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# Global Virtual Teams: A New Frontier for Capstone Design*

ALAN PARKINSON, HOLT ZAUGG and ISAKU TATEISHI
Brigham Young University, Provo, UT 84604 USA. E-mail: parkinson@byu.edu, zauggh@gmail.com, isaku80@gmail.com

As engineering becomes more global in nature, engineering design is increasingly being accomplished through global virtual (GV) teams. These types of teams are usually defined as being geographically dispersed, spanning several different countries and time zones, being composed of team members with little prior association, and communicating through electronic means. GV teams overlay a number of new challenges on top of the usual challenges for design teams. This paper will review some of the efforts taking place at universities in the U.S. with GV teams, including our own experience. We propose a 'three ring' Venn diagram as a framework for understanding the issues associated with GV teams. We discuss these rings in some detail and provide recommendations for establishing successful GV teams.

**Keywords:** global virtual teams; cross-cultural teams; global engineering; global competence

## 1. Introduction

The changes that are transforming the practice of engineering include the ability to communicate in real time anywhere in the world, the prominence of international markets, the development of global product supply chains, the shift to offshore manufacturing, the scale and reach of multi-national corporations, and the emergence of skilled engineering workforces around the world.

One example of these changes on product development is the BlackBerry Torch 9800 Smartphone, introduced in August 2010. The circuit board of the phone contains a power management chip from the United States, memory chips from Korea, a GPS receiver from the United Kingdom, RF transceivers from Germany and Japan, an application and communications processor from the United States, and a video/image processor from Switzerland [1]. Thus at least six countries supply different chips for the circuit board alone. The country count goes higher when other parts not on the circuit board are included (plastic and sheet metal parts, battery, touch screen, etc.). This is clearly a global product—assembled from international parts and for sale in international markets. A number of other examples from different disciplines have been presented elsewhere [2].

The development of global products is often accomplished through global teams. These may be 'physical' or 'virtual' teams or some blend in-between. A physical team implies the team members, who may be from various countries, are co-located and work together face-to-face. In a virtual global team, team members interact through various means of electronic communication. Blends of these paradigms also exist; for example, team members may travel to be together at the beginning or end of the design project and work as a GV team in between. In this paper we focus on virtual teams.

To work effectively on virtual teams, engineers need an expanded skill set. Some of these skills are related to the global aspect of the team, such as avoiding ethnocentrism, communicating across cultures, and understanding the impact of culture on how engineering processes are executed, and some are related to the virtual nature of the team, such as choosing the right form of electronic communication for the task, managing electronic files across geographically dispersed groups, and building trust when face-to-face meetings are not possible.

For the past three years, faculty at Brigham Young University (BYU) have been engaged in GV teams. Building on those efforts, we recently initiated a National Science Foundation sponsored research program to develop and assess the effectiveness of GV Teams. In this paper we explore the use of GV capstone design teams as a means to accomplish two objectives: 1) to familiarize students with what is becoming, more and more, a standard industry practice, and 2) to develop in students important elements of global and virtual team competence.

We will first review some of the advantages and disadvantages of GV teams. We then will present some GV activities at various universities. We present a Venn diagram as a framework for understanding the issues associated with GV teams and provide some recommendations for establishing successful GV teams

## 2. GV teams in capstone design: advantages and challenges

We believe the virtual teaming approach as a model for capstone design has the following potential advantages:

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- Students have an opportunity to become familiar with a design approach being adopted by industry. As companies become more global and tools for collaboration become more sophisticated, companies are increasingly using GV teams for product development. The authors recently experienced this first hand. At visits to Hewlett Packard and Cisco systems in Bangalore, India, both companies were using their own conference systems to conduct design meetings with teams in the U.S.
- While learning the design process, students can also develop some global skills. Specifically, students can develop some level of proficiency working in or directing a team of ethnic and cultural diversity, learn how to communicate across cultures and understand how cultural differences affect how engineering tasks are performed. GV teams, by their nature, involve activities that force students to address these issues.
- GV teams can be incorporated into existing design courses. This approach is one way to introduce students to global issues that can be integrated within the existing curriculum. Other ways of developing global competence, such as study abroad programs, can be quite resource intensive. However, we should point out we view this experience as complementary to, and not a replacement for, other means of teaching global skills.

Certainly this approach also has its challenges. Besides the regular challenges faced by a design team, virtual 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 virtual team must overcome the substantial limitations of electronic communication. Developing individual commitment and trust among team members and establishing role definitions may be more difficult in a virtual team [3].

## 3. GV Teams at U.S. Universities

This section reviews some of the GV activities being conducted with universities in the United States. The intent of this section is to highlight present efforts to use GV teams in engineering education. It is likely there is a lot of activity that we do not yet know about or that has not been reported in the literature. In most cases assessment of these activities is not reported.

The University of Colorado conducted a GV team with students at the University of Stuttgart in Germany and University of Sydney in Australia. The objective was to develop a blended wing body aircraft with a hybrid power plant [4].

