Design of an International Joint Course on Grand Challenges for Engineering

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An International Joint Course on Grand Challenges for Engineering

This paper presents an international joint course on the subject of National Academy of Engineering (NAE) Grand Challenges for Engineering (GCE), which is collaboratively developed by Arizona State University in the USA and University of New South Wales in Australia. In the fall semester of 2016, a total of 28 undergraduate engineering freshmen (15 ASU and 13 UNSW students) were carefully selected to participate in this joint course. Videoconferencing technology was employed to support the synchronized lectures on a weekly basis, and a variety of information and communication technologies were utilized to support team collaborations. The main course components included: weekly lectures, team project, individual research paper, and cross-cultural exercise. More specifically, a total of 20 lectures were offered on a biweekly basis (twice a week), which included 5 special guest lectures delivered by experts who specialize on different GCE topics (i.e., cyber security, sustainable manufacturing, personalized learning, bioenergy, etc.). The class was divided into 6 globally distributed project teams to identify a GCE, analyse relevant needs, and propose a future solution. Students from the same university were tasked to work together to produce a mini-movie to present their observations of the culture of their home campus. Students also utilized digital portfolios in the course to complete reflections on class content related to each Grand Challenge theme area. It should be noted that, ASU operates a well-established NAE Grand Challenge Scholars Program that enrols more than 100 students every year. Through the knowledge transfer initialized by the joint course, UNSW aims to gradually launch its own Grand Challenges for Engineering program locally in Australia.

This work provides information about the course and describes the outcomes of the course as related to the students’ experience, instructor’s experience, and comparison to other courses. Formal assessment of course effectiveness was not completed in this pilot effort. To solicit feedback from participating students about their experience in the course, a focus group was conducted at UNSW and written feedback from small groups of students was obtained at ASU. Last but not least, some lessons learnt will be reflected by the course instructors with respect to, for example, how to design the course schedule constrained by the time and calendar difference, how to divide responsibilities between the collaborating instructors, and how to grade assignments in consideration of different grading policies.

1. Introduction

This work describes a new international joint course on the subject of the National Academy of Engineering (NAE) Grand Challenges for Engineering (GCE), collaboratively developed by Arizona State University in the USA (hereafter referred to as “ASU”) and the University of New South Wales in Australia (hereafter referred to as “UNSW”). Such a joint course is made possible by the PLuS (Phoenix-London-Sydney) Alliance that is recently established by three global universities including ASU, UNSW, and the King’s College London. The NAE GCE, defined by a community of professionals in 2008, describe large important problems faced by societies across the globe including providing access to clean water, making solar
energy more economical, restoring and improving urban infrastructure, securing cyberspace, and engineering better medicines. The NAE GCE are an ideal subject for such a global course as they describe a set of complex problems that exemplify problems faced by local and national communities around the world. Furthermore, these problems can only be addressed through interdisciplinary collaboration between professionals in many different fields and regions of the world.

In order to solve the important societal problems present in the world today, including the GCE, future generations of engineers must have an interdisciplinary, global perspective. In education, there are several different ways that students may become more culturally aware and develop a more global perspective including living in a different country (study abroad), interacting with students abroad through international courses, working on global project teams, or learning about another culture through a textbook or course materials. Several universities, including ASU and UNSW involved in this work, have recognized the value in global collaboration and have supported efforts to encourage global research and educational opportunities. In fact, the joint course described in this paper was made possible in part by an education and research alliance that was recently established by three global universities in the USA, UK, and Australia. In the United States, the NAE has responded to this need by encouraging universities to develop programs dedicated to preparing students with the broad perspective and skillset they need to solve global challenges, the NAE Grand Challenge Scholars Program (GCSP). The GCSP requires students to engage in curricular and co-curricular activities in research, entrepreneurship, interdisciplinary, global, and service learning areas to become globally competent engineers. It should be noted that ASU has a well-established GCSP that admits approximately 100 students each year. Through the knowledge transfer initialized by this joint course, UNSW aims to gradually launch its own Grand Challenges for Engineering program locally in Australia.

2. Course Design

This global course is focused on exploring the multiple technical and nontechnical dimensions of the NAE GCE. This course was adapted from a similar course implemented at ASU, with changes made to provide opportunities for students to gain cultural awareness and experience working in global teams. There were 28 freshmen engineering students in this course, with nearly equal participation from ASU (15 students) and UNSW (13 students). The ASU students in this course are all participants in the NAE Grand Challenge Scholars Program (GCSP); this course satisfies one of the requirements for that program. The ASU students self-selected to join this special section of the course in response to advertising about this unique global opportunity or based on their scheduling preferences. The UNSW students were recruited based on their interest in this unique global course opportunity and the subject of GCE, as well as their previously demonstrated academic performance. Students from both universities participated in synchronized class sessions, made possible through videoconferencing technology, on a biweekly basis (twice per week) for approximately twelve weeks in this course. After the twelve weeks of collaboration and interaction between
the two universities, the ASU students completed the three remaining weeks of their semester in the course finishing up individual assignments and sharing project work at a poster session.

