

dDesign Education: A Globally Distributed Capstone Engineering Design Experience

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This paper documents the initial efforts to create a globally distributed Mechanical Engineering Capstone Design Course at Texas A&M. Collaborating student teams were split between Texas A&M College Station and Texas A&M Qatar in Doha Qatar. The initial effort featured two different projects. One project was a product for deep-sea oil field applications. The other project was a simulator to be used for training new wheel chair users. Student ability to adapt to the challenges associated with globally distributed engineering was high. Project collaboration was successfully achieved through email, internet user groups, and video conferences. Instructor collaboration and consistency between the collaborating campuses was the least well-solved challenge of the project. To improve instructor consistency in the future, the creation of detailed grading rubrics is suggested.

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Introduction and Background

Engineering is, and is becoming increasingly more so, a physically and culturally global activity¹. Project teams are often comprised of engineers from different countries, with different primary languages, and who view projects from different cultural contexts¹. As with practice, engineering education is becoming more global². Nevertheless, engineering education remains a more regional activity than engineering practice³. Even though the students may come from different backgrounds and thus can be thought of as culturally global, students live in the same communities, attend lecture in common classrooms, and work in common study rooms and computer labs.

As collocation is in contrast to the global practice of engineering, it has some pedagogical disadvantages relevant in the context of capstone engineering design courses that attempt to serve as an experienced based transition from the classroom to the workplace. In practice management, engineering, and customers are globally distributed. In contrast, capstone engineering design students typically work with a project sponsor and customer in the same, or similar, time zone. Whereas in engineering practice, problem clarification may evolve slowly through an email thread or threads, students can sit in the same room at the same time as they hash through needs, requirements, and constraints. In engineering practice, solutions and concepts are generated individually. As part of a capstone class, students are able to share a common blackboard as they dynamically interact to brainstorm ideas.

As with practicing engineers, students continue to use a greater degree of connectivity media such as email and cell phones to work together on projects. Even so,

they share a common workday and work week upon which they build a schedule. As a result, responses to text messages are received in minutes or hours. Similarly, emails are typically returned in hours. Also, the importance of a common workweek on managing schedule and deadlines can be important.

Transition from a collocated engineering design experience to a distributed one can pose a challenge for new engineers⁴. Integrating distributed engineering design as part of a senior design capstone experience allows students to develop the skills needed to better execute distributed engineering design in practice.

To better prepare students for the distributed nature of engineering practice, The College of Engineering at Texas A&M University is developing a globally distributed capstone engineering design course. Initial efforts began in the spring semester of 2009 in Petroleum Engineering. Recently, efforts have extended to capstone courses in Mechanical and Electrical Engineering. In this paper, the structure and practice of this course as implemented in Mechanical Engineering is discussed. Though the course is still in the early stages of development, lessons learned and associated conclusions are presented.

The rest of this paper is organized as follows. The curricular and physical structure of the Mechanical Engineering Capstone Design Course is presented followed by a discussion of primary student activities and behavior. The next section presents lessons learned during this first effort at globally distributed design, which we will call dDesign from here forward, education. The final section concludes the paper and outlines future work for the immediate and long-term dDesign education activity.

Texas A&M Mechanical Engineering Capstone Design

The Mechanical Engineering Capstone Design Course at Texas A&M is a two semester, team and project based course. Projects are primarily provided and sponsored by companies, government agencies, research labs, and individuals. Projects include a wide range of scale and scope.

The course is organized with one main lecture, which all students attend, and multiple break-out sections or studios. The lecture section on the Texas A&M College Station (TAMUCS) side has approximately eighty to one hundred students. The studio sections on the TAMUCS side have from eight to thirty students. Lecture covers basic topics in design theory, methodology, and the design process. In studios, students are mentored by a studio instructor and work together on the design project. The large lecture section meets twice a week. The small studio sections meet once a week.

Teams of four students are typically assigned to the smaller projects. For larger projects, multiple teams of about four students are assigned to work on different aspects of a single project. Teams include a management team and multiple teams with specific technical focus. Dependent on project scale, the final deliverables may be a paper design or report, a proof of concept prototype, or a fully functional prototype.

Texas A&M Qatar (TAMUQ) is part of Education City located in Doha, Qatar. Education City is a project established by the Qatar Foundation to develop excellence in higher education based on curricular practice and pedagogical philosophy as practiced in the United States. Education City houses six universities. TAMUQ provides programs in Engineering. Virginia Commonwealth, Cornell, Carnegie Mellon, Georgetown, and Northwestern University provide other degrees of regional importance. Classes are coeducational. The language of instruction is English.