The University of Idaho has partnered with the Ecole Nationale d'Aerotechnique in a CATIA-based solid modeling course [5]. Students at the two locations developed a virtual prototype of an assembly. Some students at each school acted as 'part owners' and were responsible for all part-level changes. Sub-assembly managers checked for errors in part design and for assembly problems and reconciled problems among the part owners. A student acting as lead engineer coordinated the work of the sub-assembly managers. The project was a model of a toy snowplow made up of many dozens of parts. Communication took place through Skype video conferencing with email backup.

Purdue University students teamed with the Lucerne University of Applied Science and Arts to enter the 'Darwin21' design competition [6]. The objective of the competition was to develop a robotic device capable of displaying five different types of emotions. Students from Lucerne traveled to Purdue at the start of the project to get acquainted and finalize team assignments, and students from Purdue traveled to Lucerne at the end of the project to assemble and debug hardware. The international team placed first among university teams at the competition.

Oregon State and Duale Hochschule Baden-Wurttemberg-Ravensburg in Germany used GV teams to develop two identical Formula SAE race cars [7]. The Oregon State team placed first in the competition held in Michigan and then raced with their German counterparts in Europe. One of the challenges for the Oregon State students was to design and build the cars completely in the metric system. The students collaborated using Skype and email, and used Google documents to share documents.

At University of Detroit Mercy, student teams in an undergraduate controls class were matched with Brazilian students from the Federal University of Minas Gerais [8]. Students completed a controls systems design project that included specification, modeling, analysis and design. The semester mismatch of more than a month was accommodated by adjusting what part of the project each local team was responsible for. The U.S. students also received instruction on globalization and cultural awareness in an accompanying one credit course. Communication was primarily through email. Interestingly, students felt that the international collaboration enhanced their learning of the technical material through exposure to real world solutions and learning from mistakes.

Syracuse and Cornell Universities are using a custom collaborative environment called 'AIDE' (Advanced Interactive Discovery Environment for

Engineering Education) to evaluate virtual design teams for engineering design education [9]. They have found that with proper training and the right collaborative tools, some elements of virtual teams are better than face-to-face meetings. In particular, they indicate that for scheduling, brainstorming, document creation, confirmations, task assignments and distribution of outcomes, 'computer mediated collaboration' is judged by participants to be superior to regular face-to-face meetings.

The Pennsylvania State University (PSU) has several GV activities underway. The Department of Mechanical and Nuclear Engineering has joined with Shanghai Jiao Tong University and Tyco International to implement a virtual design experience [10]. Student teams of 2–3 at each site worked on one of two projects sponsored by Tyco. Prior to the start of the project, faculty at the two universities prepared a detailed schedule, including major video conference dates. The students communicated almost daily using email; Adobe Connect was used for video conferences. Students used a common electronic depository for their files. Students 'delivered technically excellent solutions to their respective projects'. Although not originally planned for, the sponsor provided support for the teams to meet at the end of the project. In post program interviews students reported the experience improved their ability to communicate, helped them develop an appreciation of ethnic and cultural differences, and increased their desire to work in an international environment.

PSU also runs an international design and entrepreneurship course involving virtual teams from PSU and Corvinus University of Budapest [11, 12] The experience begins with a four week class in international project management and engineering design. Students review case studies and discuss the challenges associated with cross-cultural project and team management. After four weeks the student teams make contact with each other (the four week offset is because the semester in Hungary starts one month later) using both in and out of class meetings. The projects focus on finding sustainable and economically viable solutions for business opportunities in the U.S., Hungary, or developing countries such as Morocco or Afghanistan. At the end of the semester, the teams meet for one week in Hungary to present their project recommendations.

Penn State Brandywine has formed international teams with members of the Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) [13]. Teams work on collaborative design projects for about five weeks, which takes them through the conceptual phase of the design process. An example project is developing portable housing for refugees. After looking at a number of collaboration software tools, they decide to use a tool called 'Collaber' for project management and coordination tasks.

Rice University implemented a course, called 'iDesign,' which involved pairing student teams from Houston, Paris, Tokyo and Abu Dhabi on projects involving oil well inspection and monitoring equipment [14]. The course was sponsored by Schlumberger Oil Services. At each location a faculty member and a Schlumberger liaison engineer advised the student teams. Students collaborated using audio and video conferencing, shared documents and CAD files. All students participated together in one lecture per week; the project lasted the entire school year. At the end of the project, students gathered at Schlumberger's Middle East Learning center in Abu Dhabi to assemble their hardware and present their projects. Challenges of the project included 'working in four different time zones, negotiating cultural differences, communicating across language barriers, dealing with incompatible school calendars and delivering functional prototypes under tight time constraints'.