The main purpose of the course was to provide students opportunities to learn more about the complex interdisciplinary global problems related to the GCE. Students in the course learn about challenges related to the GCE, engineering solutions being developed, and the societal issues (sociocultural, economic, political, and environmental) that can influence and constrain those solutions. Through this course, students were given opportunities to explore their interests related to the GCE in order to help them to develop future plans for their learning and professional development. In addition, students in this technology-enabled global course section had the unique opportunity to work with and learn from students across the globe to gain firsthand cross-cultural experience. The global nature of this course provided students with the opportunity to develop more cultural awareness and gain experience collaborating with team members separated by a large distance and time difference.

3. Course Structure/Organization

The course was organized around three different types of learning experiences: (1) Global Team Project; (2) Cross-cultural exercise and (3) GCE Theme exploration (activities and expert lectures). The global team project began at the start of the course and continued throughout, culminating in final project presentations. The first three weeks of the semester were focused on introducing students to the context of the course and helping students to get started on their team projects, including identifying topics for their project, forming teams, and working through the initial stages of the design process. Approximately half way through
the semester, a cross-cultural exercise was assigned and completed by two teams at each university. Five weeks of the semester, beginning after the initial project weeks, were dedicated to exploring technical and societal aspects of the GCE related to each of five theme areas: Security, Sustainability, Health, Energy, and Education. The Global team project, cross-cultural exercise, and the GCE discussions with faculty and students were the activities that contributed most to making this a unique global experience. The opportunity to interact and collaborate with students and faculty from an UNSW is what distinguished this course from other sections of a similar course for the GCSP at ASU.

The global team project required students to work in a globally distributed team of 4-5 students to identify a specific problem related to the GCE, analyse relevant needs, and propose a future solution. The student teams were formed based on mutual interests in specific problems related to GCE identified by students during the first class meeting. Project topics identified by students included improving health and living conditions for refugees in Jordan, providing water supply during disaster relief, developing a more rapid means of detecting cancer, and creating more sustainable residential infrastructure. The major deliverables for the project included a needs analysis, description of the solution and enabling technologies, and a final project presentation. At the start of the project, students were asked to find a specific problem area to focus on, identify customer and stakeholders, and analyse their needs. When conceptualizing a proposed future solution for the customer, students were asked to describe the technological needs (what technologies and future advancement are required) as well as the potential societal challenges and impact. Students were given time on a few class days to work on their team projects, but the majority of the project work was done outside of class. To communicate and collaborate with their team members on this project, students used a variety of different tools including Trello, various tools within the Google suite (Docs, Hangouts, Slides, etc.), and social media.

In the cross-cultural exercise, students presented and discussed the culture of each of the universities. First, student teams of 6-8 students from the same university worked together to create a mini-movie to describe their observations of the culture of their home campus. These videos were then shared during class. After watching the videos, students were asked to share their observations, focusing on similarities and differences observed between the two cultures. Students were also given the opportunity to ask questions of students from the other university in order to learn more about their culture.

For each of the five GCE theme areas, students participated in an in-class discussion to explore related societal issues impacting engineering solutions, and learned about current engineering work from an expert working in the area. The class discussions were focused on exploring different societal concerns related to the GCEs and included a class debate on the ethics of medical applications, discussion of future impacts of a dependence on renewable energy, and examining a case study about a sustainable solution to provide drinking water. The expert lectures were provided by faculty from both Universities on their current research on important topics including cyber security, sustainable manufacturing, personalized learning, bioenergy, and neural control of prosthetics. Through these interactions with other
students and faculty at the two institutions students also gained some insights into culture of the two institutions and countries, as culture often influenced perspectives on issues and the examples that were provided during discussions. After each GCE theme week, students were asked to summarize and reflect on their experience in a digital portfolio in order to help them to connect their learning to their interests and experience. Students also completed an individual research paper as an additional class assignment describing examples of work being done in one of the GCE theme areas to further explore their interests.

