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Jay R. Goldberg
Marquette University, jay.goldberg@marquette.edu

Susannah Howe
Smith College

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Virtual Capstone Design Teams: Preparing for Global Innovation*

JAY GOLDBERG
Department of Biomedical Engineering, Marquette University, P.O. Box 1881, Milwaukee WI 53201, USA.
E-mail: jay.goldberg@mu.edu

SUSANNAH HOWE
Picker Engineering Program, Smith College, 151 Ford Hall, Northampton MA 01063, USA. E-mail: showe@smith.edu

Global innovation requires collaboration between groups of people located in different parts of the world, and is a growing trend in industry. Virtual teams are often used to manage new product development projects. These teams are similar to traditional teams but are geographically separated and rely heavily on virtual methods of communication (email, Skype, teleconferencing, etc.) instead of regular face-to-face meetings. Experience working as a member of a virtual capstone design team can help prepare students for this growing trend. To begin preparing students for work on virtual teams in industry, we co-advised two virtual capstone design projects with students from Marquette University and Smith College. This paper describes our experience with managing two virtual capstone design project teams across institutions. Presented here are the challenges we encountered, the lessons we learned as a result of this experience, as well our recommendations for others who might want to include virtual project teams in their capstone design courses. We also include retrospective feedback from the students on these teams regarding their perceived value of their virtual team experience to their careers in engineering.

Keywords: virtual teams; geographically-distributed teams; global innovation; capstone design

1. Introduction

Global innovation requires collaboration between groups of people located in different parts of the world and is a growing trend in industry. These teams are often referred to as virtual or geographically distributed teams. Virtual teams are defined as "small, temporary groups of geographically, organizationally, and/or time dispersed knowledge workers who coordinate their work, mainly with electronic information and communication technologies to carry out one or more organizational tasks" [1]. Often, team members from various departments of an organization who need to work together to design, develop, and introduce new products are not in the same location. For example, R&D personnel may be located in the United States, the production facility may be located in Ireland, and other key personnel may be located in Singapore. In this situation, a virtual team can be formed to complete the new product development project. Virtual teams are similar to traditional teams but are geographically separated and rely heavily on virtual methods of communication (email, Skype, teleconferencing, etc.) instead of regular face-to-face meetings.

In a recent industry survey conducted by Siemens Enterprise Communications, 79% of respondents stated that they always or frequently work in distributed teams [2]. The common use of virtual teams in industry is motivated by increased productivity, improved project outcomes, reduced relocation costs, and the ability to attract better employees [3]. In many companies, the specialized skills needed for new product development are often found in localized geographic areas of excellence scattered around the world. To access the needed skills and to bring them together to focus on projects, companies need to move from traditional face-to-face teams to virtual teams or use a combination of both [4, 5].

Management of virtual teams presents some unique problems resulting from cultural, language, and time zone differences, and geographic separation. The biggest challenges to virtual teams are developing trust and effective patterns of communication [6]. Since virtual team members cannot see their distant team members following through on commitments, they must trust that the work is getting done correctly and in a timely manner. Trust is difficult to develop if team members have never met each other in person. Geographic separation does not allow the informal social interactions needed to build trust and camaraderie among all team members.

In RW3 Culture Wizard's recent survey of global business professionals, the vast majority of respondents indicated that they had worked on virtual teams but only 16% received training to prepare them [7]. To prepare engineering students to con-

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tribute to global innovation projects in industry, experience with virtual teams during their undergraduate years would be helpful. The capstone design course can provide opportunities for students to gain experience with virtual teams (domestic or global). Zaugg, et al. state that "when completed correctly a global virtual team experience enhances the educational experience of students and prepares them for participation on global virtual teams in the workplace" [8]. The recent ASEE/NSF Report on *Transforming Undergraduate Engineering Education* [9] specifically endorses virtual teams as an opportunity for students to improve their cultural awareness and teamwork skills.

Virtual teams have been used in engineering design courses for many years. In 2001, Syracuse and Cornell Universities (both in upstate New York) began the Advanced Interactive Discovery Environment (AIDE) for Engineering Education project to create a virtual environment based on best practices of virtual, collaborative engineering environments [3, 10]. Their goal was to help facilitate successful outcomes of geographically distributed teams. AIDE was used as part of a two-semester, engineering capstone design course taught simultaneously at both institutions. The interactions of virtual teams consisting of students from Syracuse and Cornell Universities were studied, and technology effectiveness and team productivity were evaluated. Recently, St. Ambrose University (Iowa) and Sweet Briar College (Virginia) included collaborative projects, run by students from both institutions, in a pre-capstone design course [6]. Global virtual team projects have been part of design courses at the University of Colorado, University of Idaho, Purdue University, Oregon State, University of Detroit-Mercy, Pennsylvania State University, Rice University, Virginia Tech, and Brigham Young University [11]. These schools have collaborated with schools in Germany, Australia, France, Brazil, France, China, Hungary, Japan, Abu Dhabi, and Mexico.