Virginia Tech has had a number of GV activities over the past five years [15]. These have included several two-semester senior capstone design projects with international teams. One such project, conducted with students from VT and ITESM Monterrey in Mexico and called 'CarTec', was to design and build a vehicle for young professional women in Mexico City. Another project, also with ITESM Monterrey, was to design and build fixtures for automotive carpets and soft door panels. As a member of the Partnership for the Advancement for Collaborative Engineering Education (PACE), an industry-university consortium led by General Motors, VT students have collaborated with students from Tuskegee University, Michigan State University, BYU, ITESM Monterrey, ITESM Toluca and University of São Paulo in Brazil. VT also teaches a course on global collaborative engineering design with colleagues from Technische Universität Darmstadt, Howard University, ITESM Monterrey and Shanghai Jiao Tong University. The team projects for the course are presented to a live, global panel of automotive experts from GM, BMW, Mercedes-Benz, Continental and Siemens.

Brigham Young has been involved with several international collaborations also as member of PACE [16–18]. 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. The following year, thirteen universities formed several global design teams involving 130+ students from eight countries. These partnerships resulted in the creation and

analysis of four concept cars. The resulting one-fourth scale clay models were displayed in the lobby of GM's Vehicle Engineering Center. During the next three years, students from twenty universities, speaking eight different languages, and spanning sixteen time zones participated in the creation, testing, and building of a Formula-1 racecar.

BYU currently is teaching an advanced CAD modeling course where students complete projects with student teams from the University of British Columbia, ITESM Toluca, Universidad Iberoamericana, University of Connecticut, Wayne State University, Hongik University, Tongji University and University of São Paulo [19]. Two senior design capstone projects are also being carried out with students from the National University of Singapore. Students are learning about GV issues by taking an accompanying 'backpack' course, taught using a virtual format. Students for the capstone projects are using Skype, Adobe Connect and Google documents to collaborate.

## 4. GV team skills

GV teams are created from the blending of qualities and traits of three different areas: teaming skills, cross-cultural skills and virtual communication skills, as shown in Fig. 1. Each of these areas requires its own set of skills. A GV team, however, requires the ability to apply all of these skills as an integrated set. In this section we will briefly discuss some of the important skills associated with each ring in Fig. 1. We will start with the Cross-Cultural ring, move to the Virtual Communication ring, and then make a few comments about the Teaming Skills ring. Papers which include discussion of many of these topics include Powell et al. [20] and Martins et al. [21].

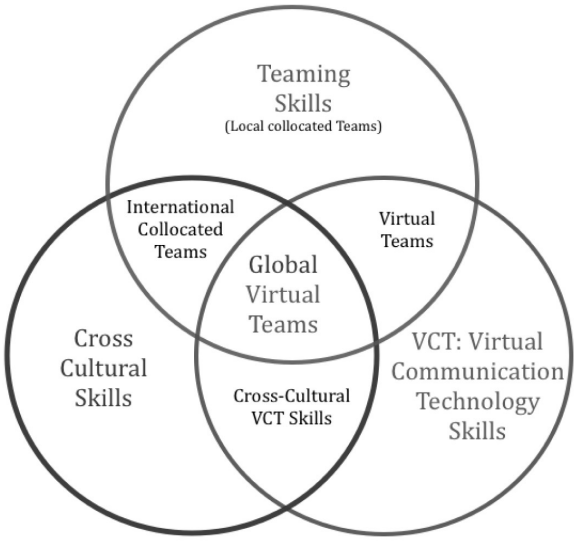


**Fig. 1.** Blending of Team, Cross-cultural, and Virtual Communication skills.

### *4.1 Cross cultural skills: avoiding ethnocentrism and developing cultural intelligence*

Many of the skills needed to be successful in a cross-cultural setting rely on some foundational knowledge and attitudes. One of these is understanding and avoiding *ethnocentrism*, the notion that one's own culture is superior to all others. 'All cultures, to some degree, display ethnocentrism, which can be the greatest single obstacle to understanding another culture' [22]. Engineers may be susceptible to a particular form of ethnocentrism: the assumption that if their country is more technologically advanced, their culture must be superior.

Ethnocentrism is an attitude to be avoided; on the positive side is the skill of developing high *cultural intelligence*. Cultural intelligence refers to the ability to interpret the actions of team members in terms of their own culture.

### *4.2 Cross cultural skills: understanding contrasting cultural values*

One key to developing high cultural intelligence is to understand *contrasting cultural values.* Cultural values can have a strong effect on how team members work together. Several scholars have proposed frameworks that can be used to categorize contrasting cultural values [23–26]. Although these frameworks are somewhat simplified, they can be useful to help students understand how culture may affect team operation. We list five dimensions representing a spectrum of contrasting cultural values.

#### *4.2.1 Collective vs. individual*

This dimension represents how much emphasis a society places on individuals and groups. In the collective culture, the needs and interests of the group take precedence. Individuals are defined by their membership in a group, and each individual is assumed to have responsibilities and duties within the group. Societies with a strong individual ethic emphasize personal development, individual credit, and personal autonomy. The U.S. tends to be more individually oriented, whereas Asian countries are often more collectively oriented [27].

