Equipping Engineering Undergraduate College Students with the Tools Needed to Transition from Solving Textbook Problems to Real-world, Industry Projects

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Introduction

The task of an engineer is to develop solutions to problems in the real-world by applying the fundamental principles of mathematics, science and creativity to solve the problem in a structured and organized way. Typically, the design of an engineering solution to a problem starts with specifications based on requirements. However, those requirements are often incomplete and require the engineer to begin the design process without all the required detail. It is the engineer's job to work within the constraint of having incomplete information, yet have a clear enough understanding of the problem to determine the known and unknown aspects of the problem from the available information.

It can be seen from the above description of the engineering problem-solving process that solely understanding mathematics and science, and having creative thinking skills are not adequate in making a competent engineer. A well-rounded and complete engineering and technology education needs not only to include a robust understanding of the aforementioned disciplines, but also an understanding of how to model practical problems into idealized systems to which the basic textbook principles can be applied. This modeling process bridges the gap between textbook theoretical knowledge gained in the classroom, and the application of this knowledge to solving problems in practice. “Research confirmed in the 90s that students learn more by grappling with open-ended problems, like creating a computer game or designing an alternative energy system, than listening to lectures.” ¹ For example, in the area of structural engineering, the process of defining a system involves defining the system geometric model, material model, load model, connection model, boundary and support conditions, and the analysis model. In a textbook problem, all of the above are explicitly given to the student who simply performs the task of applying a specific analysis model and the associated hand-calculations to obtain a solution to the problem. This is an essential tool in an engineer’s repertoire of skills. However, this is far from being an adequate, complete set of skills.

Undergraduate engineering and technology programs at U.S. universities tend to be highly focused on the theoretical aspect of engineering ¹. The theoretical background builds an engineer's analytical thinking skills which are necessary in order to produce an optimally engineered product. It gives an engineer or technologist a sense of confidence when confronted by unfamiliar and challenging problems. Despite the benefits of theory-intensive undergraduate engineering and technology curriculums, there exists one significant drawback: fresh graduates are unskilled at the process of representing real-world systems as idealized models that can be subsequently analyzed using theoretical textbook principles. This conclusion was based upon anecdotal feedback received from employers and freshly graduated engineers. This anecdotal
feedback was enough to initiate a more formal process to explore the transition from the classroom to the real-world for an engineer or technologist.

The capstone course, where students do projects with industry, attempts to fill in the void between theory and practice. However, based upon feedback from fresh engineering graduates, it does not perform an optimum job of doing so since it is a single course taken during the students' senior year. For this reason, this paper presents two approaches to enhance the capstone experience.

**Purpose of the Study**

The purpose of this study is to present an improvement to the existing capstone experience in the engineering curriculum. The enhancements include:

1) Introduction of “mini-capstone” projects in the sophomore and junior level courses. These mini-capstone projects are derived from the main capstone done in the senior year and are done in collaboration with industry partners.

2) Addition of a “presentation” component in the senior year capstone course where industry participants present projects related to coursework.

**Significance of the Study**

Based upon the background search in the next section, it can be seen that introducing project-based learning in the classroom has already been done and is beneficial. The recommendations in this study are unique in the following ways:

1) Professor-created classroom projects have already been implemented in engineering courses and have been found to be beneficial. Notre Dame’s engineering dean says that "his engineering school has gradually improved its retention rate over the past decade by creating design projects for freshmen"\(^1\). The recommended mini-capstone projects are different in that these are mandatory and done in collaboration with industry. Additionally, the mini-capstone projects are derived from the main capstone projects and are scaled-down versions of these projects. Finally, the mini-capstone projects are introduced in the sophomore and junior years in relevant technical courses, unlike the existing capstone which is done in the senior year. This maintains a link with industry early-on, and demonstrates the application of classroom knowledge to practical projects. “Notre Dame’s engineering dean, Peter Kilpatrick, will be the first to concede that sophomore and junior years, which focus mainly on theory, remain a “weak link” in technical education”\(^1\).

2) The existing senior year capstone course is expanded by mandating bi-monthly presentations by industry participants from the pool of those involved in the capstone
projects. First, this would help students transition into industry and provide them with an opportunity to interact and network directly with potential future employers. Some professors or schools may have such a system in place. However, it is not universally mandated within a required course. Second, the amount of presentations is two per month which amounts to about 8 different project presentations during a student’s last semester. Third, the content of these presentations is uniquely defined. It is essential that the technical content presented is closely linked to the theory that the students learn in the classroom and is specifically focused on teaching the students the complex approach followed and the challenges faced in modeling industry problems. Currently, there are no provisions that define the content and goals of presentations made by industry presenters even though such presentations do occur.

