Geographically Distributed Teams in Engineering Design: Best Practices and Issues in Cases of International Teams Working from Different Continents

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Geographically Distributed Teams in Engineering Design: Best Practices and Issues in Cases of International Teams Working from Opposite Hemispheres

Abstract

It is not rare to have engineering design teams in companies, working from different parts of the world on a shared project. This new addition to the working context has been triggered by advances in communication technologies and the knowledge economy. This begs the question, are today’s engineering students prepared to enter the workforce in this new international teaming environment? Most of the research that reports on geographically distributed teams or virtual teams is performed under industrial contexts. Thus, research is limited with regards to collaborative or distributed teams in educational environments (Dym et al. 2015). This is what motivates our study.

This paper investigates the challenges and benefits of partnering students located in different continents under a problem-based, innovation driven, engineering-design course. For this, we build on previous experiences of teaming up students from Chile and the United States, as well as students from Finland and Mexico. In this second endeavor, we grouped seven students from Finland and Chile to fulfill a semester long course. The students met physically during two specific periods of the semester and then worked remotely throughout the span of the project. Students followed the same curriculum and deliverables. Qualitative data analysis was performed on semi-structured interviews (taken at different points of the semester), blogs and other forms of self-reported data. The outcomes are presented as a case study.

The contributions of this paper are threefold. First, and aligned with the interest of accreditation institutions such as ABET, it provides insight on how to instill the ability to work within global teams to ensure that graduates will have the skills to enter the profession successfully. Secondly, we identify strategies to orchestrate the work of cross-cultural teams. These can be taken by any educator and can be translated to its own engineering teaching practice. Finally, we examine the potential pitfalls in cross-cultural teams. We assert that, as in the field of medicine, it is critical to discuss the issues and complications so that the intervention can contribute to the educational experience. Future work may involve the study of more cases with engagement of the community at ASEE.

Introduction

While the global trend toward increased inter-university co-operation continues apace, these oft-international collaborations have been branching out from the largely research-based into new pedagogical endeavors. Engineering design education has, in recent decades, been taking a leading role in experimenting in these collaborative projects. The impetus for this has been both economic and strategic. Of the former, these collaborations far afield offer opportunities to share resources, attract international students, and apply for funding from international organizations. With regards to the strategic aspect, these also address a key performance indicator for many universities – student satisfaction. Recent research on Finnish engineering students (TEK 2014, 2015) has identified that many graduates wish for universities to place greater emphasis on developing those working life skills, such as teamwork and intercultural communication skills, that prepare them for careers in an international work context. The ABET Accreditation Criteria (2017) shares this same concern for preparing students in US universities for future working life in a global context.

Today, geographically distributed or virtual teams are quite relevant in business environments. According to a survey of 379 human resource professionals, 66% of multinational companies utilize virtual teams, with the aim of improving productivity, boosting collaboration among global talent,
minimizing travel costs and accommodating for global work projects (SHRM 2012). Virtual teams tend to succeed when they possess a high degree of trust, clear communication, effective leadership, and suitable technology; conversely, they need to overcome multiple time zones, language barriers, and different approaches to conflict resolution (Bergiel, Bergiel & Balsmeier 2008).

Since the 1990s, project-based learning has become a mainstay of student-centered engineering education (Knight, Carlson, and Sullivan 2007) wherein teams of students are tasked with providing solutions to an engineering challenge, often in the form of a client brief. For universities collaborating across vast distances, this can translate into teams with participants that are divided by space, time, specialization, culture, and language. While this has the advantage of emulating the authentic practice of geographically distributed teams within multinational companies, it also poses several challenges related to communication, culture, and content.

The ability to collaborate in different media in real-time has been dependent on advances in communication technologies and the knowledge economy. As such, collaboration is no longer strictly tied to face-to-face interactions but can be conducted virtually through a myriad of social media and communication technologies. However, while considerable research has been conducted on international teams in business, the research remains somewhat scant with regards to collaborative or distributed teams in educational environments (Dym et al. 2015).

Correspondingly, this paper aims to partly address this shortcoming by descriptively exposing cases of team project collaborations between engineering students from universities located in four different countries -- Chile, Finland, Mexico, and the United States.

**Research Questions**

This article portrays a series of cases where teams of students distributed across three continents (North America, South America, and Europe) were exposed to common engineering design challenges. By contrasting the different situations, we expect to answer the following questions:

- Which are the best practices when working with geographically distributed teams of students in engineering design?
- Which are the common pitfalls to avoid when students are paired in virtual or geographically distributed teams?

