
AC 2012-3881: CAPSTONE DESIGN: INSIGHTS FROM AN INTERNATIONAL COLLABORATIVE STUDENT TEAM

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Capstone Design: Insights from an International Collaborative Student Team

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Abstract:

Since 2005 the Civil Engineering Department at Rose-Hulman Institute of Technology (RHIT) has had at least one international capstone design project each year. For each of those projects, the student team worked on a project for a client in another country. This year the international project was designed by an international collaborative student team. Three students from RHIT were paired with three students from Kwame Nkrumah University of Science and Technology (KNUST) in Ghana to design a project in Ghana. The academic grades for all six students were inextricably linked; therefore, the six were forced to work collaboratively in order to produce a successful design.

In order to complete the project, the team had to overcome several new challenges. Although all six students spoke English, their dialects and accents were very different. Adding to the communication challenges was the need to work remotely. The students were unable to meet face-to-face. In addition, only the KNUST students were able to visit the project site, so they had to relay critical information to the RHIT students.

The instructors also had to overcome challenges. The two schools were on different term schedules. The capstone design courses had different durations, learning objectives, and deliverables. Therefore, the instructors had to adapt their expectations and demands on the students in order to facilitate the collaboration within the team.

This paper provides unique insights and lessons learned from both the student and instructor perspective. It shows how well the student team achieved the educational outcomes, and summarizes the benefits the students gained beyond technical skills. The paper concludes with recommendations for programs that would like to develop an international collaborative student team experience.

Introduction:

Capstone design is long standing tradition in civil engineering and required by ABET for accreditation (ABET 2011). The importance of exposing students to cultures other than their own has been emphasized as important for engineers for some time (Friedman 2005). At Rose-Hulman Institute of Technology (RHIT), we have been combining the two experiences for at least one capstone design team each year since 2005. For the first six years, the students' interaction with other cultures was limited to communication with the client, the user of the facility they were designing. Of those six years, three of the projects were obtained through the Kwame Nkrumah University of Science and Technology (KNUST) in Ghana. The assigned

team from RHIT created a design solution for the same client that the design teams at KNUST were serving. This year, the two schools collaborated to allow students to experience the benefits and challenges of working on an international team made of students from both schools.

Overview of Capstone Design at RHIT:

RHIT is on a quarter system with 10 week terms. The academic year starts the first week of September. The capstone design course meets 3 hours per week in the fall and spring terms, and 6 hours per week in the winter term. The course objectives are as follows:

1. Analyze a client’s objectives and formulate an engineering problem statement.
2. Develop multiple solutions to an engineering problem and determine the merits and deficiencies of each solution.
3. Recommend the most appropriate solution based on client and engineer developed criteria.
4. Develop a design for the most appropriate solution(s) to meet a client’s objectives.
5. Explain and document the solution in oral and written formats.
6. Work effectively in an engineering team by utilizing individual strengths and communication.

Each team is made of 4 or 5 students and is assigned to a different project for an external client with a real need. On the first day of class students individually rank order the projects. The faculty then make team assignments based on student preference. The teams create three written reports and make three oral presentations to communicate their design (Table 1).

Table 1. Primary deliverables from capstone design teams at RHIT

Deliverable	Week Due	Key Content
Proposal	4	Description of problem, client's goals, and team's plan to achieve those goals.
Proposal Presentation	6	
Progress Report	13	Progress to date: typically preliminary feasibility study, geotechnical investigation, description of options for the most important design decision, and a rational evaluation of those options.
Progress Presentation	15	
Final Report	24	Details of the design, drawings, and a cost estimate.
Final Presentation	26-28	

Overview of Capstone Design at KNUST:

KNUST is on a semester system with 16 week terms. The academic year starts the fourth week of August, two weeks before RHIT. Capstone is only offered during the fall term. The course meets 2 hours per week. The main objective of the course is to introduce the students to the various stages of a design project:

1. Planning/Conceptual Phase – Perform desk studies, perform field studies, collect and analyze data, determine relevant design standards and specifications, and analyze design options.
2. Engineering Phase – Design best option, document the design, develop construction specifications and drawings, prepare cost estimates, and perform economic analysis.

