Developing Cross-Cultural Virtual Teams for Engineering Design Education

Alan Parkinson, C. Greg Jensen, Spencer Magleby
Brigham Young University, Provo, Utah, USA

Abstract – *As engineering becomes more global in nature, the use of cross-cultural virtual design teams has become more prevalent in industrial settings. These teams collaborate via Internet-based communication and design tools. For the past five years, faculty at Brigham Young University have developed approaches to use virtual teams in academic settings and have coordinated the efforts of student design teams from Australia, Brazil, Canada, China, Germany, India, Korea, Mexico, Sweden, and the United States. Building on those efforts, we have initiated a research program to develop and assess the effectiveness of virtual, collaborative, cross-cultural design experiences. We comment on our approach, method and experience thus far. The authors also wish to explore the development of a database of schools interested in participating in this kind of international educational experience.*

Index Terms *– Engineering Design Education.*

INTRODUCTION

The globalization of engineering has been the result of a confluence of forces and changes taking place over the past two decades. [1] Perhaps ironically, technology developed by engineers has been a main driving force acting to change engineering practice. For example, advances in telecommunications now make possible inexpensive, real-time communication virtually anywhere in the world. Although now considered commonplace, this is a monumental achievement in the history of humankind. Worldwide communications have been accompanied by the development of low cost computing and the rise of the Internet as a means for organizing and sharing data. Taken together, these developments have made it possible to place and retrieve engineering data sets from any global location which in turn has fueled the out-sourcing of engineering tasks to wherever it is most efficient for them to be completed.

Along with technology, major geopolitical and economic changes have also facilitated the globalization of engineering. The past 20 years have seen the dissolution of the Soviet Union, whereby the 15 member states declared their independence and moved toward market economies. The European Union was formed and has become one of the largest single markets in the world, with a combined $17 trillion economy.[2] China and India, representing more than one third of the world's population, have become important players in global markets and technology development, not to mention a huge consumer base. Across the world, free trade barriers have dropped, and the influence of multi-national corporations has increased.[3]

The net result of these driving forces is that many engineering companies now compete on a global scale. As examples of the importance of global markets, we note that 67% of Hewlett Packard's revenues, 79% of Intel's revenues, and 60% of General Motor's revenues in 2007 were from abroad.[4]

The above discussion makes primarily an economic argument for global education —markets and competition for markets are now global. However, perhaps the most compelling reason for global competence relates to the nature and scope of the problems faced by humankind. Recently, for example, the U.S. National Academy of Engineering issued a list of grand challenges for engineering.[5] Many of these are global in scope and relate to sustaining life on the planet, such as making solar energy economical, developing carbon sequestration methods, managing the nitrogen cycle, and providing access to clean water. These are critical problems which cut across ethnic, cultural and national boundaries, and they will require cooperation among nations and peoples if they are to be solved.

As a result of these changes, a number of credible voices are suggesting that engineers need to learn global skills. For example, the report of a recent summit sponsored by the U. S. National Science Foundation called on educators to, "integrate global education into the engineering curriculum to impact all students, recognizing global competency as one of the highest priorities for all graduates."[6] There are at least two challenges associated with this call for action.

First, the term "global competence" encompasses a broad range of attributes and skills. Achieving this broad competence in engineering graduates will challenge our current modes of education. For example, Parkinson et al.[7] discuss 13 dimensions of global competence. These dimensions include appreciating other cultures, being able to communicate across cultures, understanding the influence of culture on engineering practice, speaking another language, working well in a team of cultural or ethnic diversity, and appreciating challenges facing humankind such as sustainability, poverty, and security. These represent a very wide spectrum of skills, and it is likely that no one approach to global competence will be able to address all of them.

Second, a scalable blueprint is needed to integrate the development of global competence within the existing engineering curriculum. This second challenge may well be the greatest considering the constraints of a typically overloaded engineering program. Traditional approaches to developing global competence, such as faculty-supervised study abroad programs, are often resource intensive. Course sizes are necessarily small and faculty must be away from their normal duties. Thus scaling up or expanding these programs for more students is often difficult. Alternative approaches should be examined as a complement to traditional programs.