In this paper, we describe our experience co-advising two capstone design projects run by virtual teams consisting of biomedical engineering students from Marquette University (MU—Milwaukee, WI) and engineering science students from Smith College (SC—Northampton, MA) during the 2011–2012 and 2012–2013 academic years. Presented here are the challenges we encountered, the lessons we learned as a result of this experience, and our recommendations for others who might want to include virtual project teams in their capstone design courses. We also include retrospective feedback from the students on these teams regarding their perceived value of their virtual team experience to their careers in engineering.

2. Rationale for virtual teams

We became aware of the growing trend in the use of virtual teams in industry from multiple sources including several alumni and other industry contacts. We also heard presentations at previous Capstone Design Conferences on the use of multinational student project teams for capstone courses, highlighting benefits and challenges [11–15]. Our goal was to provide some of our students with a virtual team experience that would prepare them for similar project work in industry. To accomplish this goal, we decided to conduct a pilot study with one virtual project team. Our intent was to eventually increase the number of virtual project teams as we gained experience in advising these teams. Instead of working with students in another country who spoke a different language, we decided to limit the number of challenges we would have to deal with by forming a team of students who shared a common language and only a one-hour time zone difference. This would allow us to focus on resolving issues related to communication, specifically the lack of face-to-face meetings, and not have to deal with other issues common to multinational virtual project teams. Moreover, we knew from previous discussions and collaborations through the Capstone Design Conferences that our teaching philosophies and course management strategies were compatible, providing a solid foundation on which to implement a virtual team experience for students in our courses.

3. Background and methodology

We piloted our virtual team experiment in 2011–2012 and continued the collaboration in 2012–2013 on another project. Details regarding these collaborations, including project topic, team size, and liaison location, are noted in Table 1. We served as both the capstone course coordinators at our respective institutions and the local project advisors for the students on our virtual teams.

The capstone design courses at both institutions are taught for two semesters but had different semester start/finish dates and different vacation schedules. To simplify course administration, reduce confusion, and maintain consistency, we agreed that the virtual teams would follow the project schedule and produce the deliverables required by the course taught at Marquette University. Grading of deliverables was conducted by both instructors using the grading rubrics used in the MU course. We advised our respective students, and met with them weekly (or as required) for project updates. In addition to these meetings, the MU and SC students set up their own schedule to

Table 1. Virtual Team Details

	2011–2012	2012–2013
Project Topic	Design of an acidosis/alkalosis detector for Type I diabetics	Design of a scalp cooling device to reduce hair loss during chemotherapy
Team Size	8 total (4 MU + 4 SC)	6 total (3 MU + 3 SC)
Student Majors	MU: 2 BME, 1 ME, 1 EE SC: 4 Engineering Science	MU: 3 BME SC: 3 Engineering Science
Liaison	Healthcare Professional in Wisconsin	Industry Engineer in Minnesota

meet as a team. Most of these virtual meetings were via Skype and most other communications were via phone, email, or text messaging. During both years, at the beginning of the spring semester (the halfway point of each project), SC student team members traveled to Milwaukee for the first and only face-to-face meeting with their MU teammates. Budget and scheduling constraints prevented additional face-to-face team meetings.

Any capstone design project could be run with a virtual team. In our experience, faculty time and technical resource constraints affect the number of virtual projects that can be run in parallel more than other factors. Projects run by virtual teams present unique challenges and benefits to students. Prior to staffing our virtual team projects, we discussed these challenges and benefits with students so that they would know what to expect if they chose to work on these projects. We emphasized the value of gaining experience working on virtual teams to their careers after graduation.

Throughout the course, we captured student and faculty impressions informally during both capstone team experiences through student reflections and peer reviews, end-of-semester course evaluations, and regular (roughly weekly) conversations between the two of us as faculty coaches. We also surveyed the students after they graduated to capture their feedback more formally. The survey included a mix of quantitative and qualitative questions regarding student perceptions of benefits, challenges, skills, and recommendations. Of the 13 alumni for whom we had email addresses, 12 responded to the survey. We tallied the quantitative responses and conducted an informal content analysis on the qualitative responses, identifying themes and representative quotes.

