Survey Comparison of National and International Capstone at Clemson University

Samantha Thoe[1] and Joshua Summers[1]
[1]*Clemson University*

Capstone design within the Mechanical Engineering department at Clemson University focuses on industry sponsored, semester long design projects for students in their final semester. Each project is assigned to three to five teams of four to five students per team. The course requires the students to fully define the engineering problem, develop a solution, and produce a prototype by the semesters' end. This course is also now being offered to students as a study abroad program in Queretaro, Mexico jointly with several Mexican universities and West Virginia University. The students work at the company site to complete a design project during a six-week semester. To determine the effect of the study abroad on students, each group of students takes a survey at the beginning and end of the course. The preliminary results of the pre-course survey indicate that students choosing the study abroad program have a different outlook on the course expectations. These results are discussed.

Corresponding Author: Samantha Thoe, sthoe@clemson.edu

Current Capstone Literature

Current research spans a wide variety of topics, from performance and assessment to development of a quality capstone program, such as:

- *Assessment Framework for Capstone Design Courses*[1]
- *From Capstone to Cornerstone*[2]
- *The CDIO Capstone Course*[3]
- *Capstone or Deadweight? Inefficiency, duplication and inequity.*[4]

Published in 1995, *A Survey of Capstone Engineering courses in North America* described a capstone course as an opportunity to provide senior-standing engineering students with experience solving "real world", open-ended engineering problems[5]. This provides a vague portrayal of the purpose of capstone but does not truly define what a capstone program is. A capstone course can be defined as 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[6], or an experiential learning activity in which analytical knowledge gained from previous courses is joined with the practice of engineering in a final, hands-on project[7] which attempts to integrate, extend, critique and apply the knowledge gained in the major[8]. The survey results were used to discuss the varied organization of capstone programs and the faculty participation therein[5]. A 2005 survey attempted to update the information generated from the original 1995 survey with limited modifications[9] [9]. Their survey focused on the organization of programs and the potential changes from the earlier survey results.

Other aspects of capstone design research outline the benefits of such programs to meet specific needs and requirements such as those set forth by ABET (also known as the Accreditation Board for Engineering and Technology). Departmental motivation for implementation of a capstone design experience comes from the opportunity for students to creatively solve an open-ended, real world design problem while working with other engineers, scientists and non-technical professionals in small design teams and develop client relations and enhancement of overall oral and written communication skills. Further motivation for capstone courses evolve from teaching students to appreciate and consider non-technical constraints in design such as ethical, political, aesthetic, environmental, economic and cultural influences[10]. Although the literature defines capstone and the motivation for its use, it fails to fully define what motivates students to participate in such programs aside from the fulfillment of their degree requirements. Knowing student motivations will allow program directors to modify the program to entice students to enroll in the course and create an educational and enjoyable experience.

Capstone at Clemson University

ME 402 is a 3-credit course in the mechanical engineering department at Clemson University. This capstone course is a one semester course offered in Fall and Spring semesters (approximately 15 weeks) as well as the second summer session (approximately 6 weeks). Organized by the faculty, industry sponsored projects are solicited for student design teams. Within this section, the course organization, team formation, course deliverables and assessment of students will be discussed.

Capstone in Clemson

Commonly, three student teams are assigned to work in parallel on each project. The teams work independently of each other and consist of 4-5 students. Each of the projects solicited are summarized and distributed to students prior to the first day of the course. Students are asked to submit a resume form which asks for information about their areas of interest and experience in co-ops and internships as well as personal fabrication experience. The form also requires the student indicate two positives and one negative choice of project or person. The teams are formed so that each student receives at least one positive from their submitted form. Expertise and experience are balanced across teams to form equilibrium amongst teams.

Each project is assigned an advisory committee comprised of two faculty advisors and other non-faculty members. A graduate coach is also assigned to each team to assist the team in accomplishing goals. The graduate coach does not directly participate in the design process but is involved only when necessary. Purposeful involvement of the graduate coach includes obtaining departmental or other resources, resolution of team issues, management of dysfunctional teams, motivate teams, and encourage positive group dynamics[11].