3) The difference between the projects that we recommend be incorporated into the curriculum and those already in existence is that our recommendations result in formal structural modifications in the curriculum, rather than informal changes made by individual professors. In the context of student retention, the National Academy of Engineering concluded that “scattered interventions” had not resulted in widespread change. The challenges that we encountered in transitioning from an informal to a formal introduction of industry-related projects is described within the paper.

Background

The senior capstone course is designed to expose undergraduate students to the issues and design experiences they are likely to encounter when solving practical engineering and technology projects. Nassersharif and Rousseau describe their philosophy in the development of a capstone course design sequence where each project must result in the development of a realized product through a formal well-documented and reproducible process where the capstone course design sequence typically consists of eleven flexible, but defined criteria.

Based upon perspectives from corporate partners published in the Journal of Engineering Education on the future of global engineering education, it can be seen that the defining characteristic of the ideal engineering education in today's world is the integration of hands-on, experiential learning with classroom-taught theory. It is vital for students to have the opportunity to work on practical projects in order to internalize the concepts that they learn in the classroom. Companies are increasingly seeking employees with a well-rounded, comprehensive educational experience encompassing a wide range of areas where students are exposed to the complexity of engineering problems in today’s world, resulting in the need for engineering colleges to transform their curricula by putting in more effort to cater to the future workplace demand. Engineering programs at the university level need to expose students to engineering problems that they are likely to encounter in the industry and better equip them for professional practice, by defining problems more comprehensively and solving them in a more holistic fashion. Based
upon feedback from students and employers, it has been seen that educational programs that are in tune with the industry’s needs and provide opportunities for practical, hands-on learning experiences result in highly motivated students that are engaged in the learning process. Graduates of such programs are well equipped with the tools needed for success in their professional lives³.

Van Hattum-Janssen and Mesquita⁴ conducted interviews of teachers exploring the benefit of using project-oriented courses in teaching engineering students. They found that the teachers strongly believed that engineering students require experiential, project-based learning. However, they were not confident of providing it to the students themselves.

Gider et al.⁵ discovered that the introduction of project-based learning into the engineering curriculum assisted in rectifying existing weaknesses in the program such as their ability to work together in collaboration and solve multidisciplinary problems in teams. They developed a course that served as a case study. The primary goal of this course was to assist students to transition into the professional world. A survey conducted at the end of this course showed positive feedback from participating students. The empirical data (enrollment ratio of students, session attendance ratio, and average student grade) reflected that the course was successful in sharpening the professional skills of engineering students.

An undergraduate project-based learning engineering pilot program⁶ was investigated in 2010 to investigate the impact of this type of learning on student attainment of ABET identified professional competencies. In the pilot program, students did not take classes but spent their time solving complex industry problems that were not well-defined like theoretical textbook problems. It was found that graduates emerged with integrated technical/professional knowledge supported by ABET competencies. This initial study indicated that the aforementioned project-based learning program was more beneficial to students’ attainment of professional competencies in comparison to studying in a conventional engineering curriculum.

Wei Xue⁷ introduced a hands-on, project-based experiential learning module into a course on micro-and nanotechnologies for mechanical engineering students. This module was combined with the existing theoretical course structure and the laboratory activities were designed to integrate textbook theoretical principles with real fabrication and characterization processes. This hands-on experience enabled the students to obtain a better comprehension of the classroom principles. Based upon student feedback obtained via surveys, it was learned that the introduction of this experiential, design-oriented module was very effective in helping students understand concepts related to micro-and nanotechnologies in the mechanical engineering program.

**Methodology**
Based upon the background search described in the previous section, it can be concluded that exposing undergraduate students to the rigors and challenges of solving practical problems for industry counts as an essential part of an engineering and technology education. This is presently accomplished via the capstone course in the senior year of the curriculum. As a result of the pilot study, we propose a modification to the courses in the curriculum by formally introducing the following into technical courses:

1. The additional of mini-capstone projects, where possible, derived from the existing senior capstone projects that have industry participants.
2. Modification of the senior capstone course to include bi-monthly project presentations by industry engineers and technologists.