4. Student impressions

Figure 1 displays student responses (strongly disagree, disagree, agree, strongly agree) to a set of statements regarding the students' virtual capstone team experience. Interestingly, although the vast majority of the students did not specifically seek out the virtual team experience (perhaps choosing the project based on its topic and/or sponsor), and the respondents are somewhat mixed as to whether the benefits outweighed the challenges, most/all of the students believe that they learned useful skills from the experience that are relevant to their work

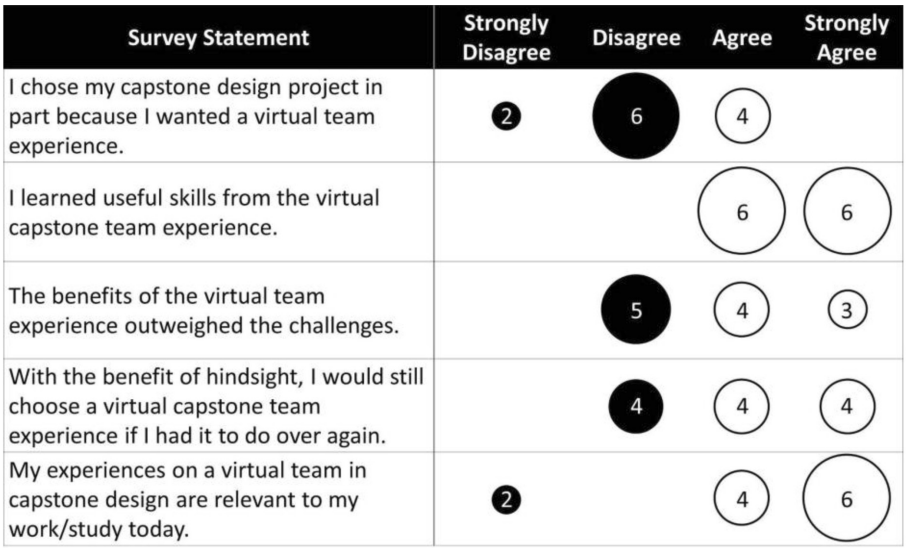

Fig. 1. Student impressions regarding their virtual capstone design experience (n = 12 of 13).

and studies after graduation. This outcome is similar to that reported by other researchers [16].

5. Challenges

The students and faculty both identified a number of challenges with the virtual team experiences:

Communication—in the post-course survey, 80% of the students specifically mentioned communication as one of their biggest virtual team challenges. As one student commented, "*corralling eight students, in two time zones, proved nearly impossible.*" Students noted difficulty communicating remotely without face-to-face interaction, trouble with communication technologies themselves, and inconsistent communication from the two faculty advisors. One student lamented "*communication issues plagued our teamwork.*"

Scheduling —time constraints and time zone differences led to difficulty with scheduling meetings, an issue exacerbated by team size. The class times at the two institutions also did not coincide, so joint presentations were rarely possible. One student noted, "*Most of the time we were unable to have a meeting during weekdays because time conflict between students from two different institutions.*"

Lack of Cohesive Team Identity—working with unfamiliar teammates from a different institution exacerbated the usual teamwork challenges faced in capstone design. During the first semester of each project, there seemed to be two distinct teams (MU and SC) working on different parts of the same project instead of one team working on the entire project, leading to, as one student called it, an "*us versus them mentality*". Another student noted, "*there seemed to be a disconnect in terms of everyone valuing the others education.*" The eventual face-to-face meeting at the start of the spring semester was helpful in creating a more cohesive team, but would have been more useful earlier in the project to promote shared understanding and trust.

Peer Reviews—as a result of task delegation and collaboration structure, students were usually more aware of the actions of their co-located teammates than those of their teammates at the other institution. This imbalance coupled with the lack of frequent face-to-face meetings made it difficult for both groups of students to effectively evaluate each other's performance on the team and project.

Construction of Prototypes—each team had access to prototyping facilities and resources for prototype construction and testing. To divide the work fairly, different parts of the prototypes were made at the two institutions. This created some logistical problems related to coordination of testing activities and availability of prototypes for classroom presentation and demonstration. One student specifically felt challenged by the "*inability to help with work that was being done offline at a different location.*" Other engineering educators experienced this similar challenge [8, 17].