Weekly design reviews are conducted with the advisory committee to discuss the team progress on the project. Prior to the midterm review, feedback is provided on the problem statement development, requirements and their elicitation, preliminary concepts, and the systematic selection of 2-3 concepts for development. After completion of the midterm review, the weekly reviews are used to provide feedback on the embodiment and detail design phases of the project which includes prototypes.

Deliverables for the course include a final design solution which often includes a prototype, a final oral presentation for the industry sponsors and a final design report detailing the solution. The oral presentation and weekly reviews occur on the Clemson University campus.

Assessment of the team and individual are performed based on the final product, presentation, people, and project aspects[12].

Clemson Capstone in Queretaro, Mexico

As well as a 3-credit hour capstone course, students that elect to take the course during the second summer session participate in a study abroad program in Queretaro, Mexico. The course is offered to Clemson students, West Virginia University students, and multiple Mexican college students majoring in mechanical or mechatronic engineering. Students are asked to submit a resume to determine areas of interest, co-op or industry experience, and fabrication experience.

Each of the industry sponsored projects is assigned one team which consists of 2-6 students based on the project intensity. The student teams are balanced based on experience and expertise. The students are assigned to industry projects without the use of the two positive one negative form used for the course at Clemson University. Teams contain at least one Clemson student, one West Virginia student and may also contain students from one or more Mexican universities participating in the program.

Unlike the course offered at Clemson, the students participating in the Mexican summer course perform their capstone design project at the industrial company their project pertains to. Each team is visited by their advisory committee once per week. The advisory committee is composed of two professors to provide feedback on the project progress.

A weekly design review is held to provide feedback on the design progress. The design review requires each team to present in the language not from their home country. Feedback and questions are asked and answered in the students' first language. The design review is attended by the advisory committee, other student teams and professors from the Mexican Universities. The first half of the program is spent on problem definition, requirements elicitation and preliminary concept development. The second half of the course is dedicated to the embodiment and detail design phases similar to the in Clemson course.

Final deliverables for the capstone course in Mexico are similar to those in the Clemson program. A final report and presentation are required. The presentation is given in two languages. Each student must present in their non-native language just like the weekly design review presentations. The final project report must be submitted in both English and Spanish. Dependent upon the project, a prototype may also be required.

Assessment for the student participants varies based on their host university. The Queretaro Clemson students are evaluated on the same rating system as the students in the Clemson course.

Survey Development

In order to learn about ME 402 students from Clemson University two surveys were developed by a doctoral student in Mechanical Engineering to examine the differences in the personal expectations of the in US and international course students. Each survey contained the same introductory questions asking for information such as their major, minor, expected graduation date and their name. The questions following were used to determine personal experience, professional or educational plans and student expectations of personal gains for the course.

At the beginning of the Summer and Fall semesters the survey was distributed to the students on the first day of the course. The students completed the survey and submitted it the same day. Two versions of the survey were administered. Some of the answer choices for the expectations question were omitted from the Capstone in Clemson survey due to lack of relevance to the course. A comparison of the expectation, relevance and personal importance answer choices on each survey can be seen in Table 1.

Table 1: Capstone Survey Question Comparison

Questions	Capstone in Clemson	Capstone in Queretaro
Goals for Program Participation:		
Greater understanding of different cultures	☐	☑
Enhance resume, increase job opportunities	☑	☑
Greater autonomy in independent decision-making	☑	☑
Increase ability to communicate	☐	☑
Intellectual stimulation and development in engineering	☑	☑
Growth in interpersonal skills and ability to adapt	☑	☑
Growth in maturity and self-confidence	☑	☑
Growth in self-awareness	☑	☑
Gain a different perspective on your ethnic heritage	☑	☑
Greater understanding of the US in world affairs and history	☑	☑
Gain a different perspective on American culture	☐	☑
Travel and see new places	☐	☑
Other	☑	☑
Relevance to Participation:		
Apply engineering knowledge to real life problems	☑	☑
Related to area of study within engineering	☑	☑
Use knowledge to serve others	☑	☑
Personal Importance of this Ability:		
Exercise Leadership Skills	☑	☑
Function on a multidisciplinary or cross functional team	☑	☑
Resolve interpersonal conflict within a group	☑	☑
Carry out projects independently	☑	☑
Approach problems from a different perspective	☑	☑

Results were compiled, analyzed and the results from the expectation, relevance to participation and personal importance are the results examined in the next section.