CROSS-CULTURAL VIRTUAL TEAMS

The approach we will discuss in this paper to address these challenges involves the use of cross-cultural, virtual (CCV) design teams. These types of teams are usually defined as being geographically dispersed, spanning several different countries or cultures, being composed of team members with little prior association or common background, and communicating through electronic means. In the experiences we report here, the teams are composed of senior level engineering students from various universities who must complete a design project. Team members communicate using various software and hardware tools such as email, audio and video conferencing, shared design documents, and CAD design models.

We believe the virtual teaming approach has the following potential advantages compared to more traditional approaches:

- Virtual international design teams, as a format for learning global skills, scales relatively well. Students already take design courses. Faculty already teach such courses. Students are not required to travel, although some may wish to travel at the beginning or end of the project. The effort required to implement this format is more incremental in nature than the quantum level of some formats such as study abroad.
- The process is similar to the process being adopted by industry. As tools for collaboration become more sophisticated, companies are conducting design and manufacturing process planning via Internet-based web tools. The authors recently experienced this first hand. At visits to Hewlett Packard and Cisco systems in Bangalore, India, both companies were using their own high-end conference systems to conduct design meetings with teams in the U.S.
- The format can address some important elements of global competence. The specific attributes which are developed by this format include gaining proficiency working in or directing a team of ethnic and cultural diversity, understanding how culture affects communication, and understanding cultural effects on how engineering tasks are performed. Global virtual teams, by their nature, involve activities which force students to address these issues. Preliminary data, as mentioned later in the paper, indicate this could be an effective way to teach some global skills.[8]

This approach also has its challenges. Besides the regular challenges faced by a design team, CCV teams have the added challenges of bringing together a culturally diverse set of people who are not co-located and may not know each other. A CCV team must overcome the limitations of electronic communication. Developing trust among team members and establishing role definitions may be more difficult in a virtual team.[9] Students will not have the rich, immersive experience associated with being physically present in another culture, as in study abroad programs. As mentioned above, we believe each type of international experience has its strengths and weaknesses and each addresses only a "slice" of the skill set needed for global competence. We see CCV teams as addressing an important and somewhat complementary slice as compared to other approaches.

There are other challenges as well. In our experience, one of the biggest challenges in running virtual teams as part of a course is the mismatch in semesters between any two universities. This has been an impediment in the development of this type of experience.

THE BYU EXPERIENCE

Brigham Young has been heavily involved with several different national/international design-and-build vehicle projects.[10,11,12] The first project was a partnership between Virginia Tech, Kettering and BYU. The students worked ten months to design, analyze and prototype an off-road vehicle (see Figure 1). The following year, thirteen universities formed a global design team that touched 130+ students from eight different countries. Their ten month partnership resulted in the virtual creation and analysis of four concept cars. The resulting ¼ scale clay models were displayed in the lobby of GM's Vehicle Engineering Center, as shown in Figure 2.

Figure 1: Off-road vehicle design-and-build project. **Figure 2: Sports car design-and-build project.**

During the next three years, students from twenty universities, speaking eight different languages, and spanning sixteen time zones participated in the creation, testing, and analysis of a Formula-1 racecar, as shown in Figure 3.

Figure 3: International Formula-1 design-and-build project.

Building on those efforts, we recently initiated a U.S. National Science Foundation sponsored research program to develop and assess the effectiveness of global collaborative design experiences in developing attributes of global competence.

PRELIMINARY RESULTS

Our initial efforts in taking an existing course and adding a global design element was the extension of the ME 471 Advanced CAE Applications course to have an international component. As part of the course, student teams use advanced parametric assembly modeling in conjunction with parametric surface and solid modeling to complete a significant project where they construct conceptual models of cars.