Ability to Provide Comprehensive and Similar Project Experiences—due to delegation of different tasks to each institution and the lack of frequent communication between the entire team, student experience was not consistent among the two groups. During the second project, for example, SC students gained more experience with verification testing and prototype construction and the MU students gained more experience with technical writing and sponsor interaction.

6. Benefits

The students identified multiple benefits associated with the virtual team experience:

Communication—on the post-course survey, 70% of the students listed improved communication skills as one of the biggest benefits of the virtual team experience, demonstrating how facing challenges can lead to positive outcomes. Students commented on their ability to communicate ideas clearly, to select and use various communication tools effectively, to listen carefully, and to provide constructive feedback. One student commented specifically on the benefit of being able to understand "*the nuances in differences in levels of professionalism, detail of thought, and effectiveness with each form of communication.*"

Teamwork/Trust—students noted the benefit of learning to work with people in different locations who may not be readily available and how to trust people they had not previously met. They also commented on their experience identifying strengths and weaknesses in self and others, collaborating with a large team to accomplish a goal, and establishing goals and common understanding.

Personal/Professional Growth—additional benefits noted by at least one student included confidence, leadership, self-assessment, documentation, time/task management, productivity, decision making, and preparation. One student recognized only after graduation the benefit of having leadership skills as a project manager. Another commented, "*Being able to work with someone from different institution help boost up my confidence level to work with anyone (even without knowing the person beforehand).*" A third student remarked on the value of regular assessment: "*For my work, myself, and other goals, I am able to objectively assess development for improvement.*"

As faculty advisors, we noted several additional benefits:

Additional Perspectives and Opinions—creation

of the virtual teams consisting of students with diverse backgrounds and different ways of looking at the design problem enhanced the pool of potential design solutions, which was also a benefit to the project sponsors.

Colleague as Sounding Board—the shared virtual capstone teams provided us the opportunity as faculty to collaborate as colleagues, share our pedagogical strategies, and calibrate our evaluation methodologies. Having such an opportunity is particularly valuable for faculty who are the sole capstone design instructors in their department and/or institution.

7. Recommendations for virtual teams

As a result of dealing with the challenges and issues described above, we plan to implement several changes to our future virtual team collaborations. These recommended changes are based on our own observations, student feedback, recommendations from the management literature [7, 18, 19], and experiences from other design educators who have implemented virtual teams [11, 17]:

- Ensure that open communication and a good working relationship exist between the capstone instructors at each institution. It is important that the collaborating instructors be able to address issues as they surface and that they provide a good model of collaboration for the students.
- Schedule a face-to-face meeting as early as possible to create and nurture a team culture and build trust among team members [6]. In our next collaborations, we will allocate travel funds for SC or MU students to visit the other's campus for a face-to-face meeting within the first few weeks of the project. This will provide opportunities for (a) informal social interaction to build trust, (b) setting goals for the project, (c) discussing project expectations, and (d) assigning roles for each team member. As one student recommended, "*Establish a respectful relationship early on and have it be nurtured in the way team meetings are conducted.*" Trust in virtual teams grows as team members display reliability, consistency, and responsiveness. This process can be initiated by assigning each team member a task that can be completed quickly, allowing them to make an immediate contribution to the project [6]. Agreeing on a decision making process is another important element of building trust: as one student advised, teams should "*decide early on how decisions will be made, whether it needs to be unanimous or majority rule.*"
- Make better use of appropriate communication and collaboration technologies to establish effective methods of communication and match the technology to the communication need: email to distribute important information, videoconferencing when it is important to observe facial expressions and body language especially in the early phases of a project when relationships are being built, conference calls for project status update meetings and to sustain camaraderie among team members [6, 20]. Providing a designated space for virtual teams equipped with reliable communication technologies would help alleviate the bandwidth and connection issues students experienced with Skype and Google Hangout. As one student recommended, "*The institutions should provide or pay for a better communication software for the virtual capstone teams so that the members will not face any technical difficulties in contacting others team members from different institution.*" In addition, we endorse developing a communication plan that defines what communications are needed, who needs to be involved, frequency, purpose, point of origination, and the communication medium to be used [19].
- Encourage student pairs across institutions to work on tasks together instead of assigning tasks to sub-teams from the same institution. This will create new sub-teams consisting of students from both institutions who will be required to work and communicate with each other on their assigned tasks. As one student commented, "*It was beneficial for my team when we matched up a Marquette team member with a Smith team member so we could meet more frequently and get up to speed with each other's progress. This allowed each team member to transfer information to the rest of their on campus team and overall everyone was more informed.*"
- Require more frequent meetings of the entire team that include both faculty advisors. This is a better alternative to having separate team meetings of each group with their respective faculty project advisors, and helps create and nurture a cohesive team culture and identity. Our goal is to prevent two geographically separate teams from working on different tasks for the same project and ensure everyone receives the same communications and understands a common set of expectations. One student specifically recommended "*I highly recommend setting weekly goals and meeting AT MINIMUM twice a month with ALL team members (conference call or Skype).*" [emphasis in original]
- Limit team size. One student suggested that we try using smaller groups, noting that "*a total of 4–6 may increase effectiveness*." To facilitate interdependence, Zaugg, et al. found that teams of 5–7 members were the most effective [8]. They suggest

