Enhancing the Civil and Environmental Engineering Capstone Program at Brigham Young University through On-Campus Internships and Graduate Student Mentors

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A selected project submitted to the faculty of Brigham Young University in partial fulfillment of the requirements for the degree of Master of Science

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December 2012

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Abstract
Culminating educational experiences such as capstone design projects are playing an increasingly important role in meeting the educational objectives of Civil & Environmental Engineering (CEE) degrees. In recent years both American Society of Civil Engineers (ASCE) and Accreditation Board for Engineering and Technology (ABET) have placed a focus on the development of management, leadership and general business skills. Capstone programs offer an ideal environment not only to provide a synthesis of the fundamental technical engineering skills in developing a culminating design project, but also to create an opportunity to focus on all of the professional practice skills necessary for students to become future leaders in their field.

Recognizing the opportunity to enhance development of these complimentary professional skills in the curriculum the CEE Department at Brigham Young University (BYU) has revamped their capstone class to provide experience in real-world hands-on projects, communication, project management, mentoring, leadership, and teamwork. This evolving program engages graduate students as mentors and facilitators of industry sponsored projects. Undergraduate student teams have the opportunity to practice important collaboration skills while completing their design project independently as an on-campus internship.

Since the program was first piloted in 2010 fifteen different agencies and companies have sponsored more than thirty projects. This paper will describe the evolution of this innovative capstone experience, and explain the current program at BYU. It will compare the BYU CEE program with other university capstone programs and provide suggestions on improving it based on the comparative research.

Defining the Capstone Course
Capstone courses have become a widespread culminating experience in undergraduate engineering programs. They are largely universal as a result of engineering programs seeking to better meet the needs of industry and have been so successful that in many cases the ABET requires universities to include them. That being said, capstone programs vary widely from school to school so it can be difficult to expect a single definition that applies to all programs. According to Fairchild and Taylor, capstone projects are “culminating experiences in which students synthesize the skills they have acquired, integrate cross-disciplinary knowledge, and connect theory and application in preparation for entry into a career.” Durel offers another perspective stating that capstone can be seen as “rite of passage or luminal threshold through which participants change their status from student to graduate. A capstone course should be both a synthesis – reflection and integration – and a bridge – a real-world preparatory experience that focuses on the post-graduation future.”

Other definitions include, “a crowning course or experience coming at the end of a sequence of courses with the specific objective of integrating a body of relatively fragmented knowledge into
a unified whole \textsuperscript{[4]}, or an experimental learning activity in which analytical knowledge gained from previous courses is joined with the practice of engineering in a final hands on project \textsuperscript{[5]} which attempts to integrate, extend, critique, and apply the knowledge gained in the major.” \textsuperscript{[6]}

In today’s world many professors and college graduates have observed that it takes more than just technical expertise to succeed in the profession. A wide range of nontechnical skills are essential: leadership, teamwork, problem solving, decision making, critical thinking, interpersonal communication, information management. These types of skills are often called “soft skills” in the professional practice. To help students develop both soft and technical skills, the objectives of a capstone course, project, or experience typically include the following \textsuperscript{[7]}:

- Provide students an opportunity to synthesize knowledge from formal and informal learning and apply it to contemporary issues in the field
- Help prepare students for a successful career by providing experiences that enhance their labor market advantage
- Increase students’ understanding of the big picture, including ethical and social issues related to the field
- Help students understand the relevance of theory and research to practice
- Provide opportunities for teamwork and leadership

Because of its importance ABET has delineated some key components that these programs need to have in order to be considered valid capstone courses and allow the students to develop and apply both soft and technical skills. ABET emphasizes the need for engineering courses that build teamwork, communication, and project based skills. In addition ABET mandates that the capstone program requires students work in multidisciplinary teams, and design a system to meet desired needs within realistic constraints.