Previously, the teams were formed only among BYU students, and the lectures and labs were available only to students enrolled in the course at BYU. In the fall of 2009, benefiting from our previously-developed relationships with other universities, we offered our first global Computer-Aided Engineering Applications course. This was done with cross-cultural, virtual teams. Students from the Universities of British Columbia (UBC) and Toronto in Canada, as well as students from Universidad Iberoamericana and ITESM-Toluca in Mexico, and students from University of São Paulo joined the ME 471 lectures and labs via an Internet link to our video conferencing bridge. Of the eight BYU teams, four teams were kept as local teams only in order to have a control group. The remaining four teams had BYU and Canadian students; two of these teams also had Brazilian students and the other two teams had students from Mexico.

A number of changes were made to the course, including adding several lectures on topics specific to cross-cultural teams such as avoiding ethnocentrism and communication across cultures. (These lectures were taught to all students, whether in an international team or not.) Lectures for the class were broadcast from BYU to all sites. Abroad students participated in lectures and assignments. The international teams held planning meetings using Skype and all teams were encouraged to use Google docs, spreadsheets and presentations to accomplish their non-CAD assignments. All international teams were required to use the same version of Siemens NX CAD software.

We conducted assessment through surveys, interviews and exam questions. We have discussed some preliminary, promising results in a previous paper.[8] For example, over 95% of the students in the international teams felt they had learned key skills in working in a global, cross-cultural team. Another encouraging finding is that the students in the international group expressed a strong desire (85%) to work again in a similar international environment. Students in the international group felt that course materials and learning activities greatly improved their ability to communicate across cultures (83%). This was considerably higher than that reported by the local students (56%).

We will be expanding our efforts this fall. We will continue with the ME 471 CAD course but add to it two student teams in our ME 475 capstone design course. To better prepare these students, we are planning to teach a "backpack" seminar which students will take in conjunction with the capstone course. Topics for the backpack course include communication technology, ethnocentrism and cultural intelligence, virtual team processes, contrasting cultural values, cultural and virtual elements of communication, conflict resolution, the effect of culture on engineering practices, and cross-cultural product design.

PROPOSAL: INTERNATIONAL DATABASE

Matching Schools

One of the difficulties in engaging in cross-cultural virtual teams is in finding suitable partners. The authors are interested to explore the development of a database that could be used to match schools for CCV teams. Any school interested in matching up with other schools should contact the authors so we can determine if there is sufficient interest to establish a web site and database of schools. No commitment on the part is implied by such contact.

Successful Matching of Teams

As we have used CCV teams, we have observed some conditions which increase the chances of team success. We discuss these in the table below. Some of this information would be available in the proposed database to help insure a good match.

Good semester match	It has become apparent that one of the greatest impediments to this kind of experience is semester and/or holiday mismatch between schools. Start and ending times for semesters can be off by a

	month or more; this makes completing a project difficult. It is extremely difficult for schools in the northern hemisphere to do CCV projects with schools in the southern hemisphere due to a total mismatch of seasons. We have also found that some academic calendars start in the August/September time frame while other schools begin their academic year in January/February.
Commitment of dean and department chair	Without the support and backing of administration, efforts on the part of faculty to implement global competencies and skills will quickly wane. Commitments and global partnerships between schools need to extend to the administrative levels. Global design experiences require more effort on the part of faculty members involved. These efforts need to be understood, appreciated, and factored into the professor’s load and compensation. The required resources (teaching assistants, graders, access to facilities, etc.) must be available.
Commitment of faculty	Faculty who advise CCV teams need to be committed to this experience. This responsibility needs to be part of their load. They should attend the expected planning, organization, and review meetings, meet with team members, supervise grading and participate fully with faculty from other schools.
Commitment of students	Students need to be taking the course for credit, no exceptions. Grades are the motivation that drive the participants to work hard and learn effective global design methods and skills.
Instruction	It is helpful if students receive additional instruction regarding how to work in both a cross-cultural and virtual environment. For the class we are teaching in this Fall, we are requiring a “backpack” seminar to address these issues.
Language skills	The teams need to have enough common language ability to communicate. Often CCV teams converse in English, as the de facto language of international business. However bi-lingual English speaking students may want to practice their second language by aligning themselves with teams which speak their second language.
CAD tools and Technology	In our experiences thus far, schools have had standardized on the same CAx tools and software. While this is not essential because of STEP and IGES translators, it does allow the teams to experience global design without the complexity of dealing with data exchange formats. Common tools and versions greatly facilitate the sharing of models, analyses and manufacturing