that larger teams may be successful with increased faculty guidance. In our experience, the 6-person team in our second collaboration was somewhat easier to coordinate and guide than the 8-person team in our initial collaboration.

- Provide opportunities for both faculty advisors and all students to interact with the project sponsor. The two virtual team projects described above were solicited through MU. As a result, one student from MU was assigned the role of sponsor contact, which prevented other team members and the SC faculty advisor from interacting with the sponsor. A more collaborative structure should result in a better understanding of the goals and expectations of the project as well as a higher level of buy-in from all team members.
- Align expectations across students, faculty advisors, and institutions. Require the team to create a team operating agreement that includes items such as procedures for working together, resolving issues, reporting project status, assigning work, attendance at team meetings, and scheduling of meetings and deadlines around holidays and key academic calendar dates [8, 19]. Ensure faculty establish unified guidelines and communicate a consistent message to the team; as one student noted, "*it helps to have both advisors be on the same page before communicating advice to each campus groups to eliminate the telephone game of he-said she-said.*"

8. Summary

Students who worked on our virtual capstone design project teams experienced some of the same challenges and benefits encountered by members of virtual teams in industry, including communication difficulties related to the lack of face-to-face interactions and lack of team cohesion and trust [6, 8, 18]. Additional specific challenges were related to prototyping, peer reviews, and experience parity. Benefits included improved communication and teamwork skills, professional development (of both students and faculty), and an enhanced pool of potential design solutions. All of the students who responded to the post-course survey (n = 12, of 13 students surveyed) agreed they had learned useful skills from the virtual capstone team experience; the vast majority (10 of 12) noted that their virtual capstone team experiences are valuable to their work/study post-graduation, and the majority (8 of 12) believed that the benefits outweighed the challenges.

We recommend that when managing virtual capstone design teams faculty should facilitate a face-to-face meeting early in the project to build trust, provide the team with appropriate virtual communication technologies, and require teams to agree on how they will operate and communicate as a team. Faculty should also communicate clearly and consistently with all team members and consider creating sub-teams consisting of students from both institutions to ensure collaboration.

Implementation of the recommendations discussed here should help future virtual teams run more smoothly and lead to better outcomes for the students and industry sponsors. We believe that any project could be run with a virtual team. However, increasing the number of virtual team projects would require additional guidance and coordination from capstone faculty as well as technical resources, constraining the number of projects that can feasibly be run at the same time this way. Thus, the fraction of projects that could be completed through virtual team collaborations is limited, in our experience, more by available instructor/advisor resources, than by any other factor. We value the virtual team experience for our students and encourage other capstone faculty to provide a virtual team experience to their students as well.

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Jay R. Goldberg, Ph.D., P.E. is Director of the Healthcare Technologies Management Program at Marquette University and the Medical College of Wisconsin (Milwaukee) and Clinical Professor of Biomedical Engineering. He teaches courses involving design and new product development and his interests include medical device design, engineering management, and design education. His industry experience includes development of new products in urology, orthopedics, gastroenterology, and dentistry. Dr. Goldberg earned a BS in general engineering (University of Illinois), an MS in bioengineering (University of Michigan), and an MS in engineering management and a PhD in Biomedical Engineering (Northwestern University). He writes a column on senior design courses for *IEEE Pulse Magazine* and published two books on capstone design courses.

Susannah Howe, Ph.D. is the Design Clinic Director in the Picker Engineering Program at Smith College, where she coordinates and teaches the capstone engineering design course. Her current research focuses on innovations in engineering design education, particularly at the capstone level. She is also involved with efforts to foster design learning in middle school students and to support entrepreneurship at primarily undergraduate institutions. Her background is in civil engineering with a focus on structural materials; she holds a B.S.E. degree from Princeton, and M.Eng. and Ph.D. degrees from Cornell.