#### *4.2.2 Equality vs. hierarchy*

This dimension deals with societal expectations regarding how people interact with each other. Societies with strong hierarchical structures have high status differences, respect for titles, little delegation of authority and formal social relations. Cultures with weak hierarchies tend to have low status differences, high delegation of authority, little respect for titles and informal social relations.

Hofstede referred to this value as 'Power Distance' [27]. The U.S. tends to have more of an equality orientation in social interactions, whereas Asian countries are often more hierarchical in nature.

#### *4.2.3 Precise vs. loose reckoning of time*

This dimension refers to how a culture approaches time. Cultures with strict reckoning of time value punctuality, clear schedules, advanced planning and focus on the critical path. Cultures with a loose reckoning of time may be less punctual, favor less rigid schedules, and emphasize multiple paths to the solution.

#### *4.2.4 Tolerance of risk and uncertainty*

This dimension refers to how comfortable a culture is in accepting uncertainty and risk. In a culture with a high toleration of risk, accepting risk is viewed as a way to achieve success. Also, it may be acceptable to bend or break rules. In cultures with low toleration of risk, it may be important to follow rules, and avoiding risk is viewed as a way to avoid failure.

#### *4.2.5 Doing/being orientation*

This dimension deals with how a society views work and competition. A 'doing' society is highly competitive, favors achievement of goals, is task oriented, and 'lives to work'. A 'being' society is more cooperative, favors development of relationships, values nurturing, and 'works to live'.

#### *4.2.6 Implications of contrasting cultural values*

The cultural values listed above are generalized but represent useful constructs for understanding cultural differences. All of these values influence how team members interact and how they interpret and execute tasks. For example, people from a collectively oriented culture might be taken aback by the passionate discussions of people from a more individually oriented culture.

Understanding cultural differences can help students understand the context of how a team member responds. However, it may be advantageous to adopt a particular set of values as a way for the team to move ahead. For example, engineering projects often run more smoothly and efficiently if a team decides to adopt a precise reckoning of time. Thus it isn't the case that all cultural values are considered equally valid for accomplishing the team's work; rather, differing cultural values are acknowledged and recognized and team members agree to adopt a set of values to make their work easier.

### *4.3 Cross-cultural skills: communication*

Effective communication is a cornerstone of any team's success and can be challenging for a co-located team. On a design project of any size, hundreds if not thousands of decisions must be made and coordinated. Besides these normal challenges, virtual cross-cultural teams have their own set of communication issues associated cross-cultural communication and virtual communication technology. We have separated them here for the purposes of discussion.

#### *4.3.1 High context vs. low context communication*

An important concept in cross-cultural communication relates to high vs. low context communication, as discussed by Hall [28]. In high context communication cultures, social settings and background information play a significant role. High context cultures are more sensitive to how messages are presented. Establishing a relationship of trust is a high priority. Negative comments are often expressed in abstract and obscure ways. In a low-context communication culture, people pay less attention to contextual conditions and emphasize the message. Communication is direct, perhaps even blunt. Task completion or goal achievement is more important than the working relationship. In expressing negative comments, people from a low-context culture tend to use direct language. The U.S. tends to be a low context communication society [28]. Students need to realize, however, that messages they feel are clear and to the point may actually offend students from a high context society.

#### *4.3.2 Saving face*

Another major issue regarding cross-cultural communication relates to saving face. 'Face' refers to one's public reputation and image. In many cultures, it is desirable to protect an individual's good social image. In order to protect the face of others, people may avoid giving feedback, discussing conflicts or saying no. In a recent symposium, an American engineer in China related how he experienced a number of communication misunderstandings with his Chinese counterparts. When he visited with them one-on-one, he realized the misunderstandings were directly related to saving face. Only by one-on-one discussions, when they were willing to be more open, was he able to understand what the real issues were regarding the problem he was trying to solve [29].

A critical situation of saving face often occurs when communication involves the use of a second language. Second language speakers often feel guilty or embarrassed when they do not understand a conversation. In order to save face, they often pretend that they understand what is said. It therefore becomes incumbent upon the primary language speakers to make allowances for second language speakers. Since GV teams usually operate in Eng-

lish, U.S. team members must be sensitive to the fact their counterparts may not understand everything which is spoken, but may be reluctant to say so. One team solved this problem by repeating important communications in email or in text messages.

#### *4.3.3 Equality vs. hierarchy and communication*

In terms of communication, people from low-power distance cultures feel they can talk openly with people of higher status, such as their supervisor or team leader, even challenging the team leader's opinions or ideas. People from high-power distance cultures may feel uncomfortable or even offended by such actions. Even though they may disagree, people from high-power distance cultures tend not to speak up. As an interesting example, this issue has been a critical factor in communication between a pilot and co-pilot in commercial aircraft. In high power distance cultures, the co-pilot was less willing to question the pilot's actions even when it was clear the pilot was making a mistake, leading to a higher rate of accidents [30].