Each design team is made of 6 students who work to develop a design solution for a neighboring community. All of the design teams work on the same project but have the autonomy to develop unique solutions. Before the course begins, the faculty divide students into teams based on their past academic performance. The teams produce two written reports and have an oral defense of their design (Table 2).

Table 2. Primary deliverables from capstone design teams at KNUST

Deliverable	Week Due	Key Content
Inception Report	4	Description of problem, client's goals, and team's plan to achieve those goals.
Progress Report	8	Progress to date
Final Report Oral Defense	12 Finals	Details of the design, drawings, and a cost estimate.

Description of Project and Team:

The project was to develop a modern market complex for the impoverished community of Mamponteng about 8 miles north-east of Kumasi in Ghana (Figure 1). Currently, residents congregate along a main thoroughfare to sell their wares road-side (Figure 2). The client was the Kwabre East District Assembly in the Ashanti Region which received a grant from the Ministry of Food and Agriculture to develop a market complex. The complex is to have lockable shops, banking facilities, washrooms and sanitary facilities, and a warehouse.



Figure 1. Map of Ghana in western Africa. The project location is slightly north-east of Kumasi (Athaia 2012).



Figure 2. Current road-side market along the main road through Mampong.

The project scope required each team at KNUST, including the international collaboration team, to develop detailed designs for the following facilities:

- Road system and parking areas.
- Foundation systems for the warehouse and water storage tank.
- Structural system for the warehouse and water storage tank.
- Water distribution system for entire complex and water storage tank.
- Stormwater management system for entire complex.
- Wastewater treatment system and solid waste management plan.

The international collaboration team consisted of three students from KNUST and three from RHIT. Common practice among teams at KNUST is for each of the six team members to focus on one of these six areas of design responsibilities. The international collaboration team followed the same practice. The KNUST team members were in charge of the road, foundation, and stormwater systems. The RHIT team members were in charge of the structural, water distribution, and wastewater systems.

The instructors from both schools had three additional goals for the international collaboration team:

1. Students would overcome the challenges associated with having team members working in different locations unable to meet face-to-face.
2. Students would improve their ability to work with engineers from other cultures.
3. Students would learn how engineering design and construction differ between cultures.

Outcomes:

The team successfully completed the design project for the community of Mampong. Scores assigned by the KNUST faculty indicated that the international collaboration team produced a design solution of typically quality as the other KNUST teams. Scores assigned by the RHIT faculty showed that the international collaboration team's design was comparable to other teams at RHIT as well.

Overcoming Challenges Associated with Different Locations

The team encountered several challenges trying to work from two different locations separated by an ocean and a 5 hour time difference. For their weekly meetings, the team used web-based software to communicate real-time. Unreliable internet service caused delays of up to 20 minutes during some meetings, but with patience the team was able to conduct its business. Between meetings, team members communicated with each other as needed via email.

None of the students indicated that the physical separation of team members impeded the collaboration. They did note, however, that the inability of the RHIT students to visit the project site put an extra burden on the KNUST students and impeded the RHIT students from fully appreciating the site characteristics. One team member also noted that lags in communication as deadlines approached led to "some anxious moments." That issue is not unique to teams physically separated though. The faculty at RHIT have seen this problem arise with other teams as well.

To share data and report content, the team used an online file sharing service. The team did not encounter technical problems with the service, but it required the team members to develop a habit of keeping the most up-to-date versions of files on the service at all times. Occasionally a team member used out-of-date information because another team member had not uploaded the new version in a timely manner.

Five of the six teammates responded to a questionnaire about their experiences on the project. One of the questions explored how well they felt they overcame the challenges of working in two locations. Those teammates unanimously agreed that they achieved this goal (Table 3).

Table 3. Student self-assessment of whether they overcame challenges associated with being at different locations.