The pilot study that led to these proposed changes was conducted during one academic year and established:

1. The type of modifications that can be made to the structure of existing courses;
2. The practical feasibility of making changes to the existing courses;
3. The extent to which these changes to the courses are required, both from a student’s and employer’s perspective.
4. The effect that these course changes will have in bridging the gap between theoretical classroom material and real-world problem solving.

To obtain concrete answers to the four items above, the pilot study got participation from industry to collaborate in mini-capstone projects and to make presentations in the capstone course. Presentations of industrial projects were conducted by technology professionals from companies located in the geographical area of our university. During the pilot study four professionals from industry were invited to present projects relevant to the course work that the students were engaged in. The industries that we approached were the entertainment, education, medical and manufacturing industries. The companies that accepted our invitation and eventually participated in the pilot project were from the entertainment and education industries. Hence, we had a success rate of 50% participation. Additionally, we invited a professor within the engineering and technology college at the university to present projects based upon the professor’s previous industrial experience.

Students enrolled in four different classes participated in the study, as shown in Table 1. The students ranged from sophomore to senior level students. In total, 50 students participated in the pilot study. The presentations were 30-45 minutes long.

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<tr>
<th>Course</th>
<th>Session</th>
<th>Year</th>
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The process followed in organizing the pilot study began by contacting the assistant vice chancellor of marketing at our university to whom we described the pilot study and its goals. The assistant vice-chancellor was enthusiastic and highly motivated to assist in the study and could bring years of experience in marketing and established relationships with industry executives. Due to the relationships that were already established with various companies, most of the executives were excited to participate in the project. This initial contact with high-level executives was developed in order to increase the chances that the technical staff and engineers working in their organizations would participate in the study and potentially collaborate in the future. The executives provided the assistant vice-chancellor with names of engineers and technical employees within their organization that would be most suited to our needs. These names were given to the professor who then contacted them, described the pilot project, and chose a topic(s) for the capstone course.

A company in the entertainment industry that agreed to participate had technical staff that were located at a distant location. Despite this distance, they were willing to work with students via video teleconference, multimedia and the internet. They also committed their time to supporting the capstone and mini-capstone projects to 1 hour per week. The other participant in the education industry was in the local vicinity and therefore could make a presentation on site and collaborate with the students in person.

Busy industry technologists were offered the following incentives to make presentations to students and to work with them on projects:

1. They would receive an outcome/product from the capstone or mini-capstone projects which they might be able to use or leverage within their organization. The mini-capstone was derived from the major capstone project which was an important incentive for participation by industry because they received an end product from the collaboration. The mini-capstone
project, however, was smaller in scope and emphasized the subject matter for the particular course, yet could be used as part of the end product that they received.

2. An opportunity to engage in corporate community service and build a stronger relationship between industry and the local university.

3. The opportunity to advertise their organization to potential future employees by networking with students and getting to know their abilities.

4. A possibility of having input into structuring the curriculum.

Finally, as part of the methodology, in order to ascertain the need for changes in the curriculum that would involve incorporating a more practical hands-on component to the existing theoretical content of an undergraduate program, we distributed a survey among students in the participating courses within the college of engineering and technology and analyzed the results. Additionally, we obtained survey-based feedback from the engineering professionals from industry that participated in the pilot study in order to obtain their perspective on the existing theoretical structure of engineering and technology curricula, the usefulness of the proposed modifications, and the level of preparedness of fresh graduates with respect to solving practical engineering problems.

Student Survey: In order to understand what the students think about the current engineering and technology programs and their structure, we developed a questionnaire that was distributed to the students after each presentation that they attended. The specific information that we wanted to obtain regarding the program’s structure was whether the program provided them with an adequate balance between theory and practice and whether they felt prepared to tackle practical problems based upon their classroom education. As discussed earlier, transitioning from theory to practice involves learning how to model real-world problems into systems to which textbook principles can be applied. We wanted to gauge the extent to which the students felt prepared to undertake such tasks and also wanted to determine whether the presentation that they attended assisted them in understanding the process. Additionally, we wanted to obtain feedback from the students on whether they felt the presentation enabled them to get a better grasp of the theoretical principles that they learned in the classroom after having seen them being applied in an industrial project scenario. The survey also intended to gauge the students’ attitude toward the existing capstone project and its ability to incorporate the practical aspects of problem solving into the curriculum. We wanted to ascertain whether they would like to have “mini-capstone” projects incorporated into the curriculum in order to give them experience with solving practical problems earlier in their degree program. Finally, we wanted to know whether they would be interested in having a series of project presentations by industry professionals integrated into the main-capstone course. The survey that we distributed to the students is found in Appendix A.

