GLOBAL DISTRIBUTED ENGINEERING STUDENT DESIGN TEAMS: EFFECTIVENESS AND LESSONS LEARNED

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ABSTRACT

Twenty-first century engineering student professional skills require the ability to work effectively in multicultural, globally distributed teams. Chalmers University of Technology (Sweden) and Penn State University (USA) have formed a collaboration to provide students with an experience in this environment to start requisite skill development. The activity is anchored by a corporate supplied project with realistic open-ended design requirements. The students are expected to mimic the operation of a multinational corporate engineering team to develop a design solution. The collaboration was initiated in September 2014 and launched in January 2015 with Volvo Group as the industrial partner. In addition to the traditional design experience outcomes, the learning objectives from a global perspective are to: (a) understand the impact of engineering in a global, economic, environmental, and societal context; (b) understand cultural/ethnic differences and develop the ability to work sensitively with them; (c) learn to function effectively in multinational teams; (d) communicate effectively in English, regardless of team members first language; and (e) develop the ability to organize and deliver communication around the globe. The paper discusses the integration of academic protocols from each university, the logistics and operation of the global student teams. At completion of the program a critique was performed from various perspectives to assess effectiveness and capture lessons learned. A pre and post survey was given to the students to assess effects on intercultural communication from the interaction. The Volvo Group personnel who interacted with the teams and supervising instructors were asked to critically evaluate the program. All information pointed to a successful program whereby the students delivered technically sound design solutions and gained professionally through the global experience. The paper concludes with a discussion of the keys to success for such a globally distributed university-corporate academic collaboration.

KEYWORDS

Global design teams, multicultural, industry sponsored educational project, CDIO Standards: 1, 3, 5, 6, 7, 8

INTRODUCTION

Corporations desire engineers who can enter the workforce and function effectively in the global economic and engineering worlds. An engineer in a global company must be able to easily cross national, cultural and language barriers to function efficiently in global product development teams. Engineering educations need to provide opportunities to prepare their graduates for the ever increasing global nature of engineering (Bourn & Neal, 2008).

Study abroad programs have traditionally been an effective tool to provide students with global experiences. However, these programs have not been widely embraced by engineering students. For example, engineering students comprise approximately 5% of the undergraduate population in the USA, with only 3% of the cohort studying abroad (Carlson, 2007). Reasons for the low participation include the rigorous prescriptive engineering curricula, the financial burden, and more fundamentally, international experiences have not been a traditional focus.

Improved communication technology has led to the increase of global virtual teams (GVTs) in industry. In GVTs, team members are globally dispersed and work together towards a common goal (Powell, Piccoli, & Ives, 2004). These teams offer benefits for the company such as round the clock progress, travel cost reductions, and improved creativity due to team diversity (Kankanhalli, Tan, & Wei, 2006). However, there are also challenges that arise in GVTs including cultural differences, communication delays, and time zone differences (Mannix, Griffith, & Neale, 2002; Qureshi & Zigurs, 2001). If not carefully managed, GVTs can create ineffective teamwork (McGrath, 1991). Teaching students to effectively work together in GVTs can help make students more effective global engineers and prepare them to be effective teammates and leaders. The GVT experience has the potential to introduce global engineering aspects and is capable of reaching engineering students en masse.

Successful implementation of a GVT in an academic setting is a challenge. To address these issues, an approach has been developed to create Global Student Teams which replicates the industry experience for students. The Global Student Teams are united by a carefully tailored industry supplied project. Each institution operates its respective culminating experience in its current format with the project driving the students to act as one cohesive team. The interaction between the Global Student Team members is facilitated by regular communication in a variety of forms (email, weekly video and teleconferences). The critical cohesive element is the interaction of the students with the global corporate project sponsor.

Penn State University (USA) Department of Mechanical and Nuclear Engineering and Chalmers University of Technology (Sweden) Mechanical Engineering program (Departments of Applied Mechanics and Product & Production Development) have joined with Volvo Group to implement Global Student Team concept. The activity merged the preexisting culminating engineering activities (i.e., Chalmers BSc Thesis and Penn State Capstone) at each respective university to minimize academic logistic issues. The program was launched in the Spring 2015 semester with two projects sponsored by the Volvo Group.

In the following sections the Global Student Teams approach will be discussed. The program organization, procedures and outcomes will first be presented. The program assessment extracted by observations from multiple sources is presented and analyzed. Finally, the lessons learned and keys to success will be summarized.

Educational Objectives

The Global Student Team concept is to provide a meaningful non travel based international design experience. The students are exposed to a real life design experience working on products for the global market. In addition to the traditional design experience learning outcomes, the added educational objectives from the Global Student Team structure include allowing the students to:

1. Understand the impact of engineering solutions in a global, economic, environment and societal context.
2. Understand cultural/ethnic differences and the ability to work sensitively with them.
3. Learn to function effectively in multi-national global team.
4. Learn to use English as the common communication language within a multilingual team.
5. Develop the ability to plan/organize and deliver communication effectively around the globe, leveraging information and communication technologies.