TAMUQ has offered bachelor of science degrees in chemical, electrical, mechanical, and petroleum engineering since 2003. TAMUQ curricula are materially identical to the ones offered at the College Station campus. The structure of the capstone design sequence at TAMUQ is the same as at TAMUCS with the difference that the lecture and studio sections are smaller at TAMUQ.

Mechanical Engineering dDesign Fall 2009

Fall semester 2009 was the first effort to create and implement dDesign at Texas A&M. The primary goal of the dDesign education effort is to better prepare TAMUQ and TAMUCS students for the globally distributed nature of engineering practice. A second goal is to discover differences that may be unique to the

educational element of the experience, though perhaps do not translate to engineering practice.

In engineering practice, the customer is effectively unconcerned with the distributed nature of the design team: the concern is on product performance. Any complexities and challenges of being distributed go on behind the scenes. Extending these ideas to dDesign education, the general and intentional implementation philosophy was to make no significant course changes for the dDesign experience. The basic structure of our dDesign implementation effort presented here illustrates how our dDesign effort was similar and different from a typical capstone design experience.

Two projects were selected for the inaugural dDesign effort. Consistent with the distributed philosophy of the class, one project sponsor was selected from the TAMUCS region and one sponsor was selected from the TAMUQ region.

The TAMUCS region project sponsor was FMC Technologies. FMC is an oil and gas company with facilities in Houston, TX. The FMC project is to develop systems and tools to recover abandoned deep-sea well equipment. The FMC project exemplifies one with an industrial customer, or engineer as customer, with an industrial or professional end user. The expected final deliverable of this project is a design report with analysis based validation for concepts selected and details designed.

The TAMUQ region project sponsor was the Shafallah Center in Doha, Qatar⁵. The Shafallah Center is a school for special needs children. The Shafallah project is to develop a wheel chair simulator training system. The simulator will be used to train children to use motorized wheel chairs for personal mobility enhancement. The Shafallah project exemplifies one with a customer with no engineering background and a consumer level end user. The final expected deliverable for the Shafallah project include detailed drawings and a functioning prototype suitable for testing and validation.

Each of the design teams had a similar distributed structure. The FMC project team consisted of two students physically located at TAMUCS and two at TAMUQ. At TAMUCS, one student had previously attended school at TAMQ. On the TAMUQ side, one of the team members was a student who had previously been studying at TAMUCS.

The Shafallah project team had three students physically located in College Station and two students in Qatar. One of the students on the College Station side had spent the previous year in Qatar studying at TAMUQ.

Resources provided the students specifically to facilitate the dDesign experience were limited. Primarily, the students were expected to use email, internet user groups, Skype, and other communication tools as needed.

The one dDesign focused resource provided to the students was a modern video-conference system with a large screen and reliable network connection. The video-conference systems at both TAMUCS and TAMUQ locations are used by multiple students and faculty. Thus, students would need to schedule with other users.

Both TAMUCS and TAMUQ students had a local lecture and studio instructor. The TAMUQ design lecture instructor has multiple year of experience teaching at TAMUCS. The corresponding author of this article served as the TAMUCS side studio instructor. The TAMUQ side studio instructor is a recent Ph. D. graduate of TAMUCS. Prior to joining TAMUQ and after finishing his Ph. D. he served for one semester as a design studio instructor at TAMUCS.

Student Activity

General observations of student activity are discussed here including some specific detail on the activity of concept generation. In this initial effort at teaching a capstone engineering design class with distributed teams, no formal measures of communication were used to measure student interactivity.

Once given the initial project statements and team assignments, students quickly adapted to the distributed nature of the team. No significant effort was needed on the part of the instructors to ensure interaction between the TAMUCS and TAMUQ students.

After one initial video-conference (with studio instructors present), the FMC team adapted email and Skype based communication. Real-time interactive communication was minimal. As project queries were passed to the sponsor and replies received, information was shared among the team members and the design project progressed.

After an initial video-conference (with studio instructors present), the Shafallah team included a once weekly video-conference in addition to email and Skype based communication.

Both the email and Skype only and the video-conference enhanced communication structures appeared to work equivalently. A casual comparison of the distributed teams communication efforts to the authors previous experience with local teams shows no significant difference. The various failures of modern internet communication such as email boxes being full and document formats being damaged as documents move from computer to computer remain. These failures were not compounded by being globally distributed.

Many of the methods and concepts taught in the capstone design course lecture are team oriented. In many cases, the methods are based on dynamic real-time team interaction. For example, Osborn's formal brainstorming method requires synchronous verbal

communication⁶. The nine-hour time difference between College Station and Doha, Qatar prevent adhering strictly to Osborn's brainstorming method. However, we were able to explore how dynamic, but not verbally-based, concept generation methods would translate to the dDesign format. An example of such a methods is the modified 6-3-5, or C-sketch, method⁷.