ABET EAC Criterion 5 states that “students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.” \textsuperscript{[8]}

**Survey of Civil Engineering Capstone Programs**

Although engineering capstone programs at different institutions may have many variations in their structure and operation, many of them share the same basic components. According to a survey of several engineering disciplines conducted by Howe and Wilbarger in 2005 \textsuperscript{[9]}, most of the universities currently offer a one to two semester engineering capstone program with simultaneous class and project components. A popular design for engineering capstone programs is to group 4-6 students into a team and either assign them projects to work on or let them choose a project that they are interested in. From their survey they found that 71\% of the projects are based on solving real world problems. Other major sources of projects are faculty research or design competitions. Schools usually participate in both real world and academic projects by pairing faculty members with the student groups.

The educational institution usually finances projects, though industry sponsorships have become more frequent. Sponsors are more often granted some or all intellectual property rights, and sponsoring companies have started becoming more involved with the student groups. It is
estimated that the majority of engineering capstone industrial sponsors are paying less than $500 per project and the cost of completing the project is less than $1,000 in most cases.

While most accredited universities have adopted capstone courses in their Civil Engineering (CE) departments few programs have published details. One reason for this may be that many of those programs are still relatively new and still evolving. According to the survey, about 50% of CE departments have capstone programs that are less than 5 years old and only about 10% have programs older than 15 years. While this information can be hard to find it does exist. For instance, the capstone course at the University of Utah has been evolving over the past 14 years. It is based upon a proposed infrastructure project, in which the students manage the entire process of developing a preliminary engineering study, including county, city and state budget information that will be used for planning purposes. The students are divided into three-person teams that are individually responsible for specific elements of the project.  

At Purdue University students also work with real projects that are either in consideration or in the process of being designed. However, different from the University of Utah program each student on a team completes the required design for one of the CE subspecialties (geotechnical, environmental/water resources, construction, and transportation).  

At the University of Berkley there is a capstone course for each different CE discipline where teams are formed to address design, construction and maintenance of contemporary civil and environmental engineered systems. While the capstone course at University of Washington is offered in 2 different sections. The first course in the sequence is a design seminar that covers the fundamentals of integrated CE practice and design. The second course involves a capstone design project that can be in transportation and construction, structures and geotechnical, environmental, or water resources and hydrology depending on a student's interest.  

Real-life projects are assigned to the CE students at North Dakota State University as well, except that the projects are selected from the community. By selecting community-based projects, the university strives to enrich the academic experience of the students and emphasize the relevance of the discipline to the society. This concept of service learning links community service and academic study so that each strengthens the other.  

The Seattle University CE capstone program has been in existence for the past 20 years and is unique in a way because the projects that it solicits are fully supported by industrial sponsors. Sponsoring agencies typically are expected to pay from $5,000–$20,000 to the university depending on the organization’s annual revenue. These funds are used to pay for the time that the faculty and staff spend supervising the projects as well as any equipment needed for the projects. In return each team spends about 800–1,000 hours on the project.  

Our review of different programs, where efforts appear to have been made to include deeper capstone learning, indicated that capstone in all of the above universities, incorporated these important elements:

- They were team based and were only available to seniors as a graduation requirement.
- Teams were either mentored by experienced engineering consultants who sponsored the projects or by faculty advisers.
• Teams worked on real world projects rather than academic or contrived ones. These projects could often involve redesigning an existing project to see if a better solution could be achieved, developing design for a new project, or working on a small portion of a larger project.

**Barriers to Implementation of Enhanced**

The programs chosen as part of the research were done so because they exemplified some of the more comprehensive capstone experiences. However it is worth noting from our own experience and observations that while ideal to have external sponsors or faculty advisers the availability and sustainability of these resources is a major challenge, especially for large programs. For example while there are many local practicing engineers including alumni who have a desire to give back to the university community the priority they place on responding to student questions relating to the project is understandably low relative to their day to day work. Similarly faculty charged with heavy teaching and research loads may not be able to fully invest in the project and be available as often and as immediately as student teams need. If questions go unanswered to do availability student teams become frustrated and the success both of the design project and the student learning experience is jeopardized.

Working on real world problems with their variety of unknowns is challenging and beneficial for students but the time involvement required by course instructors is significant in developing the projects and insuring that they are of sufficient high quality to meet course objectives while being realistic in their demands on the students. A key element in overcoming both of these barriers is funding. While some engineering capstone programs receive a monetary grant or donation in order to support the effort it would appear that this is not common practice among civil engineering programs. Thus faculty time and mentors must be done on a more voluntary basis or resources allocated from already existing pools.