GLOBAL STUDENT TEAM OPERATION

Students enrolled in their respective culminating experience at either Chalmers or Penn State. Teams were formed with three students at each university. The student team activities were organized to operate in a similar fashion as a Volvo GVT. Chalmers and Penn State professors operated their respective courses in their current form with the project tasking providing the mechanism for the students to work together.

Prior to the project launch, the Chalmers and Penn State professors prepared a detailed, comprehensive schedule; including arranging major video conference dates and times with the Volvo project sponsors. The forced critical milestone scheduling helped keep the teams focused and resolved any potential conflicts with respect to national or school holidays. The milestone scheduling removed any uncertainty while trying to arrange meetings with many people across multiple time zones that could have potentially delayed the student progress.

The student teams were ultimately asked to develop intermediate milestones and deliverables around the faculty supplied schedule. In coordination with their Volvo sponsors, the students organized the tasking and separation of responsibilities. They leveraged the respective capabilities at each university to their advantages.

Project Development and Selection

Project selection was critical for program operation as it formed the cornerstone for the student collaboration. The project must be realistic, technically challenging and amenable to global engineering participation. Thoughtful project selection and tasking was critical to facilitate the separate yet integrated student activity. The projects originated from the Volvo Group, with one project each proposed and supervised from Volvo (Sweden) and Volvo (North America). Penn State and Chalmers professors worked very closely with the Volvo personnel to select projects which met the criteria. An overview of the two projects selected follow.

Device to Open/Close the Airflow through a Grille and Cooling Module

Reducing cooling airflow through a radiator and grille opening of a long haul truck, Figure 1(A), can decrease aerodynamic drag and fuel consumption. The students were asked to investigate different technical solutions for devices to control the cooling airflow through a truck. Specifically they were tasked with conceptualizing multiple solutions, selecting the most promising design solution, constructing a functional prototype and validating the prototype design.

Roof Mounted Aero Device with Actuator Positioning

A roof mounted fairing, Figure 1(B), directs the air flow around the nose of a trailer improving the aerodynamics and improving fuel efficiency. In some operations, trucks make trips without a trailer and the raised fairing creates unnecessary aerodynamic drag. The student team was asked to 1) design an automated lifting mechanism to raise and lower the roof mounted fairing and 2) to aerodynamically optimize the device shape and configuration to provide optimum performance in both the raised and lowered position. The team was tasked to construct a prototype to demonstrate the mechanical operation and to provide a computational fluid dynamics analysis of the aerodynamic performance.

(A)

(B)

Figure 1. Volvo project photos: (A) Truck cooling grille, and (B) Roof mounted truck fairing.

Communication

Constant communication between the students was crucial to the team success. Initially web based video conferences were scheduled by the faculty. The video conferences were led by the professors and provided a platform for the students to meet each other and form effective team procedures. As the students became more familiar communicating effectively in this environment, they assumed control of the scheduling and leadership. The teams ultimately organized and held video meetings at their convenience.

At several critical points throughout the project, the students were required to deliver formal presentations to the Volvo project sponsors/mentors. The coaching from the professors helped refine the communication ability of the students in this video conference environment.

The student teams communicated almost daily via email. The students used a common electronic depository to store their files so any team member could access the most current information at any time of the day from anywhere. The students ultimately developed procedures to communicate very effectively exploiting many of the electronic collaborative tools readily available. Moreover, they also developed skills and routines to handle global CAE simulations and tools. In particular, they successfully developed common CAD, FEM and CFD models enabling simultaneous developments without conflicts.

Reporting and Student Evaluation

A separate yet integrated student reporting and evaluation scheme was used. A common reporting format was agreed upon by the professors and followed by the students. All reports were prepared in English, with the Executive Summary of major reports also presented in Swedish. Each university applied their respective standards and marking scale to the unified report.

Global Student Team Structured Protocol

The teams' success relied heavily on a structured operational protocol established a priori by the professors at Chalmers and Penn State. This structure gave the students specific tasks to be fulfilled to ensure the students were efficiently utilizing their time. This was important due to the short four months' time the students had to complete the project. The protocol included team building exercises, introduction to the sponsor, establishing team member responsibilities, developing a CAD system level design and fabricating prototypes.

The teams initially had team building exercises and were introduced to the Volvo sponsors through video conferences. Team building exercises included 1) having teammates give short presentations about themselves; 2) having USA and Sweden student cohorts deliver brief presentations about what it is like to live and go to school in their respective countries, and 3) having the student teams' work together to write a team contract which described how the members will function together on the project. The contract clarified the cooperative rules and how to handle a situation if a teammate does not fulfill the agreement. The teams also continued team building exercises midway through the semester when the Chalmers students had the opportunity to visit the Penn State, USA. During this visit the teams worked together on their projects in the machine shop. Social events were organized, including an American baseball game and a professional corporate style dinner. These virtual and in person team building activities helped to enhance the team spirit and allow for free flowing communication.