**Methodology**

Qualitative data was collected in different cases regarding geographically distributed teams in universities located in different hemispheres. It compiles information from 2014 through 2016. Different modalities of exchange were explored. Nonetheless, patterns of best practices and pitfalls were clearly present. Data was collected with the consent of students and other participants, such as instructors and teaching assistants. Self reported data on blogs and timesheets obeyed similar parameters in the cases involving the Chilean university. So data was comparable throughout the cases. On the other hand, data coming from interviews (done by a team of external researchers) involved open ended questions that lead to construct the participants’ point of view on the benefits and issues coming up by working with international teams. On the earlier cases, data was reduced using in-vivo coding. The insights coming from that coding served as a basis to work on the latter cases. This is work in progress. We continue analyzing data of some of the cases in order to yield more precise information that can be published. However, we believe that some early insights can be useful for the purposes and objectives of this conference.

*Case 1: Students from UC (Chile) and Notre Dame University (United States)*
Funded by a Chilean (CORFO Engineering 2030) and American (Notre Dame) grant in 2014 to promote the relationship between UC Chile and Notre Dame University, the two universities launched a year-long project that aimed to understand how students worked in International Teams. In the first semester, third and fourth year engineering students collaborated in co-located teams (i.e. with students from their own class in their own geographical zone) on the same engineering-design open-ended challenge. On the second stage (semester), two teams of four students each (two American students, two Chileans) met in South Bend, Indiana for a week to undertake a common workshop. Then, they continued to work remotely during the following three months and met again in Santiago, Chile for a week. During that period, they prototyped the solutions they had designed during the remote time. To facilitate the process, professors from each university accompanied the teams during the travel. It is important to note that the endeavor was framed within a studio-based course (in the case of Chile) and the engineering design capstone course (in the case of Notre Dame). For the recruitment of the students, all participants were expected to have a very good command of spoken and written English.

Case 2: Students from UC (Chile) and Aalto University (Finland)
With funding from a Chilean grant (CORFO Engineering 2030) and Aalto Design Factory to encourage international relationships, the two universities launched a one-semester project in 2016 that built on Case 1. This collaboration brought together two studio research-based courses in engineering-design with two teams comprised of three students (two Chilean and one Finnish) and four students (two Chilean and two Finnish). To launch the process, Chilean students travelled to Helsinki to undergo a one-week workshop with the Finnish students. Students then worked remotely during the following three months in a common engineering-design open-ended challenge. After that, the Finnish students travelled with their professor to Santiago, Chile to prototype their solutions. The Aalto students included a Spanish-speaking Mexican student and an Iranian with Finnish nationality. For the recruitment of the students, all participants were expected to have a very good command of spoken and written English.

Case 3: Students from UC (Chile) and University of Dayton (United States)
In the same year within the same studio-based course in engineering design, four students from the University of Dayton (Ohio) and three students from UC in Santiago, Chile. As there was no travel budget for the Chilean students, the geographically distributed team had to work remotely for the whole semester. In this case, the engineering-design open-ended challenge was tied to a local community in the south of Chile that would profit socially from the yielded solution. For the recruitment of the students, all participants were expected to have a very good command of spoken and written English. Since the Dayton students had to travel to the south of Chile, most of them had a basic notion of Spanish. After the semester ended, the Dayton students (mostly civil engineers) travelled with their professor to Santiago, Chile and to the south of Chile subsequently. The travelling was financed by UD through their ETHOS program. Instructors from both universities had met before in Santiago, Chile during a UD reconnaissance trip.

Case 4: Students from Aalto University (Finland) and Tec de Monterrey (Mexico)
In 2015, 15 students from Tec de Monterrey (Mexico) travelled to Helsinki for a joint summer school where they collaborated with 15 Aalto students on two project-based courses: “Challenge Breakers” provided by an Aalto teacher and “Creativity and Innovation” provided by a Tec de Monterrey teacher. The teams consisted of four to six students with a mixture of students from both institutions. Each course had been previously held in each institution with only minor changes regarding practicalities in order to expose the students to two different ways of teaching and also providing the teachers with an opportunity to share their teaching practices. The entire six-week program took place in the Aalto University Design Factory, and the target was to provide the international cross-cultural
experience to both students and teachers. For the recruitment of the students, all participants were expected to have a very good command of spoken and written English. In Fig 1 the students of the Challenge Breakers course at the kickoff session.