4. Lessons Learned

4.1 Student Perspectives

At the conclusion of the course, informal assessment methods were used at both universities to gather feedback from students regarding their experience in the course. At UNSW, a focus group interview was conducted to solicit the participating students’ reflections on their learning experience and suggestions for further course refinement. The focus group interview was moderated by a motivated student and attended by all students at UNSW. At ASU, students were asked to work in small groups to create a ‘Pros’ and ‘Cons’ list describing the positive and negative aspects of the course, and to provide suggestions for course improvement. The findings from both universities included similar themes and content, and are summarized below, organized with respect to instructional design, teamwork in globally distributed teams, and technology-enhanced international learning.

With respect to the instructional design, overall, all of the students agreed that a highly rewarding learning experience has been successfully delivered. Firstly, the team project was highly regarded. It was suggested that the expectations and requirements should be more made more explicit, because it is not uncommon that different students would take up the same assignment differently. It was also suggested that the key project milestones and deliverables could be announced all together at the beginning of the class, so that students can develop a comprehensive understanding of the expected outcome. Students enjoyed the opportunity to gain experience working with people from a different country and culture on the team project. Secondly, the cross-cultural exercise was highly regarded, as it enabled students to examine those small pieces of their everyday campus life from the cultural perspective. Some students felt that more guidance could have been provided for the cross-cultural exercise which may have increased the impact it had on the students. It was suggested that the exercise could be designed to be more relevant to the GCE topics with regards to, for example, the challenges of sustainability or personalized learning on campus. Thirdly, guest lectures were commonly regarded to be the most eye-opening and valuable component of this course. In terms of the content of the guest lectures, it was suggested that the abstract overview of a GCE topic is more beneficial than the specific elaboration of technical details. It should be noted that, some students had expressed strong interests in joining the research groups of the guest presenters. Last but not least, in addition to the existing course components, it was suggested to add weekly tutorial sessions, during which,
students can organize team meetings and seek advice from instructors in terms of project progress.

With respect to student understandings about teamwork, it was acknowledged by most of the students that the teamwork was overall effective, with varying degrees of effectiveness in regards to different aspects of teamwork (e.g., goal, leadership, solving problems, utilizing resources, experimentation, cohesion, trust with team members, communication, evaluation, etc.) [5-6]. For certain teams, it was difficult to reach a consensus on goal and objectives with respect to, for example, the choice of GCE topic. For most of the teams student’s trust with team members from the other university was relatively low. Students also indicated that it was often difficult to communicate across the large distance and time difference, and suggested that a better, perhaps more standardized way of communicating should be used for this team project in the future. Though the level of team cohesion varied among different teams, generally speaking, most of the students had perceived a reasonably high level of team cohesion, especially towards the end of the project. Most of the teams had failed to constantly examine how the team functions and experiment with new ways of teamwork, even though the team members were fully aware of various issues regarding teamwork. Most of the teams had followed the co-leadership models and the split-task approach. As a result, the project reports were mostly completed by means of equally dividing sections to different team members, and then co-constructed through online document editing tools, for example, Google Docs. Some students observed that their team members from the other university seemed to be more knowledgeable than they were about the engineering topics, which perhaps may be related to a difference in the curriculum between the two universities. Last but not least, the students all agree that this unique experience made them realize the general challenges and opportunities associated with a globally distributed team for the global workplace.

With respect to students’ reflections on technologies, overall, they were satisfied with the technology-enhanced learning experience. There was a class consensus that a reasonably effective global learning experience has been delivered, made possible by technologies. It was reflected by students that, initially, they were overwhelmed by the number of technologies (e.g., videoconferencing, Google Suite, learning management system, digital portfolio, video production, etc.) involved in this course. Since these technologies are all commercial applications that are not exclusively designed for the purpose of teaching and learning, it was suggested by students that a specific user guidance would be helpful for them to take up the technology. Furthermore, various social networking platforms (e.g., Facebook, Twitter, and Instagram) were commonly used by all the teams to facilitate teamwork, in particular, the social dimension of teamwork. As a result, on one hand, the team communication and collaboration were made more convenient. On the other hand, however, it also caused some unexpected “conflicts”. For example, some students were frustrated by the fact that, although their teammates were “clearly on Facebook”, they were reluctant to respond to the call for team meetings. Finally, it was suggested that a specialized project management tool should to be introduced. Some possible options were discussed and compared. In the end, Slack was considered to be a suitable option.
Inspired by the unique course experience, most of the UNSW students became highly motivated to participate in the NAE Grand Challenge Scholars Program. During the focus group interview, students had expressed strong interests in the possibility of launching a local GCE Scholar Program. Situated in the local context of UNSW, students had envisioned the future of creating their GCE scholar profiles along three directions: interdisciplinary research, international experience, and social impacts. Firstly, since thesis is a required course for every undergraduate at UNSW, some students are particularly interested in the development pathway of identifying a GCE focus in Year 1, engaging in research exploration in Year 2, formulating a specific thesis topic under the identified GCE thesis in Year 3, and completing the thesis in Year 4. Secondly, inspired by the international experience tasted in this course, students are interested in the subsequent learning opportunities of conducting field studies overseas, or participating in oversea study or student exchange programs. Finally, some students became motivated to promote the social awareness of GCEs at the local community in Sydney, Australia. In particular, it was suggested by two female students that the sociotechnical nature of GCE makes it an especially suitable subject for the outreach activities to high schools and middle schools in order to encourage more women in choosing engineering majors in college.