Both teams decided to have a rotating team leader scheme with two-week term for each member. The teams also decided to have a designated secretary on a rotating schedule. The role of the secretary focused on scheduling, documenting group meetings and ensuring that all material was available in the common depository. The teams appointed two contact persons, one from each site, whose main task was to be the industrial sponsor point-of-contact. Communication dates for eight web meetings throughout the course of the project were scheduled with the Volvo sponsors. Next, the student team prepared a Gantt chart to diagram the different steps, deadlines, deliverables and responsibilities.

The team followed a systematic development process that starting by investigating competitor's products and patents. The team established thorough requirement specifications and customer needs in close cooperation with Volvo. Several preliminary concepts were generated, first individually and then as a team to further develop concepts by creating new designs and by combining features from existing concepts. All concepts were evaluated in an elimination matrix. The most promising concepts were evaluated using Pugh and Keselring matrix selection methods and the concept that best fulfilled the customer needs was identified.

Next, a general system level design was developed with the cooperation of the entire team. The various component development work was divided among team members with clearly identified responsible persons. CAD models of different parts were developed, enabling work to be performed in parallel. Materials and processes were selected using CES EduPack software (Cambridge, United Kingdom). Finite element models (FEM) were used to conduct thermal, stress and deformation analyses on critical parts. Computational fluid dynamics (CFD) models were used to analyze the aerodynamic performance to ensure fulfillment of the requirements. The grill airflow behavior was modeled in both a closed and open position. The roof fairing air flow was similarly modeled in both upright and lowered positions. Design for Assembly (DFA) and Design for Manufacturing (DFM) analyses were conducted to ensure ease of production. Finally, cost analyses were completed using CES EduPack together with market prices for off the shelf components. Both teams were able to design, develop, and validate successful functional prototypes.

ASSESSMENT OF PROGRAM OUTCOMES

The technical outcomes, professional skill development outcomes, and benefits from an industry perspective were all assessed. It was found that the Global Student Teams approached offered numerous benefits to both student development and industry. The assessment of these outcomes is detailed in the following sections.

Assessment of Technical Project Outcomes

The global teams' technical solutions were remarkably good and the students benefited professionally from the experience. The students developed and deepened their technological knowledge and skills. Professional skills such as communication, teamwork and project management were enhanced by working in this global environment. Survey results showed the students found it extremely rewarding to work in an international team. They gained valuable experiences in how to handle time differences, different work cultures, and international communication. The specific technical outcomes of the two Global Student Teams are discussed in the following two sections.

Device to Open/Close the Airflow through a Grille and Cooling Module

The project produced a fully detailed CAD rendering, as shown in Figure 2, and the development of a functional full scale prototype. The prototype and CAD model contained numerous creative design aspects including unique aerodynamic grill blade design and a novel lightweight lattice frame design.

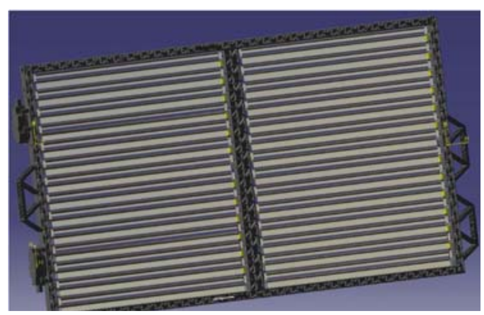


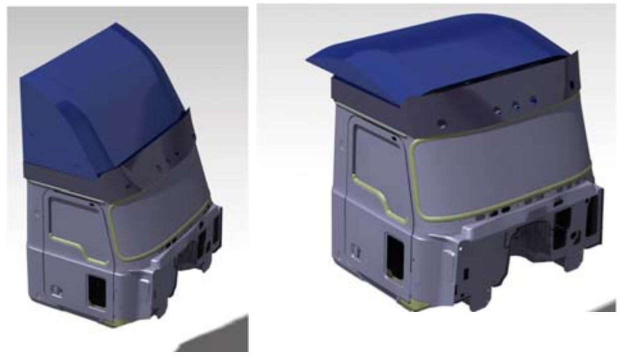
Figure 2: CAD model rendering of grill and cooling module developed by the global student team.

Roof Mounted Aero Device with Actuator Positioning

The team successfully designed and fabricated both a small scale and a full scale prototype of the automated roof mounted fairing. The team created a fully detailed CAD rendering, shown in Figure 3. The team developed several novel concepts including a folding design for the sides which allow for a flat profile when retracted, and a novel linkage system to allow for effective pneumatic actuation.