Statement	Strongly Agree (5)	Agree (4)	Neither Agree/Disagree (3)	Disagree (2)	Strongly Disagree (1)	Average
We overcame challenges associated with having team members working in different locations unable to meet face-to-face.		5				4.0

Improving Ability to Work with Engineers from Other Cultures

The students from both countries learned to adapt in order to work effectively with engineering students from another culture. One student found the biggest cultural challenge to be the difference in how engineering design is communicated in the two cultures. The team overcame that challenge by sharing example reports from previous years. In the end, four of the six team members cited the collaboration between all the members of the team as the best part of working on this project: “The commitment of all the team members and the way we found solutions to all the difficulties we faced during the project is something unique to our group.”

English is the primary language at both schools. However, the team members did encounter some difficulties communicating verbally. At times the students from RHIT struggled to understand team members from KNUST because of their accent. And at times the students from KNUST struggled to understand team members from RHIT because they spoke very quickly compared to what is typical in Ghana. The team overcame both issues by slowing down and asking members to repeat what they were saying as needed.

In the questionnaire, the five respondents strongly agreed that this experience improved their own abilities to work with engineers from other cultures (Table 4).

Table 4. Student self-assessment of whether they improved their ability to work with engineers from other cultures.

Statement	Strongly Agree (5)	Agree (4)	Neither Agree/Disagree (3)	Disagree (2)	Strongly Disagree (1)	Average
This experience improved my ability to work with engineers from other cultures.	3	2				4.6

Learning How Engineering Design and Construction Differ Between Cultures

The students discovered and came to appreciate that engineering design and construction is not done the same way in all cultures (Table 5). All three team members from RHIT indicated that the most frustrating part of the project was trying to get information needed to perform the design: site data, preferred construction methods, and social norms that might impact design choices. One student pointed out “It was important for us to try and understand how the local residents would use our design solutions and then pick the solutions that would be most sustainable for them. In many cases, the design solutions varied greatly from the solutions we would have chosen if we were designing this in America.” Another indicated “There are several different codes and regulations that Civil Engineers are expected to follow, but in some cases, it is important to understand how your design will be used and consider any design solutions that may deviate from the code.”

Table 5. Student self-assessment of understanding of the differences in design and construction between cultures.

Statement	Strongly Agree (5)	Agree (4)	Neither Agree/Disagree (3)	Disagree (2)	Strongly Disagree (1)	Average
This experience taught me how engineering design and construction differ between cultures.	1	4				4.2

The frustration was felt by the other team members as well. Two of the team members from KNUST indicated that their biggest frustration was trying to track down information requested by the team members from RHIT. That information is not typically used in engineering design in their culture.

Ultimately the panel of faculty and practitioners at the oral defense declared that the team created an adequate design solution that was appropriate to the region. Therefore, the team successfully worked through their frustrations.

Challenges:

The team made an important recommendation. To create the most appropriate solution, the designers need to understand the users. That is best achieved by meeting with them and observing them. Although the KNUST team members were able to have those interactions, the members from RHIT were not. Relaying information about the people who will use the design is not as effective as meeting with the people directly. Therefore, team members from both schools recommended that the students from RHIT visit Ghana at the beginning of the project.

The biggest challenges for the faculty were procedural. The team members were each registered for the capstone design course in their home school along with other teams of students who did not have international members. Therefore, the faculty had to determine which course’s expectations and procedures to use. We chose to use predominately the expectations and procedures from KNUST because that capstone design course had the shortest duration. Until the faculty at RHIT become more familiar with those expectations and procedures, the students from RHIT will continue to feel burdened to appease two masters.

The faculty at KNUST indicated that although there was only one international collaboration team, the members of other teams also learned a lot about the experience. Unfortunately, the other teams at RHIT did not experience much benefit. The faculty at RHIT intend to expand the impact by having the members of the international collaboration team make a presentation about the cultural interactions, challenges, and benefits.

Conclusions:

This first experience with an international collaborative team for capstone design had sufficient success that the schools intend to offer the program again next year. Despite the many challenges that the team members faced, all of the team members indicated that they would consider working on the same team again given the opportunity. In fact, four of the team members indicated that they would “definitely request this team again”. The students all felt that they successfully achieved the three goals of the collaboration, and the instructors concur. However, making the changes identified in the Challenges section would make the experience even more beneficial.

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