**Capstone Course at BYU CEE Department**

*History*

As with many other CE programs, BYU has sought to enhance the capstone experience in order to meet important educational objectives outlined by ABET and ASCE and provide graduates with the best possible preparation for professional practice. Over the past 15-20 years the culminating design or capstone experience has made several transformations motivated by increased emphasis on capstone as well as feedback from students and alumni.

Early versions of the capstone class at BYU included a one-hour communications class where students were given opportunities in writing and presenting skills and issues relative to business practice and public policy were discussed. The technical objectives of the capstone class were met by the reinforced concrete design class, which was a senior class heavily focused on design.

As ABET and others capstone emphasized more rigor and integrated culminating experiences the BYU program adopted a class that combined the one-hour communication and professional practice class with a project based on the design of a commercial shopping center. This problem
included design from all the sub-disciplines in the department with structural teams focused on
the design of the store, geotechnical on seismic analysis and retaining walls, transportation on the
flow of traffic, and water resources and environmental on drainage. This provided a more
integrated approach to the culminating design, but the problem was contrived and theoretical in
nature without having hard constraints. Further, students taking the class in subsequent years
would have easy access to the work of previous years, even though this practice was
discouraged.

The next iteration of the BYU capstone class merged the communications class together with a
culminating design project. In this case the students were allowed to form teams of 3-5 students
and choose their own projects. Many projects were innovative and based somewhat on real
constraints. However, students tended to stay within the realm of doing things that they already
had acquired skills for. Since they were responsible for defining their own scope of work they
would simply avoid or work around issues in their design that might cause additional research
and training. While the program was markedly better than previous versions of the class, in most
cases it still lacked the ability for them to develop confidence in moving beyond the safety of
tools, methods, analysis that they already had acquired. Student evaluations improved but many
still felt the exercise was more of a hoop to jump through than the kind of experience that
genuinely prepared them for professional practice.

2009 Alumni Survey
Recognizing the importance of developing business practice skills the BYU CEE Department
adopted a Master’s of Engineering Management in the mid 1980’s which during the 1990’s
became a minor in business management that could be earned during the Master’s program. This
minor consisted of a 3-credit class in accounting, a 3-credit class in finance and one 3-credit
elective from the business or public management school. In the fall of 2008 the business and
accounting schools which housed the program decided they could no longer offer the program.
In response to evaluating the need to redefine and continue this program as well as assess many
other aspects of both the Master’s and Bachelor’s programs a comprehensive survey was
conducted of all alumni. Results from more than 450 respondents as shown in Figure 1 clearly
communicated the importance of developing professional practice skills and that our
department’s greatest weaknesses were focused in that area. These are the same skills for which
the capstone class should be designed to meet.
The survey asked respondents in a free response format to indicate the greatest weakness and for the purposes of understanding the trends better all responses were sorted into the four categories shown in the chart. Overwhelmingly what the alumni were saying is that they felt well prepared technically to practice civil engineering but that they wished they had been more prepared for the business side of their profession including more experience on real projects, a better understanding of developing work, managing projects and people in a business, and working through public entities who often are the clients and/or gatekeepers of large projects. The survey became a primary motivator in developing the integrated graduate mentoring program to replace the management minor that had recently been dropped as well as a significant opportunity to strengthen our undergraduate capstone program. The following sections provide an overview to this integrated program which constitutes the current capstone class.

**Program Overview**

The CEE capstone Program at BYU is a two semester program for undergraduate and graduate students. While graduate students take classes in civil engineering business operations, project management, and leadership they serve as mentors to the undergraduate teams. They assist in working with project sponsors to acquire knowledge about the project and prepare requests for proposals with a rough scope of work during the fall semester. Undergraduate students while learning fundamentals of professional practice develop proposals for the various sponsored projects from these RFPs during fall semester then complete the work in what is called capstone internship on campus during the winter semester with the graduate mentor already familiar with the specific project assigned as a mentor.