There are other cultural communication issues, such as how much emotion is acceptable in a conversation, how to deal with silence, and the subtleties of non-verbal communication. It is crucial for students to understand that there are fundamental differences in how people communicate that are driven by culture. *Communication follows culture.*

### *4.4 Virtual communication skills*

In addition to issues associated with cross-cultural communication, with GV teams there are also issues related to virtual communication. At the most basic level, students need to have the ability to use technology to communicate. This includes texting, email, audio calls, one-on-one video conferencing, and team video conferencing using any number of commercial software products. In addition, team members need to be able to share presentations, written documents and electronic files.

Besides just the ability to use these tools, however, students need to understand their appropriate use. This leads to the concept of media richness.

#### *4.4.1 Media richness*

In using technology, students need to understand the concept of media *immediacy* or *media richness.* These terms refer to the ability of a technology to replicate the communication that occurs in a face-to-face meeting. Technologies with low media richness can only transmit a message (e.g., e-mail). Technologies with high media richness can transmit some emotion and intent including nonverbal communication (e.g., video conferencing). After reviewing several studies regarding media richness, Martins et al. concluded that high media richness positively impacts team effectiveness, amount of communication, the relationships among team members, and team commitment [21].

For a GV team, this means there may be times when email is not the appropriate communication tool. In particular, if it is important to carefully explain the reasoning behind a decision, including to express empathy or support, or to modify communication based on the reaction of the abroad team, a richer communication technology would be more appropriate, as it allows team members to better explain to and experience the reactions of their abroad colleagues and respond accordingly.

### *4.5 Teaming skills*

Since being able to be an effective member of a team is a required accredited outcome for all engineering programs, we assume students are already receiving instruction and practice in teamwork. However, GV teams require additional or enhanced teaming skills related to the cross-cultural and virtual aspects of a GV team. We will only briefly touch on some of the additional skills here.

#### *4.5.1 Team leadership*

Because of the additional challenges associated with the virtual format, leadership in virtual teams is critical. Jarvenpaa and Leidner, in their seminal paper on communication and trust in virtual teams, mention that the leader in the high performance student teams they studied emerged 'after an individual had produced something or exhibited skills, ability, or interest critical for the role. Moreover, the leadership role was not static but rather rotated among members, depending on the task to be accomplished' [3]. In other words, the leader first demonstrated competence to lead the team and established some credibility. They further mention that leaders need to insure that team members have a clear understanding of their responsibilities and should be proactive in maintaining high levels of communication. Also, in successful, high trust teams, leaders were able to remain calm during 'crises' and keep the team moving forward.

Susan Bray, a consultant on virtual teams, gives some 'habits of highly successful globally distributed team leaders' [31]. These include modeling an intercultural mindset, creating a shared vision and alignment to common goals, facilitating agreement about roles and responsibilities, adopting effective collaboration tools, establishing communication protocols, building a sense of team spirit and community, and attracting resources for the team.

#### *4.5.2 Building trust*

As mentioned earlier, it is often harder to develop

trust among team members in a GV team because of the physical and cultural separation of team members. Jarvenpaa and Leidner identify several communication behaviors that help virtual teams build trust and work effectively [3]. Early in the team formation and task initiation it is helpful if teams engage in social communication (e.g., discussion of hobbies and families), and convey enthusiasm for the work. Later on, their research suggests successful teams have predictable and regular communication patterns and give substantial and timely responses to each other's work.

## 5. Enhancing GV team skills

In the previous section we presented some skills associated with the cross-cultural and virtual nature of GV teams. In this section we would like to discuss how these skills might be better developed beyond just letting the teams run without any intervention. A main tenet of our work is that *learning in the GV team format can be maximized by designing in appropriate instruction and exercises*. We note that the recommendations made here are incomplete as our study of GV teams is on-going.

One approach to GV teams is to just put the students together and let them run. This actually works out pretty well. Engineering students tend to be very task-oriented, and they will figure out a way to get their work done. They will find they share much in common with other engineering students around the world. They will likely develop a good solution to the design problem.

However, we believe they will miss some of the subtleties of their interaction with abroad teams and miss opportunities to enhance their global skills if they aren't attuned to picking up clues. For example, unless students are aware of the contrasting cultural values given in the previous section, they are likely to miss their influence in team operations. They may, for example, write emails that are insensitive to the cultural values of their colleagues without knowing they are doing this. Their colleagues may not bring this to their attention for the sake of getting along or to allow them to save face.

### *5.1 Instruction*

Not surprisingly, it has been found [20, 21] that GV team performance improves when GV teams are given instruction in cross-cultural interaction and effective use of communication technology. A difficulty arises in squeezing this into a course already crowded with engineering topics.