Presenter Survey: We also conducted another survey in which we distributed a questionnaire to the project presenters (see Appendix B). This survey was designed to gain an industry professional’s perspective on the following issues:
1. The level of preparedness that fresh engineering graduates have when it comes to applying classroom theoretical principles to solving problems that they are likely to encounter in industry.
2. The practical feasibility of conducting the proposed course changes, (i.e., in terms of time investment needed from industry’s end).
3. The potential of the proposed changes in helping develop industry / academia collaboration.
4. Improving and providing direction to academic course content in a way that supports what industry desires from fresh graduates.
5. Potential improvement of the existing capstone course via the proposed changes.

**Pilot Project Results**

The results of the pilot study helped us establish the modifications to existing courses that would introduce students to project-based solutions to industry problems, and the challenges that they are likely to face in the future as professional engineers and technologists. On conclusion, the pilot study enabled us to obtain a clearer understanding of the types of presentations that need to be made, the type and scope of the projects that can be done, and the approximate time for each presentation in order to obtain an understanding of the problem being presented without consuming too much class time.

Additionally, the pilot study helped us define the structure of a mini-capstone project that is incorporated into an existing technical course. It helped us understand whether it was practically feasible to incorporate this task into the classroom experience.

After completing the pilot study, based upon the survey results (presented and analyzed subsequently) we concluded that:

1. It was possible to get the participation of industry technologists that were excited about engaging in collaboration with academic institutions on a potential semester-to-semester basis.
2. The content of the presentations appropriately described the process employed by engineers in modeling and solving problems in industry. Additionally, the presentations showed how industry projects applied classroom theory concepts.
3. The duration of each presentation was adequate to cover the content that needed to be presented without consuming too much time.
4. It was practically feasible to integrate the industry presentations into the existing courses and the capstone course.
5. It was practically feasible to implement the changes of adding a mini-capstone project into the existing technical courses.
6. The course modifications were necessary, both from the student’s and employer’s perspectives.
7. The structure of modifications to the courses were desirable.
8. The course modifications would be effective in bridging the gap between theoretical classroom material and problem solving in industry.

Survey Analysis

This section provides an analysis of the survey-based feedback that was obtained from students that participated in the pilot study. Feedback received from industry professionals that participated in the pilot study is also discussed. Table 2 presents the participant responses to each question in the survey. It quantifies the survey results by displaying both the absolute number of students that provided a positive or negative response to each question in the survey, and the percentage of the total number of participants that responded positively and negatively.

Table 2: Survey Results: Student Survey

<table>
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<tr>
<th>Q¹</th>
<th>yes²</th>
<th>no³</th>
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<td>5</td>
<td>90</td>
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1: Q: Question from survey (see Appendix A)
2: yes: Total number of students that answered with a “yes”
3: no: Total number of students that answered with a “no”
4: yes (%): Percentage of the total number of students that responded with a “yes” (total number of students = 50)
5: no (%): Percentage of the total number of students that responded with a “no” (total number of students = 50)

The primary purpose of conducting this pilot study was:

1. To ascertain (from both an industry employer's and student's perspective) whether fresh engineering and technology graduates are adequately prepared to solve problems in industry and whether the courses that they complete need to be modified to include a more practical component, thereby bridging the gap between theory and practice. Questions 1 and 2 in both the student survey (Appendix A) and the presenter survey (Appendix B) attempt to gain feedback from students and industry professionals to answer this question.
2. To present modifications to existing courses and obtain feedback from both industry professionals and students as to whether these modifications are desirable, beneficial, and practically feasible to implement. Questions 3 to 10 in the student survey and questions 3, 5, 6, and 9 in the presenter survey attempt to gain feedback from students and industry professionals to answer this question.

The pilot study also found that there exist fringe benefits that can arise by incorporating the recommended changes to courses. These include enhanced collaboration between industry and academia, and more networking opportunities for both students and potential future employers. Question 11 in the student survey and questions 4 and 7 in the presenter survey attempt to gain feedback from students and industry professionals to answer this question. These questions are presented below.