The overall objective of capstone is for students to synthesize the fundamentals of engineering analysis learned in the curriculum and learn the professional practices necessary to develop a quality solution for an engineering design project.
To achieve this, each student is to:

1. Understand what engineering design is and complete a design project to the satisfaction of a project sponsor.
2. Learn and apply the basic principles of project management so that quality work can be accounted for and completed on time.
3. Integrate foundational engineering knowledge and experience.
4. Participate both in leading and following roles as a team member on a high-functioning team.
5. Take responsibility to learn and work independently; seeking outside help, advice, and feedback as needed to complete assigned work on the design project.
6. Develop the attributes of a competent practicing civil engineer.

Graduate Business Operations and Project Management and Leadership Class
To replace the vacated management minor a two course sequence for graduate students has been developed which goes beyond what students are able to learn in the undergraduate capstone class. During the fall semester students learn about balance sheets, profitability, and the general business aspects of civil engineering firms. Much of this class is taught by alumni and others in professional practice who share their experiences in managing and owning a firm. The primary responsibility in terms of homework for students during this semester is to work with undergraduate capstone project sponsors to develop an RFP to which undergraduate teams will respond to and they will become mentors for. There is one graduate student assigned to each project and during the three to four month period they try to learn enough about the project they are assigned that they can take ownership of it in the sense that they can answer many of the questions undergraduates will have when they begin to work on it.

In the winter semester they mentor the undergraduate students during the execution of their project while they complete a separate class on project management and leadership. They act as one part mentor to the students in helping them to develop high functioning teams and one part client by being the first line of defense in responding to questions teams may have about their projects. This is a critical element of the program, because while sponsors generally begin with the best of intentions to be involved with the capstone teams, their reality is that the capstone project is fairly low on their priority of tasks. The program would not be sustainable if it took project sponsors days or weeks to respond to a team’s inquiry. By virtue of the fact the graduate students have a broader and deeper technical background and that they have already become familiar with the project while developing an RFP over the course of the fall semester they are able to respond quickly to most of the questions and thus run interference on the time obligations that would otherwise be required of sponsors for the projects to be successful.

Individual outcomes for both of these classes, Business Operations and Project Management and Leadership, are described in the following two sections.

Fall Course Outcomes, Business Operations
1. Understand the basic concepts of finance and accounting
2. Understand the basic concepts of budget, cost management, marketing, branding, strategy, profitability, and competition
3. Learn the purpose and creation of request for proposals and statement of qualifications
4. Understand the purpose and types of bonds and how they are issued
5. Gain an understand of how people, opportunities, context, and possibilities for risk and reward are critical to the success of a new venture
6. Develop a business plan for a new civil engineering venture

**Winter Course Outcomes, Project Management and Leadership**

1. Understand the scope of project management and learn different management styles
2. Become confident in your ability to lead a team
3. Learn how to recognize and appropriately address conflict
4. Know how to effectively manage relationships and be accountable to them for contracted work
5. Learn effective leadership skills including communications, coaching, and managing risk
6. Become a more compassionate and concerned leader and team member

**Undergraduate Capstone Professional Development and Internship Class**

As with the graduate classes emphasizing civil engineering professional practice, the undergraduate capstone experience is a two semester class where the first semester is a one credit hour experience that focuses on professional and business aspects of civil engineering organizations. During this semester they learn the basics of economics, sustainability, project development, communication, and teamwork. Students are organized into teams of 3-5 students and the semester culminates with a team developed proposal for one of the sponsored projects. During the winter semester student teams work on the execution of their design project in an on campus internship. These are not paid internships, rather they independently organize themselves and work 6-8 hours weekly including team organizational meetings to complete their projects. An emphasis is given to team process as well as project completion with readings, discussions, goal setting provided by the course instructor and facilitated within individual groups by the graduate student mentors. The outcomes for Professional Development and Internship classes are given in the below sections.

Capstone projects are solicited from private and public agencies. These projects include work that may have been previously completed but which a second opinion is desired, or a preliminary feasibility study, or to simply obtain new insights from current practice. Since the program was begun fifteen different agencies and companies have sponsored more than thirty projects. Table 1 lists the projects that have been undertaken in this course for the 2012 and 2013 years.