#### *5.1.1 A 'Backpack' course*

One approach taken at BYU and other schools is to offer a concurrent seminar to the design course that tries to provide 'just-in-time' instruction. At BYU we refer to this as a 'backpack' course. The course meets just once a week, and it covers many of the issues discussed in this paper. The course topics, as given in Table 1, provide a broad overview of team issues and challenges resulting from participation on a GV team. This approach connects directly to the students' experience while working on their project.

We offered this seminar for the first time during fall semester 2010. The course was taught synchronously to students at BYU and students at the National University of Singapore. This allowed for interaction between local and international students in a classroom setting and set the stage for further interactions outside of class and in team activities. The assignments required students to practice both cross-cultural and virtual communication skills.

#### *5.1.2 Some suggested resources*

Much of our backpack course has been developed based on the materials presented here. We would be pleased to share our materials with others. We mention two external resources we have found to be helpful.

First, we have found CultureGrams™ to be useful in this kind of setting. CultureGrams are a very condensed overview of the culture of a country. In four very dense pages, they discuss topics such as Language, Religion, Personal Appearance, General Attitudes, Greetings, Gestures, Visiting, Eating, Family, Dating and Marriage, Life Cycle, Recreation and Holidays. Originally developed at BYU for missionaries, CultureGrams are now widely sold to

**Table 1.** List of topics taught in the ME 495R: Principles of Global Virtual Teams

| | |
|---|---|
| 1 | Introduction: the globalization of engineering |
| 2 | Virtual Communication Technology: how to use various communication technologies |
| 3 | Team Start-up Processes: establishing swift trust |
| 4 | Contrasting Cultural Values: power distance, collective vs. individual societies, precise vs. loose reckoning of time, etc. |
| 5 | Cross Cultural Communication: high and low context societies, saving face, non-verbal communication etc. |
| 7 | Virtual Communication: media richness and immediacy, appropriate use of technology |
| 9 | Leadership in GV teams: leadership, team roles and processes |
| 10 | Building Trust: how can GV teams overcome the limitations of separation and build trust among team members |
| 11 | Decision Making in GV teams |
| 12 | Cross-Cultural Engineering Practices |
| 13 | Cross-Cultural Product Design |

corporate executives by an external company [32]. We have used them successfully in an exercise where students trade CultureGrams with their counterparts abroad and then discuss how accurate they are as a representation of their country's cultural attitudes and values.

A second resource we wish to mention are numerous materials posted on the 'Global Hub' maintained by Purdue University [33]. Global Hub is a repository for materials relating to globalization which are freely shared. For example, there is an excellent set of videos developed by Downey et al. on how culture affects engineering practices [34].

Following the recommendations of Bray, we also suggest that teams execute a communications 'contract' which spells out expectations for communication, such as 'Everyone will attend all meetings, will be on time, and will stay for the entire meeting,' and 'Everyone will check and respond to emails within 24 hours' [31].

### *5.2 Preliminary findings*

Data collection for our research is underway but not complete. Nevertheless, preliminary data from the advanced CAD modeling course suggests promising results. Students expressed a strong desire (85%) to work again in a similar international environment. Students felt that course materials and learning activities greatly improved their ability to communicate across cultures (83%). As examples, students indicated they adjusted their interactions to be more formal or casual based on the culture of the abroad students on their GV team. Students monitored their use of slang and jargon to improve interactions and understanding with other team members. Often students would follow up with text messages or email to make sure oral conversations were understood. Team projects for the GV teams were evaluated to be of the same or slightly higher quality than non GV (local) teams.

Students also learned to use virtual communication tools in ways that modeled successful collocated teams. For example, initial meetings using Skype had the local and abroad team members addressing concerns and questions only through their respective team leaders. Within a few weeks all team members began addressing each other directly. Several teams employed two or three technologies during team meetings (i.e. Skype, texting, document sharing, etc.) to facilitate stronger communication and understanding.

## 6. Logistics

There are some issues in managing GV teams that are associated with logistics. We will focus here primarily on administrative issues. These include:

- Semester Mismatch. One of the greatest impediments to academic GV Teams is semester and/or holiday mismatch between schools. For example, whereas U.S. schools may start their semester at the beginning of September, European schools often start in the middle of October; this makes completing a project difficult. It is can be very difficult for schools in the northern hemisphere to do GV projects with schools in the southern hemisphere due to a total misalignment of seasons—students in one hemisphere are in their summer break while other students are in the middle of their semester.
- Careful Preplanning. Because of semester mismatch, success is facilitated and frustrations lessened if the instructors on each side get together before class starts to plan out how the mismatch will be addressed and to correlate calendars and design reviews.
- Commitment of Students. Students need to be taking the course for credit. If students at one location are not being graded, in general they do not have the same commitment to the experience as students in other locations. Since they are depending on each other, this lack of commitment drags down the whole team.
- Commitment of Faculty. Faculty who advise GV teams need to be committed to this experience. 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 Administration. Without the support of the administration, efforts on the part of faculty to implement global competencies and skills will quickly wane. Global design experiences require more effort on the part of faculty members involved. These efforts need to be understood, appreciated, and factored into the faculty member's load. The required resources (teaching assistants, graders, access to facilities) must be made available.
- Common CAD Tools. In our experiences thus far, schools have 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.
- Managing Complexity. A GV team is more complex than a regular team. It is therefore helpful to reduce or manage complexity where possible. For example, we have found that it is easier if we limit the global teams to students from two locations, instead of three or four. In getting things off to a

good start, practice meetings should be held where the communication technology can be tested and debugged. Something as simple as people turning off their microphones to eliminate feedback can be worked out in advance.