Question 11 from the student survey: “Was it helpful to you to meet industry professionals in person and network with them with the intention of possibly working with them in the future?” (Y/N)

Question 4 from the presenter survey: “Do you think that the proposed course would benefit industry professionals by providing them with a recruiting / networking tool in the form of this course?” (Y/N)

Question 7 from the presenter survey: “In addition to the traditional approach of networking with students (i.e., campus career fair), do you think the proposed course would be beneficial to you in recruiting potential future employees (the benefit of such a course could be due to the fact that you as an employer now have tangible evidence of a future employee’s ability to apply textbook principles on the job)?” (Y/N)

The survey feedback was obtained from three industry presenters. The industry professionals that participated in this pilot study unanimously responded positively to all the questions in the presenter survey that they completed (Appendix B). From their perspective, it would be beneficial for industry if colleges modified their courses to incorporate more practical hands-on applications. This is reflected by their positive answers to questions 1 and 2 of the presenter survey shown below.

Question 1 of the presenter survey: “Based on your experience in industry, do you feel that fresh graduates are adequately equipped to solve practical engineering problems (i.e., making assumptions that are used to model real-world situations into engineering systems to which theoretical textbook principles can be applied)?” (Y/N)

Question 2 of the presenter survey: “Would you prefer it if students entering your company were more exposed to the challenges faced by an engineer while solving real-world problems?” (Y/N)
The student survey (Appendix A) feedback shows the support of introducing industry projects into courses as proposed in our pilot study. Table 2 shows that a majority of the participants (>75%; see column 4 in Table 2) responded positively to 9 out of 11 questions in the survey (81.81% of the questions). However, the responses to the first two questions (see column 4 in Table 2) do not fit into this trend.

A majority of the student participants responded negatively to the first two questions shown below (please note that “yes” response to the first question constitutes a negative response).

Question 1 in student survey: “Do you think undergraduate college–level engineering programs are too theoretical? (Y/N)

Question 2 in student survey: “Do you feel adequately prepared to tackle real-world problems based solely on the textbook theoretical principles that you have learned in class?” (Y/N)

Based upon this, it is reasonable to conclude that students feel that undergraduate engineering and technology programs focus excessively on theory, at the expense of hands-on experience. The majority of students were under the impression that their program is overly focused on theory and does not give them an adequate preparation to solve industry problems. These results support our claim, that from the students’ perspective, engineering and technology programs at the undergraduate level do not adequately prepare students to tackle practical problems and need to include modifications to existing courses that incorporate a focus on the application of textbook theory to the solution of industry problems.

Additionally, all the industry presenters surveyed were of the opinion that the modifications to the curriculum as suggested by this study (described in detail subsequently) would be beneficial in assisting students in transitioning from the classroom to the real-world. This is validated by their positive responses to questions 3, 5, and 6 in the presenter survey (see below).

Question 3 of the presenter survey: “Do you think that the proposed course would be an efficient and beneficial way to assist students in transitioning from the classroom to the real world?” (Y/N)

Question 5 of the presenter survey: “Do you think that having student’s work on small components on real-world projects throughout their degree would be a good way to help them to keep the bigger picture in mind right from the start of their educational experience and thereby more smoothly transition to the real-world? (Y/N)

Question 6 of the presenter survey: “Currently the capstone course is used to give students the experience of doing a real-world problem. This course is the only course of this type and is offered in the final semester of the student’s degree program. Do you think exposing the students
to numerous real-world problems in two ways (a and b below) would be a good addition to the existing capstone course in helping students transition from the classroom to industry?" (Y/N) 
a) right from the start of the degree in each of the technical courses, and 
b) in the form one course in their final semester involving weekly presentations of the sort you just made,

Over 90% of the students surveyed indicated that the modifications to the curriculum recommended by this investigation are desirable. This is apparent from their positive responses to questions 3, 9, and 10 (see column 4 in Table 2) in the student-survey (Appendix A). Questions 3, 9, and 10 of the student survey are shown below. The students indicated that being exposed to an industry problem and its solution process by an industry professional helped them bridge the gap between classroom theory and practical application.

Question 3 of the student survey: “Did you find that the presentation of a real-world problem by an industry professional helped you bridge the gap between theory in the classroom and applying this theory to a real-world problem? By “bridging the gap”, we mean gaining an introductory awareness of the challenging process that engineers go through in defining an engineering system (i.e., modeling) in the real-world when they have only a limited amount of information available to them. Defining a system involves specifying the system configuration, geometry, boundary conditions, solution/analysis algorithm. In other words, did the presentation help you appreciate the level of detail that a practicing engineer goes through in solving a real-world problem?” (Y / N)

Question 9 of the student survey: “The Capstone project is completed in your final year and involves fairly large groups in which each student focuses on a narrow area. In addition to this, do you feel that having a small real-world project component at the end of every technical course would be beneficial to you towards improving your understanding of the theoretical contents of the course that you completed? (Y / N)

Question 10 of the student survey: “Would you like a course during the final semester of your degree program where an industry professional presents a complete real-world project on a weekly basis just as was presented in this class?” (Y / N)

98% of the students surveyed indicated that the presenters did a good job of discussing an industrial application, as reflected by positive responses to question 7 (see column 4 in Table 2) in the student survey (Appendix A). Question 7 of the student survey is shown below. This information is useful in that it demonstrates that it is practically possible to make effective modifications to the existing curriculum that expose students to real-world scenarios.