	information. All participating schools need T1 or preferably T3 Internet connectivity; consigning students to something less would reduce their collaboration and participation in the overall experience. One school should have Internet meeting hosting capabilities as well as data serving and storage capabilities.

SUMMARY

In this paper we have discussed the driving forces for the globalization of engineering. We have asserted that there is both an economic imperative and "grand challenges" imperative for engineers to develop global competence. We discussed two difficulties in developing global competence: 1) the broad set of skills this encompasses and 2) the integration into the curriculum and scaling of programs to reach a large fraction of students within acceptable resource constraints. We presented the potential of cross-cultural virtual teams to be part of the solution to this problem. We intend (given sufficient interest) to explore the development of a database of schools interested in this type of experience as a way to facilitate the matching of schools and teams. We invite interested schools to contact the lead author via email at parkinson@byu.edu.

ACKNOWLEDGEMENTS

This research is supported by U.S. National Science Foundation grant EEC 0948997. This support is gratefully acknowledged.

References

[1] A. Parkinson, "The Rationale for Developing Global Competence," *Online Journal for Global Engineering Education*, Vol. 4, Issue 2, 2009.

[2]International Monetary Fund statistics, http://www.imf.org/external/pubs/ft/weo/2008/01/weodata/weorept.aspx?sy=2007&ey=2007&scsm=1&ssd=1&sort=country&ds=.&br=1&c=998&s=NGDPD%2CPPPGDP%2CPPPSH&grp=1&a=1&pr.x=26&pr.y=7

[3] See, for example, Manfred B. Steger, *Globalization, A Very Short Introduction*, Oxford, 2003

[4] GM revenues from GM investor relations, HP revenues from Fortune Magazine, http://money.cnn.com/magazines/fortune/fortune500/2008/snapshots/206.html; Intel Revenues from Intel investor relations

[5] www.engineeringchallenges.org

[6] Grandin, J. M. and E. D. Hirleman, "Educating Engineers as Global Citizens: A Call for Action," Report of the National Summit Meeting on the Globalization of Engineering Education, March, 2009. Can be accessed at: //digitalcommons.uri.edu/ojgee/vol4/iss1

[7] Parkinson, A. R., J. N. Harb, S. P. Magleby, "Developing Global Competence in Engineers: What Does it Mean? What is Most Important?", *Proceedings ASEE Annual Conference and Exposition*, Austin TX, 2009.

[8] A. Parkinson, C. G. Jensen, H. Zaugg, and S. Magleby, "Developing Global Competence Through Cross-Cultural Virtual Teams: Preliminary Observations," *Proceedings ASEE Annual Conference and Exposition*, June 21-23, 2010.

[9] Jarvenpaa S. L. and D. E. Leidner, "Communication and Trust in Global Virtual Teams," *Organization Science*, Vol. 10, No. 6, 1999, pg. 791-815.

[10]N. C. Giullian., Jensen, C.G., McCammon, J. and Brooks, B., "Hosting/Participating in Global Collaborative PACE Projects," *Proceedings, ASEE Annual Conference and Exposition*, June 24-27, 2007, Honolulu, Hawaii.

[11]Webster, M.J., Korth, D. and Jensen, C.G., "PACE Global Vehicle Collaboration," *Proceedings ASEE Annual Conference and Exposition*, June 24-27, 2007, Honolulu, Hawaii.

[12]Carlson, O.J., Webster, M.J. and Jensen, C.G., "Multinational Design: Keys to Incorporating Multinational Design," *Proceedings ASEE Annual Conference and Exposition*, June 24-27, 2007, Honolulu, Hawaii.