## 7. Economic considerations

As discussed in Section 3 on GV activities in the United States, there are two main formats for GV teams which significantly affect the economic expense of a GV team: GV teams that travel at either the beginning or end of their design experience, and GV teams that do not travel.

If travel is not part of the experience, then GV teams can be quite inexpensive in terms of direct costs. In the case of BYU, although we provided more capable software, students gravitated to Skype for personal and team video conferencing because of ease of use. Text messaging also occurred in Skype, I-chat and Google chat lines. Document sharing was achieved through e-mail or Google docs. While many of these offer higher functionality for a cost, they also offer free use with limited, but adequate space for the virtual communication needed on a GV team. In some cases, large CAD files were shared using a commercial product for which both the local and abroad universities already had a license.

Travel for a GV team obviously raises the cost significantly, both in terms of time and expense. Anecdotal evidence suggests this travel can have a significant effect on the overall experience. The impact of meeting face-to-face at the beginning or end of the team project is something which needs to be studied.

## 8. Summary

In this paper we have discussed the operation of Global Virtual (GV) teams. GV teams are geographically dispersed, span several different countries and time zones, are often composed of team members with little prior association, and communicate through electronic means. GV teams overlay a number of new challenges on top of the usual challenges for design teams. As engineering design becomes more global in nature, GV teams are becoming more prevalent. They also are a means of providing students with an international engineering experience and with the opportunity to learn some global skills.

A GV team involves the integration of three types of skills: Teaming skills, Cross-cultural skills, and Virtual communication skills. We have discussed some specific knowledge and skills that students should learn to help them be successful and to develop cultural intelligence. A main assumption of the paper is that a relatively small amount of additional instruction can help maximize the learning of this design format for students.

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## References

1. Piece by Piece: The Suppliers Behind the New BlackBerry Torch Smartphone, *Wall Street Journal*, August 17, 2010.
2. A. Parkinson, The Rationale for Developing Global Competence, *Online Journal for Global Engineering Education*, Vol. 4, Issue 2, 2009.
3. S. L. Jarvenpaa and D. E. Leidner, Communication and Trust in Global Virtual Teams, *Organization Science,* **10**(6), 1999, pp. 791–815.
4. J. Koster, E. Serani, A. Velazco, T. Wiley, C. D. Munz, H. Kurz, E. Kramer, K.C. Wong, K. Lehmkuehler and D. Verstraete, HPYERION: An International Collaboration, *Proceedings of the 7th International CDIO Conference,* Technical University of Denmark, Copenhagen, June 20–23, 2011.
5. J. McCormack and S. Beyerlein, Email to author, University of Idaho, June 2010, and Sep 2010. See also http://www.webs1.uidaho.edu/mindworks, Accessed 26 February 2011.
6. J. Richardson and G. Blackwell, International Collaboration Through the Swiss Darwin21 Design Competition, Paper AC 2010–1281, *Proceedings ASEE Annual Conference and Exposition*, Louisville, Kentucky, June 20–23, 2010
7. See http://www.wired.com/autopia/2010/07/global-formula-racing/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+wired%2Findex+%28Wired%3A+Index+3+%28Top+Stories+2%29%29 (Accessed August 2010).
8. R. Hill and P. Pena, International Collaboration in an Undergraduate Control Systems Course, Paper AC 2010–224, *Proceedings ASEE Annual Conference and Exposition*, Louisville, Kentucky, June 20–23, 2010
9. D. J. Rick, B. D. Davidson, J. F. Dannenhoffer and G. Gary, Improving the Effectiveness of Virtual Teams by Adapting Team Processes, *Computer Supported Cooperative Work,* **16**, 2007, pp. 567–594.
10. M. Trethewey, C. Li and P. Piccolomini, A University-Corporate Partnership to Deliver a Global Engineering Experience, *ASEE 9th Global Colloquium on Engineering Education*, Paper GC 2010-48, Singapore, Oct 2010. Also email from Leland Engel to author.
11. R. J. Schuhmann, Preparing Engineering Students to Lead International Collaborations (Submitted for publication, *1st Global Colloquium on Project Oriented Engineering Education*, October 2009, Technische Universität Berlin, Berlin, Germany)
12. R. J. Schuhmann and S. Zappe, Invited paper, Shaping the World: Teaching Global Leadership Skills to Engineers, *ASEE Global Colloquium*, Cape Town, South Africa, October 2008
13. I. Esparragoza, R. Mejia and C. Rodriguez, Collaborative Tools for Global Design Project Management: Case Study of an Academic Experience, Paper AC 2010-433, *Proceedings ASEE Annual Conference and Exposition*, Louisville, Kentucky, June 20–23, 2010.
14. See http://www.scribd.com/doc/22487928/Rice-Engineering-Magazine-Fall-2009 See page 26 (Accessed August 2010).
15. J. H. Bøhn, E-mail to author, September 2010.
16. N. C. Giullian, C. G. Jensen, J. McCammon and B. Brooks, Hosting/Participating in Global Collaborative PACE Projects, *Proceedings, ASEE Annual Conference and Exposition*, June 24–27, 2007, Honolulu, Hawaii.
17. M. J. Webster, D. Korth and C. G. Jensen, PACE Global