**Fall Course Outcomes, Capstone Professional Development**

1. Perform a triple bottom line analysis of an existing civil engineering project by evaluating social, environmental, and economic impact.
2. Learn about an existing civil engineering project by gathering and organizing information from published literature and the internet.
3. Understand the changing roles of the USA and another country in the modern world in both contemporary society and civil engineering.
4. Explain the time value of money, construct cash-flow diagrams, and perform present worth or annual payments analysis of alternatives.
5. Outline tasks assigned to each team member for projects and reports to be completed in study abroad and culminating design courses.
6. Know the steps necessary to become a licensed professional engineer. Become committed to life-long learning.
7. Understand the procurement of engineering services and the associated legal and liability issues involved.
8. Understand the differing roles of practicing professionals, business managers, public administrators and others in project development.
9. Understand how to communicate effectively.

Winter Course Outcomes, Capstone Internship
1. Understand and be able to apply conception, formulation, analysis, and search for solutions to civil engineering design problems.
2. Be able to integrate topics from various civil engineering disciplines to solve problems with multiple realistic constraints.
3. Be able to obtain and evaluate appropriate standards from databases, handbooks, experiments, and literature.
4. Be able to make estimates, assess reasonableness of solutions, and select appropriate engineering designs.
5. Be able to communicate with groups by giving effective, well-organized oral presentations.
6. Be able to communicate in a team environment.
7. Understand the proper use of visual aids in oral presentations.
8. Be able to compose professional documents in a clear, concise, and effective manner.
9. Understand the proper design and use of graphics in technical documents.
10. Function on multidisciplinary teams.
11. Be effective in written communications.
<table>
<thead>
<tr>
<th>Project synopsis</th>
<th>Disciplines involved</th>
<th>Sponsoring agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design a roundabout and examine the feasibility using roundabouts on typical intersections in Riverton, Utah.</td>
<td>Transportation</td>
<td>Riverton City, Utah</td>
</tr>
<tr>
<td>Evaluate the Midas Creek drainage capacity, obstructions, and improvements.</td>
<td>Water, structural</td>
<td>South Jordan City Engineering, Utah</td>
</tr>
<tr>
<td>Design a temple steeple in a high seismic zone.</td>
<td>Structural</td>
<td>LDS Church Temple and Special Projects Department, Utah</td>
</tr>
<tr>
<td>Prepare a speed/warrant analysis for the Daybreak Parkway Couplet.</td>
<td>Transportation</td>
<td>Rio Tinto – Kennecott Utah Copper</td>
</tr>
<tr>
<td>Design a multi-use detention basin that provides flood control, but can be used for recreation during dry weather.</td>
<td>Water, structural</td>
<td>Riverton City, Utah</td>
</tr>
<tr>
<td>Prepare a master plan for the Copper Creek that includes hydrologic analysis and alternatives to convey flood flows.</td>
<td>Water, structural</td>
<td>Salt Lake County Flood Control, Utah</td>
</tr>
<tr>
<td>Design a water storage tank for the Wallsburg Camp.</td>
<td>Structural</td>
<td>BYU Physical Facilities Department, Provo Utah</td>
</tr>
<tr>
<td>Design a footing for the restored Provo Tabernacle (temple).</td>
<td>Structural</td>
<td>Jordan Valley Water Conservancy District, Utah</td>
</tr>
<tr>
<td>Prepare a Midas Creek flood study for 10, 50, 100, and 500 year storm events.</td>
<td>Water, structural</td>
<td>Salt Lake County Flood Division, Utah</td>
</tr>
<tr>
<td>Evaluate the current and future level of services (LOS) for one of the roundabouts in South Jordan, Utah.</td>
<td>Transportation</td>
<td>South Jordan City, Utah</td>
</tr>
<tr>
<td>Design a Bluffdale City stormwater conveyance.</td>
<td>Structural</td>
<td>Bluffdale City, Utah</td>
</tr>
<tr>
<td>Prepare a Brackish water treatment plan.</td>
<td>Water, structural</td>
<td>Mike Chandler (private resident), St. George, Utah</td>
</tr>
<tr>
<td>Analyze building inventory data for Utah county to upgrade the FEMA and State Hazus earthquake model.</td>
<td>Geotechnical</td>
<td>Infrastructure Resilience Department, URS Corporation, Utah</td>
</tr>
<tr>
<td>Provide the design of the relocation of a steel-framed structure currently located in Riverton City, Utah.</td>
<td>Structural</td>
<td>Riverton City department of engineering, Utah</td>
</tr>
<tr>
<td>Create standard details and specs for the seismic bracing of mechanical systems utilized in LDS temples.</td>
<td>Structural</td>
<td>LDS Church Temple and Special Projects Department, Utah</td>
</tr>
<tr>
<td>Design a water-treatment and monitoring plan for Cinnamon Creek Camp Spring in northern Utah.</td>
<td>Water, environmental</td>
<td>LDS Church, Utah</td>
</tr>
<tr>
<td>Design a water-treatment and monitoring plan for Koholowo Camp Spring in Santanqui Canyon, Utah.</td>
<td>Water, environmental</td>
<td>LDS Church, Utah</td>
</tr>
<tr>
<td>Design plans and specifications for guard rails, horizontal pavement alignment and striping, and lighting system for the twin Bebo bridges.</td>
<td>Structural</td>
<td>Rio Tinto – Kennecott Utah Copper</td>
</tr>
<tr>
<td>Provide horizontal and vertical alignments for a roadway design.</td>
<td>Transportation</td>
<td>Springville City, Utah</td>
</tr>
<tr>
<td>Propose a replacement of the Bartholomew culinary water tank in left-hand fork of Hobble Creek Canyon, Utah.</td>
<td>Water, environmental</td>
<td>City of Springville Public Works Department, Utah</td>
</tr>
<tr>
<td>Design a plan that changes two “tee” intersections into two 4-way intersections, with a new connecting roadway between the two new intersections.</td>
<td>Transportation</td>
<td>Springville City Public Works department, Utah</td>
</tr>
<tr>
<td>Develop recommendations for how to remove a third lane of traffic making it effectively two lanes.</td>
<td>Transportation</td>
<td>Rio Tinto – Kennecott Utah Copper</td>
</tr>
<tr>
<td>Completely re-design an apartment complex parking lot in Provo, Utah.</td>
<td>Transportation</td>
<td>Provo City, Utah</td>
</tr>
</tbody>
</table>
Each capstone team is assigned a graduate student mentor who guides them through the development of a design solution for the project. Graduate mentors serve as a liaison between the project sponsor and the team, and help the teams to meet the needs and wants of the sponsoring organization.