The students were confronted and solved many items not typically experienced in final year projects. They worked through international intellectual property, procurement issues and ultimately manufactured, assembled components designed around the globe into a functional prototype.

The solutions and project deliverables from the Global Student Teams were on par with the upper tier of industry sponsored teams comprised of capstone student teams completely at Penn State or Chalmers. The global distribution did not harm the technical project outcomes in any manner and the different educational and cultural perspectives actually enhanced the designs.



(A) (B)

Figure 3: CAD model rendering of faring in both (A) Up and (B) Down positions

Assessment of Professional Skill Development

Assessment of the students’ professional and intercultural growth through the global teaming experience was performed by multiple methods. A pre and post survey was given to the students to evaluate the intercultural communication, teamwork and skill development. The survey was adapted from the work of Lu et al. (Lu, Chen, Trethewey, Litzinger, & Zappe, 2011) which was developed by professionals in intercultural communications and assessment. The survey results ultimately were difficult to quantitatively evaluate due to the small sample size of students. Hence the evaluations are qualitative in nature based upon the surveys, instructor observations and conversations with the students.

The students at both universities thoroughly enjoyed the experience and appreciated the opportunity to expand their international perspectives. The communication between the teams was very effective and professional. The mentorship of the corporate sponsors, in this regard, was beneficial. The students mastered the technology to enable international communication and exchange of information quickly. Through the regular video and voice conferencing the students rapidly became friends which helped drive the cohesiveness and teamwork effectiveness. Post program evaluation indicated that the experience piqued the students’ interest in learning more about other cultures and working internationally. This was apparent in the USA students who are not as regularly exposed to other languages and countries as their European counterparts tend to be.

The overall excellent outcomes from the professional skill and communication perspective may have been facilitated by the similarities of both universities and students. The cultures, education and life experiences of both student nationality groups were far more similar than different. Hence, differences were small to begin with and easy to overcome if encountered. Furthermore, the ease of communication within the team can be attributed to the Swedish students’ mastery of the English language, oral and written, and their comfort level to use it.

Assessment from the Industry Perspective

When hiring new student graduates, corporations must allow time for these new employees to become acquainted and familiarized with the way of working, which is usually substantially different from their educational endeavors – especially if the corporation is global. The newly employed could easily be overwhelmed by the way projects with colleagues spread over the world are run using email and phone as the main communication tools for delivering results into the project work.

Therefore, the Volvo Group highly appreciates the initiative between Penn State and Chalmers, who are both part of the Volvo Group Academic Partner Program, to allow students to experience a true working situation as part of their education. This incorporates not only experience solving a product oriented technical problem, but also understanding the need to be receptive to new cultures, tackle language barriers and to drive progress without meeting in person. These are important skills to be successful in a global corporation.

LESSONS LEARNED

The project success can be contributed to the three components that have been assembled for this program. 1) a group of serious, motivated and mature students; 2) engaged, responsive, patient and instructional project sponsors/mentors backed by strong Volvo Group corporate support; 3) adaptable and engaged professors backed by strongly supportive university administrations. Five key lessons learned for the creation of a successful Global Student Team project include:

1. Motivated students are critical to project success. The students who elected to participate in this pilot program were motivated by the global aspects of the activity. Much of the program success can be attributed to the drive and dedication of these students. Future challenges may arise when teams are comprised of students not predisposed to global participation.
2. Engaged industry sponsorship is crucial. Industry mentors who practice global engineering can anticipate the student pitfalls and help guide them. Furthermore, they can lead by example and show the students how to work effectively in this challenging environment.
3. Careful project selection is necessary as not all potential projects are amenable to being worked on by a Global Student Team. The project objectives should be well formed with separable items and tasks. The system integration serves to drive the interaction and communication.
4. It is critical that the instructional faculty at the partner universities have a strong working relationship. Close communication and team work on part of the faculty is necessary to guide the student teams and program success.
5. The students require access to video conferencing technology on their schedule with few hardware and facilities constraints. The universities need to have specially tailored video conference rooms to enable high quality web meetings to facilitate communication and technical information sharing.

SUMMARY

The inaugural offering of the Global Student Team concept between Chalmers University of Technology, Penn State University and Volvo Group was highly successful. The technical and professional growth of the students in Global Teams was on par with other high performing co-located domestic student teams. This offers evidence that the geographically distributed nature of the team has not been detrimental, but actually enhanced the project. Furthermore, the experience provides an added value with regard to global perspectives, intercultural and interpersonal skill development, and cross language communication.

The students report the program was very worthwhile and indeed delivered a meaningful international experience. The program created significant interest in the participating students' peer groups. The peer groups expressed their desire to have such an experience. The next step entails program expansion to deliver the experience to many more students.

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