![Fig 1 Students attending Challenge Breakers 2015](image)

**Results and Discussion**

After analyzing the process and outcomes of these four cases where students from two universities located in two different continents teamed up in order to attain a common open-ended engineering design challenge, it is possible to discern some patterns. Since ABET has changed to an outcomes-based approach known as Engineering Criteria (EC), education in engineering has been transformed beyond the importance of science and mathematics fundamentals. Communication skills and other types of teamwork-related outcomes have become a natural focus for this new means of assessing engineering education. Here are some of the initial patterns found in these four cases that should be addressed within this context:

**Benefits of International Collaborations in Teams of Students**

**ACQUIRING NEW SKILL SETS:**
Those skills and behaviors promoted by the ABET EC revision from 2005 are encouraged through this international experience. Although participation in an international team effort is more complex than sticking to a group of individuals from the same cultural background, the experience complements the general technical content that the students have to go through. In interviews conducted following the international collaboration, students acknowledge the difficulties of the experience. Nonetheless, they also concede how this experience “opens them up” to a new standard
FOREIGN LANGUAGE DEVELOPMENT:
Communication is a key competency when considering the effectiveness of teams (Sheridan, Evans and Reeve 2012). In the case of international teams, it is quite common to group participants together with different first languages. By default, this often necessitates the need for a lingua franca with which all team members have sufficient understanding. Mirroring the international business context, English was chosen as the lingua franca in all four cases. Students in Chile, Finland, and Mexico were subsequently accepted into each project based on their command of spoken and written English. The students in the United States were native English speakers. However, it should be noted that while this provided for a common understanding, it does pose a challenge for the non-native speakers (NNS) of English. As the NNSs are unable to express themselves as articulately as they might in their native language, this can manifest a separate sense of self within the second language (Dörnyei 2005). This can provide motivation for the students to improve their language skills during the course but can also act as a source of frustration. Generally, it was clear that language support, such as integrated language teaching, could enhance the development of individual and team communication skills.

Spanish was also utilized at times in cases 2, 3, and 4. In case 3, this was quite limited as the US students had only a basic understanding. In case 4, the Aalto teacher occasionally spoke Spanish with the Mexican students in order to clarify instructions for an activity or answer a complex question. Alternating between languages, or code-switching, is quite common when two speakers share multiple languages. While it has the downside of temporarily excluding non-speakers, it can speed up the overall collaboration process and ensure full participation in an activity. In case 2, there were some challenges with code-switching. One team had three native Spanish speakers, albeit with two dialects, and one Finnish speaker with a basic understanding of Spanish. Although the occasional use of Spanish provided for increased collaboration, it meant that the Finn was at times excluded from some communication, creating some tension within the group. Moreover, it was noted that not all of the study materials were available in English which added to the Chilean student workload to translate for the non-Spanish speakers.

CULTURAL DIFFERENCES:
According to the 2017-2018 ABET Accreditation Criteria, students are expected, among other learning outcomes, to have undertaken a “broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context” (ABET 2017). Given this need for universities in the US and elsewhere to prepare engineering design students for careers in international contexts, it is imperative to offer opportunities for students to experience authentic collaborative work scenarios across cultures.

Students participating in these international experiences are likely to benefit by learning to identify cultural differences earlier and adapt to them faster in future international engagements. In each of these four cases, students were expected to work alongside team members from a different culture. Although the students shared the demands of fulfilling the course task, this alone cannot function as the sole means for establishing trust, open communication, and shared goal setting. For
this, there needs to be some degree of socializing and team building outside of the regular classroom sessions which was encouraged in each of the four cases.

Challenges and Issues

CHOOSING THE RIGHT CANDIDATES (shortage of available students):
In the cases 1 and 3, the projects received applications from students that were highly motivated and typically exhibited high grade point averages. The commitment of the students was demonstrably high in their application and throughout the whole course experience. The ND students were required to attend class a week before the start of regular classes. In their applications, which involved an essay, both ND and UC students exhibited interest in working in other similar initiatives outside the engineering curriculum. These involved Christian missions, social and scout camps among others. Students in case 3 expressed in their essays that they enrolled in the course with the knowledge that developing a solution would benefit an entire community. This motivated them in their work, and they regularly met their teammates knowing that this was crucial for the success of the project. In the case of the UC students working with the Finnish teams on case 2, there was a shortage of available students. Although flights and other travel expenses were covered for both visits, the applications were limited due to students lacking confidence in their English language proficiency coupled with the prospect of missing a week of classes due to the long trip. In a competitive school like UC, this became a challenge. The Chilean students that applied were not as committed nor as disciplined as in previous projects. The Finnish students, on the other hand, experienced similar scheduling conflicts as in case 1 in that they needed to start their semester a week before the official commencement of studies. This presented problems for those with summer employment, a very common practice among Finnish students.