Question 7 of the student survey: “Did you find that the presenter did a reasonable job of discussing a real-world application?” (Y / N)
A majority of the students responded positively (see column 4 in Table 2) to questions 4, 5, 6, and 8 (see below) in the same survey. Based upon this, it can be concluded that the structure of the presentations (duration, presentation method, technical content, level of detail incorporated, relevance to their coursework, and practical relevance) was adequate to fulfil this study’s objectives. This provides a foundation that can be used in the future while incorporating the proposed modifications to the curriculum.

Question 4 of the student survey: “Did the presentation help you crystallize and better understand the textbook classroom theoretical concepts that you have already covered?” (Y/N)

Question 5 of the student survey: “Did the presentation expose you to situations that required you to tap into your reservoir of theoretical textbook knowledge to understand a real-world engineering situation better?” (Y/N)

Question 6 of the student survey: “Did you find that you encountered situations during the presentation where you could apply some of the hand-calculations you learned in class?” (Y/N)

Question 8 of the student survey: “Did the presentation have enough detail that you found it useful? To elaborate: some presentations can be too abstract and general. Some presentations can be too focused on detail, and you as a listener can get lost in the detail. Was there a healthy balance between the two aforementioned extremes?” (Y/N)

**Proposed Changes to Existing Curriculum**

Based upon the analysis of the survey results described in the previous section, we propose the following modifications to the curriculum:

*Mini-Capstone Modifications:* The proposed mini-capstone modification to technical courses consists of adding: 1) an industry project or a component of an industry project derived from the capstone project, and 2) one presentation made by an industry professional which will be made in the final quarter of the course.

By solving a series of such small industry-related problems in various courses during the course of their degree program, students will be exposed to the practical application of their classroom knowledge and the process of modeling real-world engineering and technology systems which will prepare them better for the industrial workplace.

The mini-capstone is leveraged from the major-capstone project which is the primary incentive for participation by industry. It is defined as a smaller scope project from the major-capstone project and that emphasizes the subject matter within the technical course. The professor will have the option of modifying the content of the project so that the technical content in the course is adequately covered within the project. The mini-capstone projects for a given semester will be included into courses that have technical content directly related to what
is being used in the main-capstone projects. Thus the courses that will have mini-capstones projects may change from semester to semester based on the projects that are selected for the capstone courses and the technologies that would be used to implement them.

Additionally, a presentation by industry participants regarding the project details and desired outcomes will be done in the capstone class as well as the relevant courses that are doing the mini-capstone. Generally, industry engineers and technologists participate in capstone projects. The novel aspect of this pilot study was to extend their participation to the mini-capstones in technical courses during the sophomore and junior years so as to prevent the development of a vacuum between year 1 and year 4 of the undergraduate degree program. The introduction of mini-capstone projects in the 2nd and 3rd year of the degree program keeps students motivated as they regularly see the relevance of their textbook knowledge to applications in industry, instead of waiting until the 4th year to see this in the capstone course.

The main challenge was to ensure the participation of companies from the industry in the mini-capstone project. This challenge was overcome by linking the mini capstone project topics to the main capstone project. At the end of the mini-capstone project, the industry participants are provided with a prototype product or component which may be incorporated as a sub-component into the main capstone product that is delivered to the industry participants. Once this connection was established, companies were willing to participate. Prior to making the link between the mini-capstones and the main capstones, we were unable to secure a commitment from industry personnel to participate in the mini-capstone projects. The additional challenge was to identify topics that would meet the companies’ needs as well as utilize the technical material specific to the courses. This may vary from semester to semester based on the projects that are lined up for the main capstone.

Typically, university networking events involve large amounts of students interacting with many employers over a short duration of time in an impersonal environment of a career fair. During such events, a short introduction to a student via a resume may not serve as an accurate indicator of a student's abilities. The mini-capstone project would provide students with a technical task to accomplish, and thereby provide the industry participant with a better idea of student technical capabilities due to their collaboration on the project.