4.2 Comparison with another global course

The UNSW instructor had accumulated rich experience from running another technology-enhanced global education program at a private research university in the USA. Such an experience enabled him to compare this GCE course with another global course that is jointly offered by 5 universities from USA, China, South Korea, India, and Israel [7]. The instructional designs of the two courses are highly identical, as both include weekly lectures, guest lectures, team project, and cross-cultural exercise.

With respect to the effectiveness of technology-enhanced learning, compared to the multi-sites videoconferencing connection, the one-to-one connection was much more reliable [7]. Nevertheless, by no means, it suggests that the course is free of technical issues (e.g., loss of audios when playing videos, background noises, failure of sharing desktop content, etc.). In most cases, the technical issues can be prevented beforehand or quickly resolved through a more effective coordination among students, instructors, and technical staff. Upon a technology-enabled global course, since technology is tightly entangled with the instructional design [8], it is imperative for the instructors to keep technical staff updated the latest instructional plan, so that they can use their domain knowledge to anticipate any technical issue in advance and troubleshoot when the issues actually occur. In practice, it should be careful not to constrain the instructional design based on the technological capability. It was interesting to observe that, generally speaking, students were rather tolerant and patient with those unexpected technical issues. This may be largely attributed to the fact that the participating students are all Millennials, who grew up with computers and the Internet.
The course is coupled with some logistical complications with respect to academic calendar, time difference, grading policy, etc. Hence, some special arrangements were made. For example, there was a gap of three weeks between the academic calendars of the two universities, which was used for students to accomplish their individual research papers. Affected by the daylight savings in Australia, the UNSW class adapted its lecture times accordingly, which caused some students to miss some parts of certain lectures due to schedule conflicts with other courses. Because UNSW does not operate a GCE Scholar program, students were waived the requirement of submitting a GCE Scholar Development Plan. Last but not least, the two universities followed different schemes to convert numerical grades to letter grades. For example, 85% is converted to the letter grade of “HD” (high distinction – the highest letter grade) at UNSW, while it is only converted to the letter grade of “B” at ASU. In practice, it is important to properly prepare students’ minds regarding these special arrangements.

Since the participating students were all first-year engineering students, the instructor also attempted to evaluate whether and to what extent their skills meet the various requirements and constraints of a globally distributed team. The evaluation was conducted based on the instructor’s subjective observations, against the benchmark of the third-year engineering students in another global course [9]. Firstly, most of the students had demonstrated strong communication skills. In particular, since there is no language barrier, the communications in teams and class were overall effective. However, it was observed that many students were lacking a sufficient negotiation skill to resolve conflicts and research agreement. Secondly, most of the students had demonstrated good problem-solving skills, when encountered with various technical, logistical, or instructional issues. However, very few of them had demonstrated a good problem-formulation skill, as reflected by their “need analysis” of the chosen GCE topic. Thirdly, although some students had demonstrated a significantly higher motivation than others, very few students had demonstrated a notably higher leadership skill. Next, the majority of students had demonstrated strong presentation and public speaking skills, as evidenced by their performances in the final team project presentations. In that regards, an interesting finding is that, generally speaking, the ASU students were more comfortable with the format of oral presentation than the UNSW students. The majority of UNSW students had prepared presentation notes, while very few ASU students had done the same. Finally, it was observed that the technical writing skill of most students was relatively low. In practice, it would take multiple iterations for most of the teams to arrive at a high-quality project report. When the relatively low technical writing skill meets various difficulties of virtual teamwork, together with the split-task approach, it should not be surprising that the quality of project reports is not particularly high.

With regards to the further development of this pilot course, an anticipated challenge or opportunity is how and in what ways this pilot course can be effectively scaled up to benefit a broader audience of students. Such a challenge is especially pressing at UNSW. Unlike ASU that maintains a well-established distance education program, UNSW is still in process of building its technological infrastructure. Furthermore, another anticipated challenge is how and in what ways to engage, motivate, and incentivize more academic staffs in supervising
the GCE students. Motivated by the success of this pilot course and students’ highly positive feedback, UNSW is motivated to launch a local GCE scholar program in Sydney, which is characterized by “transdisciplinary research”, “global perspective”, “cultural competence”, and “social consciousness”. Multiple former students of this course will be engaged, as lead users, in contributing to this initiative.