Survey Results

The results shown in Figure 1 are for the answer choices that were available on both surveys. This is done to provide the comparison desired. Figure 1 shows consistency in expectations for the course among both in Clemson students and ME 402 students taking the course as a study abroad in Queretaro. The results indicate personal growth in interpersonal skills and maturity and resume enhancement are the two most popular motivations for taking ME 402.

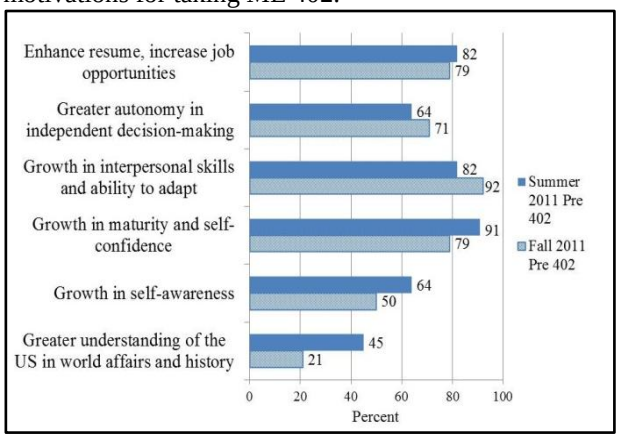

Figure 1: Student Expectations for ME402 Course

Figure 2 displays the response from students about the influential nature of this course on their future. A majority of the students indicate that the course will be influential to their future. It can be seen that no student attending the capstone course in Mexico, indicated as the "Summer Pre 402", finds the course insignificant to their future.

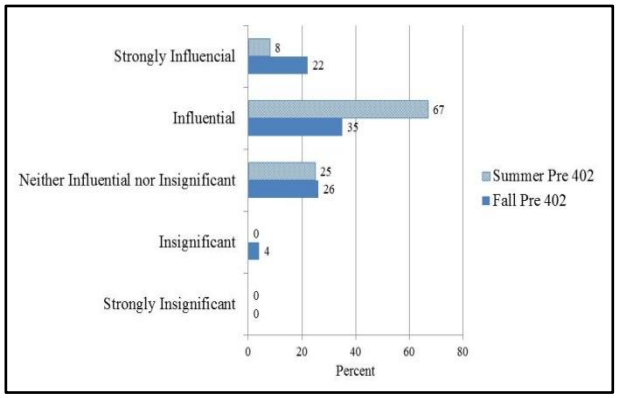

Figure 2: Influence to Student Future

Relevance to the decision to take the course for each session, Summer and Fall, was measured in asking three questions. The results are shown in Figure 3. From the chart it can be seen that students believe that applying their engineering knowledge was strongly relevant in the choice to participate in the course for both groups of students. Use of their knowledge to serve others was only classified as relevant to both groups of students for the majority. The same majority classification can be seen for the relevance of the course relating to their area of study. The table included in Figure 3 shows the numerical percentages for each bar.

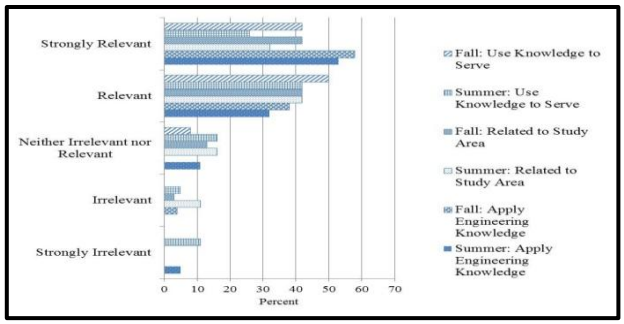

Figure 3: Relevance to decision to take course

Conclusion and Future Work

Students participating in both ME402 courses have similar motivations for taking the course. Different factors influence choices to take the course such as timing. This is not examined in the survey analysis. Students indicate that the course is influential to their future and are motivated to take it to apply their engineering knowledge in a real life setting.

To further this research, the survey will be edited to ensure compatibility between versions and a post course survey will be implemented. The final goal of the research is to determine if the study abroad course alters the students outlook on future goals and to ensure the students in the six-week study abroad program receive and equivalent experience to those in the 15-week program.

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