**Major-Capstone Modifications:** The proposed senior design capstone course modification will include the addition of a bi-monthly presentation made by a professional from industry. Each presentation will be 30-45 minutes long. This hour will be divided into 30-45 minute and 15 minute segments. The 30-45 minute segment will include the presentation by the industry professional on a topic relevant to the course. The presenter will describe every component of the engineering system that was modeled and clearly state the assumptions made in doing so, and the solution that was used in order to solve the problem after the modelling process was complete. In the 15 minute segment, students will be free to ask the presenter any questions that
they may have regarding the problem that was just presented. These presentations will qualitatively expose the students to the high level of abstract thought that an engineer utilizes to solve problems in industry. Exposure to approximately 6-8 such presentations over the semester will help students understand what is involved in solving less defined real-world problems. Based upon survey feedback from industry presenters and students, we have concluded that a brief introduction to problem solving by industry professionals in the classroom environment would be an excellent addition to the existing theory-focused engineering and technology curriculum. Finally, since the capstone course is strategically placed in the final semester of the senior year, it is an ideal time for students to internalize and integrate the large amount of knowledge that they have absorbed over their degree and see what aspects of it are most relevant in industry. This should give students a sense of confidence in their knowledge and abilities before embarking in their career in the professional world.

Conclusions

The main goal of our study was to investigate whether undergraduate engineering and technology programs at U.S. colleges need to include more industry projects into courses that are offered earlier in the curriculum. In order to accomplish this goal, a pilot study was conducted in which industry professionals presented industry projects to students, demonstrating to them the steps involved and the nature of the assumptions made in solving these problems.

Additionally, students’ level of preparedness to solve industry problems was obtained via surveys distributed to students and industry presenters. The majority of students and all the industry presenters indicated that it would be beneficial for students to be provided with an increased exposure to industry problems. In light of this feedback, modifications to technical courses and the senior capstone course are recommended. These modifications include introducing mini-capstone projects into courses earlier in the curriculum, and adding presentations by industry professionals to the capstone course.

The present study was a small-scale pilot study done in 4 courses and involved 3 presenters from industry. Therefore it is difficult to come up with definitive conclusions unless the study is continued in the future and extended to other courses involving more industry participants. One of the main goals of this pilot study was to determine a way to ensure industry participation in the mini-capstone projects. Before a larger scale version of such a study can be formally implemented, it was beneficial to perform a smaller scale pilot study to help refine the process. Based upon this small study, we established that the way to ensure industry participation was to link the mini-capstones to the major capstone project thereby giving the industry participant a tangible incentive to participate since they would be provided with a prototype product at the end of the capstone. Therefore, we used the senior design capstone project as leverage for the industry participation in mini-capstone projects and presentations. Additionally, we were successful in ensuring the participation of 3 industry participants despite giving them only six
weeks’ notice. Despite this short notice, they were very enthusiastic and motivated to participate in this study since they saw value in it and potential future collaboration. A larger scale introduction of the mini-capstones into the undergraduate programs would require more time than just six weeks in order to establish a formal system. This pilot project has provided us with a system that can be followed while attempting to ensure the participation of industry partners in mini-capstone projects formally implemented into the program on a larger scale.

Positive feedback received from industry professionals and students that participated in the study supported the structure and practical feasibility of incorporating the aforementioned modifications into the courses. These modifications helped to lay the foundation early-on for the incremental development of thinking skills necessary to solve industry problems and showed the relevance of learning theoretical knowledge in the classroom. The series of presentations of projects by industry professionals in the final semester of the curriculum not only exposed students to a variety of different types of problems that taught them how to model real-world systems, but also helped them to integrate the knowledge that they have acquired over the course of their studies prior to graduation, thereby helping them transition into the professional world. Finally, increased networking opportunities for both students and employers constituted a fringe benefit to the recommended modifications.