TIP: Recruiting the right students and offering possibilities for more individuals to apply is very relevant (e.g. English language support and permission from other professors for students to miss classes). It was observed that providing a whole summer program including a full academic load and teachers from both institutions attracted a large number of high quality students even when financial support was not available as was experienced in case 4.

CHOOSING THE RIGHT TEACHING STAFF:
It was also a challenge to include teaching staff when the program ran in regular teaching periods, as it could create scheduling conflicts for teachers with prior commitments. In case 2, it was quite challenging to find a suitable time to travel to Santiago. Cases 1 and 4 also ran in regular teaching periods and did not experience such difficulties, but case four, which ran in the summer, had to cut short the visiting teacher’s trip. This matter did not affect the contents of any of the courses for the students, but it greatly limited the teacher’s time to exchange best practices by being present throughout the entire program.

TEACHING SCHEDULES CAN DIFFER SIGNIFICANTLY:
Differences in teaching schedules vary from country to country but are more noticeable, and harder to adapt to, when working across hemispheres due to the inversion of seasons, and summer holidays occurring at different times. Cases 1, 2, and 3 were between universities in opposite hemispheres; hence, the academic semester in the second part of the year was chosen as it is less affected by this
phenomena. Nonetheless, it still had some effect as, for example in case 2, the autumn period starts in September in Finland, and the spring semester in Chile starts in July. This difference was also present between the northern hemisphere universities of Mexico and Finland. In this case, the summer period in Finland begins in June and ends in August while in Mexico, it is from June to July.

TIP. If planning a program between universities in different hemispheres it is likely that the autumn in the northern hemisphere and the spring in the southern hemisphere will be the closest match.

TIME ZONES:
Working in different time zones poses another concern that is becoming more and more common nowadays. However, with advances in technology and telecommunications, it is more of an organizational challenge than a technical one. It could be clearly observed in case 2 that the typical team dynamics, such as task assignment, scheduling, and erroneous assumptions, were to some extent amplified. Teachers could see that the team was segmented between the students from each institution and sometimes the teachers would hear first of a problem than the team members abroad. This is not new to local team dynamics and in the same way it was overcome by the students successfully.

Conclusion

In order to prepare students for working life, engineering education has to adapt in order to prepare the next generation of engineers for the ever-changing working landscape. Globalization has brought with it a new set of challenges, and technology has evolved to enable engineers to collaborate in real-time in multiple modalities with their peers from around the world. As most research on geographically distributed teams has hitherto focused on industrial scenarios, this study sought new ways to prepare future engineers to face different languages, cultures and ways of working.

This paper investigated the challenges and benefits of partnering students located in different continents under problem-based, innovation-driven, engineering-design courses. Four cases were analyzed in order to identify patterns, the most difficult challenges faced, and also the tangible benefits of participating in these kinds of courses. Case 1 paired students from Chile and the United States; Case 2 students from Chile and Finland; Case 3 from Chile and the United States, and Case 4 from Finland and Mexico.

Three main contributions were presented in this paper showing the Benefits of International Collaborations in Teams of Students as well as its Challenges and Issues and it provides insight on how to instill the ability to work within global teams.

The identified Benefits of having the students work on international teams are:

1. ACQUIRING NEW SKILL SETS
2. FOREIGN LANGUAGE DEVELOPMENT
3. CULTURAL DIFFERENCES

And the most significant observed challenges:

1. CHOOSING THE RIGHT CANDIDATES
2. CHOOSING THE RIGHT TEACHING STAFF
3. TEACHING SCHEDULES CAN DIFFER SIGNIFICANTLY
4. TIME ZONES
We assert that, as in the field of medicine, it is critical to discuss the issues and complications so that the intervention can contribute to the educational experience. Future work may involve the study of more cases with engagement of the community at ASEE.

References