to
5 orders of magnitude! This was linked to over-emphasis on precise calculations and complex
methods, and lack of emphasis on approximations (e.g. answers given with too many significant
digits). Approximation skills were required for engineers when using the slide rule before
electronic calculators became widely available in the 1970’s. This ties back into confidence in
early decision making when evaluating a solution, as well as efficient use of time and resources
as an engineer as non-options are ruled out early. It is useful for coursework and a crucial skill
for a practicing engineer.

-The quad chart.
A standard single page slide that conveys the key elements of a project (often used by
government agencies) was required from every group. Groups were allowed 3 minutes to present
their quad chart.
-The elevator pitch.

Student groups were required to create and deliver a presentation describing their proposal idea in less than 10 minutes, with sufficient detail for an informed audience to understand the approach. A shortened version using just the quad chart was limited to 3 minutes. The ability to deliver a coherent summary of a technical idea in a few minutes is an important skill useful throughout an engineer’s career, whether the audience is a customer, a manager, an investor, a supervised employee or a team member.

-Peer review of group presentations in class.

Each student group presented its proposal in its class section and was graded by the proposer’s peers. The top proposal selected from each class section was presented to a panel of engineering and intellectual property professionals at an industry summit held at the end of the semester.

Results and Discussion

Proposal Quality-
Out of 53 groups, 53 submitted a final proposal, representing a completion rate of 100%.

One group proposed to develop an acoustic absorbing panel using dense spheres of various sizes dispersed in a rubberized sheet. This concept is currently being actively investigated for sonar absorption on marine vessels and represents a surprising level of sophistication for freshman students. On the other hand, there were some interesting responses from groups, including the submission of an RFP instead of a proposal. Another group decided to subcontract all of the technical work and simply charge a fee. The peer review of this approach was surprisingly unforgiving.

Several of the proposals contained potentially patentable intellectual property. The group that received first place in the industry summit filed a provisional patent on energy harvesting in a hiking boot with the financial support of the institution. Another group, using knowledge about patents and filing at the United States Patent and Trademark Office (USPTO) that was learned in class, drafted and filed a provisional patent, paid for by the group, on their acoustic absorbing arrangement for office areas. The same students expressed interest in building a prototype for
deployment in one of the staff offices. Staff members were eager to evaluate the prototypes once logistical details were resolved. These are excellent examples of not only the quality of the proposed ideas, but also the students’ continued engagement in the projects after the class ended.

Compliance with RFP or BAA specifications-
Although the completion rate of proposals was 100%, there were a number of compliance issues in the proposals. The most common issues involved insufficient discussion of prior art, a shallow technical description of the proposed approach, unrealistic time schedules, unrealistic materials budget, and a lack of awareness of the difficulty of accomplishing some of the tasks chosen by the proposing team. Most of these shortcomings were a direct result of the student cohort’s lack of engineering courses prior to enrolling in this class. Some of the proposed solutions, while clever, were technically too advanced for the students to fully describe or to make informed decisions about how much time a specific task would require. For example, does assembling a prototype flexible solar panel into cloth take a day, a week, or three months? How many people are needed? Freshmen students found it difficult to generate informed estimates of time and costs associated with this type of task. Even with lecture material explaining the need for building in contingencies for time and budget, there was often an a priori assumption that each task would be accomplished with no time delays or cost overruns. Again, this is a consequence of the students having a lack of experience with participating in an engineering project outside of the classroom, especially one that involves new technologies or processes.

Industry feedback-
At the end of the semester, the top nine student groups presented their proposals to a panel of judges that included senior engineers and intellectual property professionals. The judges were uniformly impressed with the quality and creativity of the solutions proposed by the student groups, in particular because the students were freshmen, and had not yet taken any formal engineering courses. This was important feedback, since the judges represented one critical group of customers being served by the engineering program- the entities that might hire students who graduate from the institution, or who might provide internship opportunities for students in their junior or senior year of study.
Student surveys-

Course assessment used publicly available data collected every semester for every course by the Office of Institutional Research and Effectiveness. Anonymous responses were provided by approximately 46% of the students. Each quantified question could be answered with a score from 1 (lowest) to 5 (highest). The questions were as follows:

Course structure:

This course engaged me to think critically.
I would recommend this course to other students if given the choice.