References

APPENDIX A

SURVEY
Real – World Application of Textbook Engineering Principles: Student’s Perspective

1. Do you think undergraduate college–level engineering programs are too theoretical? (Y / N)
2. Do you feel adequately prepared to tackle real-world problems based solely on the textbook theoretical principles that you have learned in class? (Y / N)
3. Did you find that the presentation of a real-world problem by an industry professional helped you bridge the gap between theory in the classroom and applying this theory to a real-world problem? By “bridging the gap”, we mean gaining an introductory awareness of the challenging process that engineers go through in defining an engineering system (i.e., modeling) in the real-world when they have only a limited amount of information available to them. Defining a system involves specifying the system configuration, geometry, boundary conditions, solution/analysis algorithm. In other words, did the presentation help you appreciate the level of detail that a practicing engineer goes through in solving a real-world problem? (Y / N)
4. Did the presentation help you crystallize and better understand the textbook classroom theoretical concepts that you have already covered? (Y / N)
5. Did the presentation expose you to situations that required you to tap into your reservoir of theoretical textbook knowledge to understand a real-world engineering situation better? (Y / N)
6. Did you find that you encountered situations during the presentation where you could apply some of the hand-calculations you learned in class? (Y / N)
7. Did you find that the presenter did a reasonable job of discussing a real-world application? (Y / N)
8. Did the presentation have enough detail that you found it useful? To elaborate: some presentations can be too abstract and general. Some presentations can be too focused on detail, and you as a listener can get lost in the detail. Was there a healthy balance between the two aforementioned extremes? (Y / N)
9. The Capstone project is completed in your final year and involves fairly large groups in which each student focuses on a narrow area. In addition to this, do you feel that having a small real-world project component at the end of every technical course would be beneficial to you towards improving your understanding of the theoretical contents of the course that you completed? (Y / N)

[Such a project component would involve an industry professional presenting a project that he/she recently worked on. After the presentation, your task would be to complete a small portion of the presented project by the end of the semester. You will work in groups to enhance your team-work skills. You will be exposed to several instances where you are required to apply textbook principles to real-world problems, and the process will thereby become more familiar to you by the time you graduate].

10. Would you like a course during the final semester of your degree program where an industry professional presents a complete real-world project on a weekly basis just as was presented in this class? (Y / N)

[The benefit of a course of this sort is that it will expose you to a variety of different practical projects and will display to you the challenges faced by an engineer in applying ideal textbook theoretical principles to real-world problems. Since this course will be in your final semester, it would help you integrate your knowledge and smoothly transition into the practical world].

11. Was it helpful to you to meet industry professionals in person and network with them with the intention of possibly working with them in the future? (Y / N)

APPENDIX B

PRESENTER SURVEY
Mini-capstone Projects and Industry Presentation Course

1. Based on your experience in industry, do you feel that fresh graduates are adequately equipped to solve practical engineering problems (i.e., making assumptions that are used to model real-world situations into engineering systems to which theoretical textbook principles can be applied)? (Y / N)
2. Would you prefer it if students entering your company were more exposed to the challenges faced by an engineer while solving real-world problems? (Y / N)
3. Do you think that the proposed course would be an efficient and beneficial way to assist students in transitioning from the classroom to the real world? (Y/N)

4. Do you think that the proposed course would benefit industry professionals by providing them with a recruiting/networking tool in the form of this course? (Y/N)

5. Do you think that having student’s work on small components on real-world projects throughout their degree would be a good way to help them to keep the bigger picture in mind right from the start of their educational experience and thereby more smoothly transition to the real-world? (Y/N)

6. Currently the capstone course is used to give students the experience of doing a real-world problem. This course is the only course of this type and is offered in the final semester of the student’s degree program. Do you think exposing the students to numerous real-world problems in two ways (a and b below) would be a good addition to the existing capstone course in helping students transition from the classroom to industry? (Y/N)
   a) right from the start of the degree in each of the technical courses, and
   b) in the form one course in their final semester involving weekly presentations of the sort you just made,

7. In addition to the traditional approach of networking with students (i.e., campus career fair), do you think the proposed course would be beneficial to you in recruiting potential future employees (the benefit of such a course could be due to the fact that you as an employer now have tangible evidence of a future employee’s ability to apply textbook principles on the job)? (Y/N)

8. Do you think a course of this type would be a good way to enhance industry/academia collaboration? (Y/N)
   The benefits of such collaboration are two-fold:
   a. interactions of this sort can give industry employers an opportunity to provide academics with valuable input and suggestions which would help academia tailor their teaching approach and content into one that is beneficial to industry?
   b. service to the academic community in your region can have add value to your career

9. If you believe this course has value to your industry (which would be reflected by answers in the affirmative above), do you think that it would be practically feasible to organize the proposed course as follows:
   a. Industry would send an employee(s) to make a presentation(s) in each semester on a volunteer basis? (Y/N)
   b. Industry would get a stipend for sending an employee(s) to make a presentation(s) in each semester? (Y/N)