In the modified 6-3-5 method, six people each sketch and annotate three ideas. After five minutes, ideas are passed around the table and new ideas are added by the next person. Five total exchanges occur. 6-3-5 was developed for six participants, but can easily be adapted for a different number.

Because of the nine-hour time difference, the exercise could not be performed during a single sitting. Thus, an overnight incubation period is introduced between the 5 minute sketching and annotating efforts. Preliminary results indicate that the incubation created minimal difference in the outcome of the exercise. Student results and evaluations of the method are consistent with those from a traditional, collocated experience.

At the end of the first semester, students from TAMUQ working on the FMC project came to the US to finalize the project and deliver final presentations to the sponsor. The final presentation, on site at FMC in Houston, Texas, received positive feedback both in terms of the technical content of the report and the students success at managing the dDesign project.

Prior to the start of the second semester on the project, TAMUCS students on the FMC and Shafallah project visited Doha, Qatar. The Doha visit allowed teammates to refine the project and visit with the project sponsors at the Shafallah Center in Doha.

Initial Doha visit response from the TAMUCS students is that that the interactive visit with the project sponsor was very beneficial. The opportunity to visit Doha was culturally rewarding and visiting with teammates was positive.

Current Status and Lessons learned

Perhaps surprisingly, the dDesign experience was only minimally different from a traditional collocated capstone experience. Students are assigned their project. The students attend lecture, learn the basic process and methods of engineering design, and apply them to their project. The students work with a faculty member in the studio session. As the students work with team members, they find common times to schedule meetings. Problems are solved. Progress is made. Reports are written.

This particular dDesign experience had several structural advantages. The class contained a diverse set of students with appropriate backgrounds and faculty with some common teaching experience. Potential

problems from working without personal contact were not noticed. Also, there were no significant problems resulting from different primary languages or cultural barriers.

The most significant problem the teams and instructors faced was the time differences. There were three time differences of importance. One was the daily time shift of nine hours. To video-conference, the Shafallah team had to meet at 9:00 AM Texas time and 6:00 PM Doha time. The different work-weeks pose another time difference challenge. The typical Doha work-week is Sunday through Thursday. Combined with the nine-hour time shift, this left Monday, Tuesday, and Wednesday in which emails were consistently returned promptly. An email requiring the recipient to do several hours or more of work before responding sent after 10:00 AM on Thursday in College Station typically received a reply on the following Sunday (Texas time). The last time difference of importance is some differences in semester scheduling. The TAMUQ semester starts two weeks prior to the TAMUCS semester. Additionally, semester breaks for Thanksgiving and Ramadan occur at different times further limiting common time on the project. The different start times created some challenges for scheduling midterm and final project dates.

Overall, the time differences were mostly a negative. But, there was some student response that the around-the-clock project progress was a good thing. Being able to email an assignment to a teammate, go to bed, wake up, and have it completed with a new assignment in return, gave the project a steady rhythm of progress and helped motivate students to continue working on the project throughout the week.

The biggest challenge of the effort seemed to be coordinating instructors. Challenges include coordinating instructor meetings based on time differences as well as coordinating instructor philosophy and expectations. The philosophy coordination challenge is not inherent in physical distribution, but remains a challenge for collaborative design or teaching. Developing common teaching philosophy and expectations is often a challenge when faculty collaborate on a course.

Compared to collocated capstone design, the dDesign experience saw a decrease in students consistently completing internal assignments on time for each other. Without face-to-face meetings, students were able avoid each other a bit more successfully.

Conclusions and Future Work

Texas A&M is developing a global capstone design class in Mechanical Engineering. The dDesign effort is leveraging common curriculums between the TAMUCS and TAMUQ campuses. Two projects were pursued,

one with a project sponsor in Houston, TX and one with a project sponsor in Doha, Qatar.

Overall, the dDesign experience was well received by the participants and sponsors. Students appreciate the opportunity to experience the challenge of managing a global project, interacting with other students and sponsors on the other side of the globe, and getting an edge up on the competition when it comes to being prepared for the global workforce.

Better instructor coordination will improve future development of the dDesign experience. The creation of formal design report grading rubrics is suggested to improve instructor coordination. Such rubrics can provide a vehicle for detailed discussion about expectations for student performance and project deliverables.

The dDesign Mechanical Engineering Capstone Course is still under development at Texas A&M. Current efforts are primarily exploratory. As the course establishes itself and clear procedures for its execution are developed, broader questions can be explored. For example, what are the differences in the learning outcomes between students taking the distributed and collocated design courses? In general, the future goal is a broader understanding of how a dDesign education can better prepare students to practice dDesign.

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