Instructor:

The instructor communicated effectively.
The instructor stimulated my interest in the subject matter.
The instructor demonstrated respect for the students.
The instructor was available to assist students in or out of class.

The overall evaluation for the course (9 sections) was 4.54. Questions related to the course structure received a score of 4.52, and the instructors received a score of 4.52. All three scores were above the institutional average for courses offered that semester.

Additional open-ended questions were part of the course assessment. The responses to two of the open-ended questions were categorized. The most common responses to the open-ended question “What did you like about the course?” were grouped and summarized in Table 1, along with the percentage of students in each grouped response. The percentages were calculated by dividing the number of times a response occurred, by the total number of students that responded to the course survey (105).

The most frequent response was an acknowledgment of the class content. This may or may not be an acknowledgment of PrBL. Much of the course content describing what engineering is, what engineers do, and other general topics associated with engineering were presented
The second and fourth most popular responses were a direct acknowledgment of the success of PrBL applied to the class, since all four of the project topics were real world problems, some of which continue to be actively explored by the private sector, universities and government laboratories.

Interestingly, the third most popular response, that the class was engaging and fun, likely had little to do with the proposals, but rather was associated with several activities that were employed to convey aspects of ethics. One of the activities organized specifically for the course was Pirate Week, during which time student groups were given clues to find components to complete an assembly. Another class exercise involved group decision-making in a tragedy-of-the-commons game. When a nearly optimal result ensued, the students broke into cheers.

To identify weaknesses or shortcomings of the course, the open-ended responses to the question “What would you recommend to improve the course?” were grouped and are listed in Table 2 along with the percentage of students mentioning each particular shortcoming. The percentages were calculated by dividing the number of times a response occurred, by the total number of students that responded to the course survey for one of the instructors (55).

<table>
<thead>
<tr>
<th>Response</th>
<th># of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpful and informative about engineering</td>
<td>36%</td>
</tr>
<tr>
<td>RFP projects</td>
<td>26%</td>
</tr>
<tr>
<td>Engaging and fun</td>
<td>26%</td>
</tr>
<tr>
<td>Worked on solution to real world problem</td>
<td>12%</td>
</tr>
<tr>
<td>Student opinion mattered</td>
<td>6%</td>
</tr>
<tr>
<td>Material that was new to student</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 1- Grouped responses to “what did you like about the course?”
<table>
<thead>
<tr>
<th>Response</th>
<th># of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine as is/ no complaints</td>
<td>32%</td>
</tr>
<tr>
<td>More assignments/ push students harder</td>
<td>13%</td>
</tr>
<tr>
<td>Add hands-on activities/ side projects</td>
<td>7%</td>
</tr>
<tr>
<td>Use better online course support tool</td>
<td>3%</td>
</tr>
<tr>
<td>Better organizing pirate week</td>
<td>3%</td>
</tr>
<tr>
<td>More class hours</td>
<td>3%</td>
</tr>
<tr>
<td>Pick teams after students get to know each other</td>
<td>2%</td>
</tr>
<tr>
<td>Assumed too much prior knowledge</td>
<td>2%</td>
</tr>
<tr>
<td>Need mechanism to improve team dynamics</td>
<td>2%</td>
</tr>
<tr>
<td>More information about what engineering is</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 2- Grouped responses to “what would you recommend to improve the course?”

The most common response was the comment that no changes were required. The next few suggestions indicated that at least some students were willing to accept more workload in the class. This is interesting considering that many of the milestone deliverables were submitted only minutes before the deadline for acceptance (much like the real world!), usually 5:00 pm on a weekday. A specific request for hands-on activities from a few students was adequately accommodated in the follow-on course, which involved immersive hands-on design, assembly and demonstration of a hardware project. Two of the comments are related to team dynamics and are discussed more fully next.

Team dynamics

When group projects are implemented in a freshman course, it is challenging to minimize the amount of social loafing that occurs. There were issues with team members not equally sharing the workload. The advantage of engaging students in teamwork early in their programs is that they begin to understand group dynamics and the need for assigning roles and responsibilities (through their past frustration) at the beginning of a project and not waiting for a professor to intervene towards the second half of a semester. They begin to understand the value of
approaches to team dynamics such as “Six Thinking Hats”. When they begin their junior cornerstone class (Design 1&2) they are better prepared to deal with a “customer” – in this case, an industry partner who has sponsored their project.