Capstone teams respond to RFPs through a bidding process to obtain a project. Once the teams examine the potential projects, they bid on those projects by submitting a proposal. Teams register their intent to propose so that they have an opportunity to see if there are other teams and how many are interested in proposing on the same projects. If only a single team responds to an RFP they will “win” that project, but if there is more than one team then the team with highest ranked proposal wins that project. In either case teams must prepare a proposal which is scored and used as part of their grade evaluation. Teams that are unsuccessful in a competitive proposal identify second, third, etc. choices from the projects that are not proposed on and their proposal score is transferred to be compared against other unsuccessful proposals. In the end there is the same number of projects as teams, and each project is assigned to one of the teams.

Proposals describe why their team is the best suited to carry-out and succeed in meeting the objectives of the given project. After the proposing window closes, each proposal is evaluated by a group made up of the graduate students who in their class have been learning about the job procurement process, including the typical RFP/proposal/evaluation process. Graduate mentors and teams are notified of their respective assignments, and are asked to have a kick-off meeting with their project sponsors as soon as possible.

Capstone team’s progress is effectively monitored through regular contact between the project sponsor, the graduate mentor and the capstone team. Teams prepare a progress report weekly that is emailed to both the graduate mentors and the project sponsors. To increase the likelihood of a successful project outcome, project sponsors and graduate mentors are asked to evaluate the project results by providing regular feedback to the teams through effective communication and surveys.

Capstone teams conclude their projects by a formal presentation to the university community and project sponsors through oral and poster presentations.