Vehicle Collaboration, *Proceedings ASEE Annual Conference and Exposition*, June 24–27, 2007, Honolulu, Hawaii.
18. O. J. Carlson, M. J. Webster and C. G. Jensen, Multinational Design: Keys to Incorporating Multinational Design, *Proceedings ASEE Annual Conference and Exposition*, June 24–27, 2007, Honolulu, Hawaii.
19. A. Parkinson, C. G. Jensen, H. Zaugg, S. Magleby, Developing Global Competence Through Cross-Cultural Virtual Teams: Preliminary Observations, *Proceedings ASEE Annual Conference and Exposition*, June 20–23, 2010, Louisville, Kentucky.
20. A. Powell, G. Piccoli and B. Ives, Virtual Teams: A Review of Current Literature and Directions for Future Research, *DataBase for Advances in Information Systems,* **35**(1), Winter 2004.
21. L. L. Martins, L. L. Gilson and M. T. Maynard, Virtual Teams: What Do We Know and Where Do We Go From Here? *Journal of Management*, **30**(6), 2004, 805–835.
22. G. Ferraro, *The Cultural Dimension of International Business,* Pearson, Fifth Edition.
23. E. T. Hall, *Understanding Cultural Differences*, Yarmouth, ME: Intercultural Press, 1990.
24. G. Hofstede, Culture's Consequences: International Differences in Work-Related Values, Thousand Oaks, CA: Sage Publication, 1980.
25. R. J. House, P. J. Hanges, M. Javidan, P. W. Dorfman and V. Gupta, *Culture, leadership and organizations: the GLOBE study of 62 societies*, Thousand Oaks, CA: Sage Publication, 2004.
26. F. Trompenaars and C. M. Hampden-Turner, Riding the Waves of Culture: Understanding Cultural Diversity in Global Business, 2nd ed. New York: McGraw-Hill, 1998.
27. G. Hofstede, Cultures and Organizations: Software of the Mind, New York: McGraw-Hill, 1991.
28. E. T. Hall, *Beyond Culture*, Garden City, NY: Anchor Books, 1976.
29. D. Brown, National Oil Well Varco, relating his experiences as a manager of an oil rig manufacturing operation, 13th Annual Colloquium on International Engineering Education, Nov. 2010.
30. M. Gladwell, *Outliers, The Story of Success,* Little, Brown and Company, 2008.
31. Bray, Susan, Meeting the Challenges of Cross-Cultural Virtual Work Teams, Workshop presented at 12th Annual Colloquium on International Engineering Education, Oct 2009. Contact: suebray@mindspring.com
32. CultureGrams, ProQuest. See www.culturegrams.com, Accessed 26 February 2011.
33. See www.globalhub.org, Accessed 26 February 2011.
34. G. Downey, Engineering Cultures Online. Global Hub, https://globalhub.org/resources/engineeringculturesonline2.0, Accessed 26 February 2011.

**Alan R. Parkinson** was appointed dean of the Ira A. Fulton College of Engineering and Technology in May 2005. Before his appointment as dean, he served as associate dean and also as chair of the Mechanical Engineering department. Dr. Parkinson received his M.S. and Ph.D. degrees from the University of Illinois and his B.S. and M.B.A. degrees from BYU. His research interests include optimization methods in engineering design, robust design, and international engineering education. Dr. Parkinson received the Design Automation Award in 2003 from the American Society of Mechanical Engineers for his work in robust design and design optimization. He was elected to Fellow status in the American Society of Mechanical Engineers in 2004.

**Holt Zaugg** is a doctoral student at Brigham Young University in the Educational Inquiry, Measurement and Evaluation program. His current research focuses on communication patterns of engineering students working on global, virtual teams and test item measurement analysis using Item Response Theory and Confirmatory Factor Analysis.

**Isaku Tateishi** is a doctoral candidate at Brigham Young University in the Instructional Psychology and Technology program. He currently researches the impact of group collaboration on creative thinking ability and how cross-cultural virtual collaboration improves competencies necessary to effectively work in the global working environment.