For future course offerings, two methods to reduce social loafing while retaining formal teams could be adopted. As reported anecdotally by colleague Professor Harvey Hyman while teaching information and technology classes such as system acquisition and software engineering, he developed an intra-team rating form known by his students as the “anti-slacker device” and weighted the results into the individual student grades. Prof. Hyman also had success with requiring one member of the team to be the lead for each milestone delivery of the project, with the caveat that the number of team members needs to be equal to or less than the number of milestones.

One of the surprising results from the use of PrBL was the apparent lack of awareness or disconnect between what a freshman student expected to pay for the services of an engineer, versus what the students expected to receive as salary once they started working as an engineer. This revelation (for the student) usually occurred after students enumerated the project tasks, decided how many of each type of employee was required to complete the tasks, and started to fill in the budget sheet with fully burdened hourly wages. They quickly discovered that project costs often are dominated by labor costs, as determined by what they expected to be paid if they worked on the project they were proposing. It turned out to be an excellent way to convey the realities of how much engineers make and the source of the money. Most of the initial proposals required the team to reduce the scope of tasks or even to eliminate tasks in order to meet the budget constraints imposed in the three RFP’s.

Conclusions

We formalize Proposal Based Learning (PrBL) as a methodology for introducing freshmen engineering students to some of the responsibilities and day-to-day activities they are likely to encounter later in their undergraduate program and once they graduate and join the workforce. Many of the skills acquired are useful for the students, whether or not they remain in the
engineering profession. Similar to Project Based Learning (PBL), the approach was adopted in
the cornerstone class Introduction to Engineering for approximately 200 students. Assessments
were performed using quality of work product, external reviews by engineering and intellectual
property professionals, and student surveys.

The four objectives of the class were met as follows:

1) improve student engagement and retention;
Retention data fall to spring semester was 97% for the academic year in which this course was
taught in the fall for engineering students at this institution. Persistence to the next academic year
(spring 2015 to fall 2015) was 76%. Two major things to note about the student population at
this institution are 1) The institution only offers “hard” STEM degrees and 2) 72% of the
students are First Time in College students – meaning they do not come from households where
the primary care giver is a college graduate. While at first glance these numbers may not seem
significant, it is worth noting that in ASEE’s best practices for student retention, the first year
retention rates are on par with ours.

2) introduce students to aspects of engineering design;
PrBL gave students experience with the engineering design process, with an emphasis on the
idea creation, evaluation, planning and budgeting of a project that responded to a customer
request. Basic calculating skills, divergent thinking around the creation of a solution, and the use
of software tools for preparing oral and written documents were all required elements for
students to succeed in the class.

3) acquire teamwork skills;
Students were introduced to Six Thinking Hats as a way to collect diverse viewpoints from all
members of the team and make choices on a path forward. Students worked in their groups on
learning activities such as Pirate week and the tragedy of the commons. As this course was
offered in the first semester of the undergraduate program, many of the students did not know
each other prior to working in groups, resulting in more intense team dynamics at times.
4) learn engineering communications tools. Students learned how to format and present a quad chart, one of the most common compact vehicles for describing a project in the engineering profession. Students learned the elements and composition of a professional technical proposal to respond to a customer’s request for a solution to a problem. Groups were required to present and defend their proposed ideas to their peers and/or a panel of judges consisting of senior engineers and intellectual property attorneys.

While this inaugural roll-out of PrBL in an introductory engineering course appears to have been successful, there are several areas requiring improvements, including tools to improve team dynamics, the need for RFP and BAA topics that are not too far beyond the student cohort’s prior technical knowledge, and the need for RFP and BAA topics that engage students who have interests in a wide variety of engineering and information technology concentrations. Future work will involve trying to assess the impact of a cornerstone class with PrBL on student success rate using several different measures of success, such as job placement, self-assessment, retention rates throughout the program, or the likelihood of graduates recommending the institution to their peers.

References