4.3 Comparison with another local GCE course

As was mentioned previously, this course was very similar to and in fact was based upon a local course developed and taught by the instructor at ASU. This instructor has several years of experience teaching the local GCE course, and in fact was teaching two sections of that local course simultaneously with this global GCE course. This experience teaching and implementing this course in both formats provides an opportunity for comparison between the local and global GCE courses.

The overall structure of the local GCE course is very similar, however, some changes were made to assignments and activities due to constraints and opportunities provided by the global setting of the course. Both courses were organized around weekly guest lectures and discussions related to the GCE, a team project, an individual research paper, and planning assignments to help students to develop plans to complete the GCSP before they graduate. This global course, however, also included the cross-cultural exercise, which required the instructor to reduce the requirements of other assignments included in the local GCE course in order to ensure an equivalent workload. The format of the in-class discussions and activities also was different between the local and global course sections. The local GCE course is designed to be a discussion-based course focused on active learning; students typically complete a different type of interactive, hands-on learning activity or discussion for each of the GCE theme areas. These learning activities include a bridge design-and-build activity, a role playing activity that simulates a security crisis, a renewable energy economics activity in which students act as utilities or energy companies, and a debate about health topics. In the global course, the only one of those activities that could be done effectively through video-conferencing was the debate about health topics; the other activities were replaced by small group discussions of different societal issues related to the GCE. Since a majority of the learning in the local GCE course is designed to occur through small group discussions or activities, it was challenging to adapt this course to fit the format of a global course with students in two distinctly different locations.

The implementation of the team project was also different between the local and global GCE courses due to the use of global project teams, instructor expertise, and differences in the course structure. The overall focus of the team project, to develop a future solution to a problem related to the GCE, was the same between the local and global sections, however, the specific deliverables were different resulting in a slightly different focus. In the local GCE course students typically complete a series of four intermediate deliverables as they progress through the project, and they present their final results in the form of a Poster and a physical (or visual) model at a poster session at the end of the semester. The project teams in
the global GCE course completed two deliverables and presented their final results to the class in a professional presentation. The ASU students also presented results of the project in poster form at a poster session at the end of their semester, as the instructor felt it would be a beneficial experience for them. In the Global GCE course, a lot more time and emphasis was put on identifying a specific problem to focus the project on, and performing a detailed needs analysis. The decision to focus more on the needs analysis portion of the project was based on multiple factors including the ASU instructor’s interest in shifting the focus of the project in that direction, and the UNSW instructor’s relevant expertise in the area of functional design. As a result of this change, the project work done by students in the Global GCE course included a much better, more detailed description of the problem and needs that their future solution was designed to fulfil when compared with the projects in the local GCE course. The students in the local GCE course were also given the opportunity to explore the societal challenges and impacts of their solutions more thoroughly through the use of science fiction, which may have influenced them to discuss more specific societal issues in their final project work.

Looking forward to future development and implementation of this pilot course, one anticipated challenge or opportunity from the perspective of ASU is related to how this global collaboration can be leveraged to provide more students with an impactful global course experience. Currently, the audience for this local (and global) GCE course is restricted to first year students, as one of the aims of the course is to help new GCSP students to become familiar with and engaged with the program. One of the challenges with teaching this course in a global format with students from outside our local GCSP, is that at times it was difficult for the local students to focus on engaging with the program since the instructor had to cater to a more expansive audience. Expanding the opportunity to participate in a global project-based course to a wider range of students, particularly those involved in the GCE focused programs at each university, may be interesting to consider. Students who participated in this pilot course were excited by this opportunity, and this positive experience had by students provides motivation to continue to improve and expand upon these efforts.

5. Conclusion

A new international joint course focused on the NAE GCE was collaboratively developed and implemented at ASU and UNSW. Students in the course learned about the interdisciplinary nature of the GCE through discussions and expert guest lectures, collaborated on global project teams to develop a future solution to a GCE-related problem, and completed a cross-cultural exercise to compare the two university cultures. Students’ response to this class was positive overall, with most students appreciating the opportunity for global collaboration but also recognizing the challenges associated with working on a globally distributed team. This pilot course is a successful example of a global course that can be developed around the GCE, through collaboration between faculty at two universities across the globe. The lessons learned from this experience will be considered by the instructors as they prepare the next offering of this course, and when discussing additional
opportunities to provide joint learning experiences for students in their respective GCE focused programs in the future.

References