**Student Response**
During the transition period from the previous program in which projects were student-selected rather than sponsored by outside organizations there was some anxiety and uncertainty. Unlike other university courses, but much like actual project work the end is not known from the beginning. Students were concerned that they would not be able to complete the work in a reasonable amount of time and effort and were generally uncomfortable with all of the uncertainty and new things they would be required to learn and implement. However, instructors have emphasized that as in professional practice if they put in the requisite hours for the internship and continued to research and work towards solutions in fact they would accomplish much more than they thought possible based on the technical background and mentality of lifelong learning as part of their undergraduate education. Initial feedback given below from indicates that the changes are having a positive impact on student learning.
“I learned so much from this class. I learned how important it is to learn from other people. I had to talk with lots of different people during this project and I really learned how important experience is in engineering.”

- “The project portion of this class was excellent. I loved that we were able to work on an actual project and go through all the steps of design. It was a good learning experience and I'm glad they've made the recent changes to this process.”
- “Overall I feel that this course has been one of the more helpful courses I have had in the undergraduate courses for helping me to understand design, and how to work together as interdisciplinary group.”
- “The capstone project was an amazing learning experience. I appreciated learning about how to write reports and the like, as well as all I learned technically in our difficult project.”
- “The project aspect of this course was very beneficial. I never thought that I would get to work on a real-world project from concept through design during my education. I learned a great deal about working together in a team to accomplish something much larger than I can do on my own.”
- “Great class! Besides an internship, this class is the only way students get to test themselves in solving real-world problems.”

Combined with the additional learning graduate students have in learning professional practice, this integrated program appears to be meeting the desired outcomes as expressed in the alumni survey. In the near future as similar surveys are repeated it will be insightful to see if in fact these students now feel more prepared to enter professional practice than they did previously.

Program Improvements
BYU CE capstone has had a successful experience in soliciting real world projects. Most of the students mentioned in their comments after the project was completed how much they appreciated solving real world problems. BYU has found that providing industry sponsored projects to the students can be a great way to prepare engineering students for the job market. In order to consistently get these types of real world projects a good partnership with local engineering companies or entities is required. The CE department is planning to improve the partnership with current sponsors by successfully completing the projects that is currently receiving, and also find new companies that are willing to partner with them.

Additionally, BYU will be highly interested in accepting financial sponsorship for the projects. In the past some organizations that provided projects for the students have offered to pay for them, however BYU did not accept the funding. Seattle University is the only school among our CE capstone program review that had their projects fully supported by industrial sponsors. Sponsoring entities, depending on the organization’s annual revenue, pay $5,000–$20,000 to the university to complete the project. If the financial sponsorship is implemented at BYU CE capstone program the funds will be used to pay for the time that the faculty and staff spend supervising the projects, as well as any extra resources needed for the completion of the projects. In return each team will spend more than 600 hours on the project.
**Conclusion**

Capstone programs are an important element of civil engineering programs and increased emphasis on professional practice development by ABET and ASCE has put more pressure on university programs to strengthen culminating design experiences. Many universities across the country have worked to evolve their capstone experience to meet these demands by including such key elements as: 1) working on real-world projects with inherent uncertainty that stretches student technical and professional practice abilities, 2) making teamwork and integral part of the experience, and 3) involving external sponsors and faculty advisers as mentors. While such elements are desirable and noble, they require significant time and other resources to do well that create critical institutional barriers to developing high functioning capstone programs.

The Civil and Environmental Engineering Department at BYU, like other institutions has been involved in this process and developed a unique program which combines further professional development practice of graduate students as mentors for undergraduate teams. This program provides the key benefits of enhancing graduate student development while contributing to the solution of some of the key challenges in the undergraduate capstone program. Specifically graduate student mentors are able to assist in the transfer of information and act in part as “clients” to real-world projects sponsored by public and private agencies. This relieves both the pressure on sponsors and faculty advisers to be available on demand to capstone teams because graduate student mentors become part of that team and can answer most of the questions that might arise and keep the team on track. The program is still not without hard institutional costs and finding ways to become completely self-sustaining financially remains a challenge.

Preliminary assessment from students who have participated thus far in this new program suggests that it is both successful in meeting learning outcomes and meeting student expectations.

**References**


