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Internationalization of the Undergraduate Engineering Program (Part 2): Application Example*

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This paper details the challenges, risks, and rewards associated with the initiation and maintenance of web-based distance collaboration projects as experienced by the two co-authors as a result of the development of their Computer Aided Design Across Universities (CADAU) project of 1999. The goal is to promote the application of distance education tools to the integration of the international engineering education experience into the undergraduate curriculum.

INTRODUCTION

OVER THE PAST decade, web-based technologies and distance education techniques have matured enough to allow US engineering colleges to bring the international educational experience home to our students through direct integration into the engineering curriculum [1]. Currently, international distance education has the potential of becoming an affordable and more accessible alternative to a full immersion study abroad programs or student exchange programs. A paper by Jones *et al.* provides a description of several engineering programs that are providing international exposure to their engineering students using distance education techniques [2].

This paper documents the co-authors' experience [3] with conducting an online international collaborative design project. The paper also includes an analysis of the students' reports on the challenges and advantages of including an international collaboration component in the undergraduate curriculum. The goal of writing this paper is to assist course instructors with the planning and development of new online international collaborative learning projects by using this work as an example.

STRUCTURING A DISTRIBUTED AND COLLABORATIVE EDUCATIONAL PROJECT

Online teaming is complicated and time-consuming for a number of reasons, including: language differences, cultural and social barriers, time zone differences, and the reliability and efficiency of the asynchronous communication tools. Simply forming teams and asking students to collaborate does not mean that they will. The collaborative activity has to be designed with great precision. A suitable course, or courses, in the curriculum has to be identified as the host for the collaborative activity. The course outline has to be restructured to allow the collaboration activity to take place without diluting the course content. The grading scheme must emphasize the importance of the collaborative activity in evaluating the students' performance in the course. Most importantly, the collaborative activity has to be of sufficient magnitude so that students are unable to accomplish the task without collaborating.

Engineering design is a creative activity supported by knowledge, skills, analysis, and testing. The parties directly involved in a design process include the design team, the organizations cooperating in the product development cycle (marketing, design, manufacturing, service centers, and recycling), and the customer. Indirectly, all life forms and the environment are involved in the design process. However, these are represented by governments and policies. Such a diverse chain implies that the interests of the parties involved in the process are very diverse and at times conflicting. Despite the complexity associated with the design process, the simple fact remains that it must result in the definition and realization of the end product or process. The end product or process cannot be defined without streamlining activities, resolving conflicts, and consolidating distributed efforts. A design course is therefore the best medium for integrating an international teaming activity into the mechanical engineering curriculum.

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Fig. 1. The final shopping cart design produced by an international team during the fall term of 2002.

The co-authors redefined the content of their two computer-aided design courses taught at Iowa State University (ISU) in the United States and the University of Technology of Compiegne (UTC) in France to include an online international collaborative design project, CAD Across Universities (CADAU). The project was initiated at Iowa State University in September of 1999 with support from the International Institute of Theoretical and Applied Physics (IITAP) at ISU, and a grant from the office of the Vice Provost for Extension. IITAP identified UTC as a partner for the collaborative project and served as the matchmaker between the two course instructors.

At the time of writing this paper, CADAU is running for the fifth consecutive year. The project topic is changed frequently. The assigned project for the year 2002 was to research, design, and model a device to assist a person in moving groceries or similar items up multiple flights of stairs unassisted.

Local design teams consisted of two undergraduate students. An international team is formed by merging a local team from ISU with a team from UTC. In the fall term of each year the project is conducted with 10 international teams. The project is not offered in the spring term due to the mismatch between the academic calendars of ISU and UTC during that term.

Students were provided with the following design constraints: 1) the total cost of the device must be less than \$100; 2) the total envelope size must not exceed 60 cm × 45 cm × 104 cm, so that it will fit in the trunk of a European-sized car; 3) the device must climb three flights of stairs in 10 minutes; 4) the device must be able to climb the stairs unassisted; 5) the device must be suitable for use as a shopping cart; 6) the load weight must be greater than 25 kg. A sample design produced by one of the international teams is presented in Fig. 1. The design shown in Fig. 1 was selected as the best design produced by the international teams for the year 2002. The design did not just satisfy the required constraints, but was also aesthetically pleasing, foldable (as can be seen in Fig. 1b), and modular, with a track that can be detached for storage and maintenance (Fig. 1c).

Fig. 2. A grocery cart design generated by an ISU team during the fall term of 2002.

Figure 2 presents a design by a local ISU team that opted not to collaborate with their peers in UTC. The design in Fig. 2 is nonfunctional due to the instability of the 'grocery tub.' Comparison between the designs in Figs. 1 and 2 clearly emphasizes the value added to the design content, and the CAD model level of detail of the design in Fig. 1, as a result of successful collaboration between team members.

ENGINEERING WEB-BASED COLLABORATIVE TOOLS

In the year 1999, an affordable internet design collaborative software package was not yet available for educational institutions. IITAP system administrators tailored a free copy of the software 'Basic Support for Cooperative Work' (BSCW) to make it simple enough for students to learn and use efficiently for file transfer between the collaborative and distributed project members.

The BSCW shared workspace environment allowed sharing of information between group members. BSCW has an integrated 'event mechanism' which provides a group with information about the activities of distributed members in their shared workspace. The features of BSCW that made it desirable as a communication mechanism were: 1) its ability to upload and download a variety of file types including CAD files

generated using I-DEAS and Pro/E; 2) a threaded discussion capability; and 3) a file- and group-management mechanism.

Two types of folders were generated for students to use in BSCW. The first type is the local folder. Course assignments, the midterm examination, and the final examination were submitted electronically by group members to their local folder. Local folders at both ISU and UTC permitted access to only local group members at those locations. The second type is the project folder. Access permission allowed international members of each group to access their project folder for uploading and downloading of files, and performing discussions and meetings.

In the year 2000 the Pro/E CAD developer PTC offered free use of its distributed collaborative portal (Pro/Collaborate) to the CAD community. By the year 2000, the co-authors unified their CAD packages to Pro/E to overcome the problems associated with the transfer of CAD data between ISU and UTC in IGES and STEP format. Therefore, it became natural at that stage to use Pro/Collaborate as a replacement for BSCW.

THE CHALLENGES OF COLLABORATING OVER THE INTERNET AS REPORTED BY STUDENTS

Classification of the collaboration challenges documented by the students in their final reports highlighted the following three difficulties: 1) language barrier; 2) asynchronous communication problems; and 3) cultural and social differences. This section documents the students' experience with these challenges as described in their final project reports.

The first and most obvious challenge was the language barrier between the French students and the American students.

> The American students knew absolutely no French and the French students were fairly competent in the English language, but consistently sent us information in half English and half French, as can be seen from this report. It was often difficult to grasp what they were trying to communicate since their English was not exceptional. This caused problems in deciding upon a final design. It was never perfectly clear what the French design idea was until the part was modeled and could be seen. (D. Davenport, P. Jensen, O. Donchery, and M. Sterlin, Group 4—Fall 2002)

> We did make a conscious effort to write very plainly in our emails. We kept out all slang terms and tried to minimize the use of words with more than one meaning. (G. Antognoli, M. Armstead, J. Ebersole, and N. Souraqui, Group 1—Fall 2002)

Another challenge was the time delay for communication between the French and American students. Group 4 indicated that:

> It most often took several days to obtain answers to questions. This made the project difficult since there was a very limited time frame in which to complete the project. Consequently, design decisions were prolonged, causing the modeling to be pushed back to the last week.

Group 1 reported:

> Also, the transferral of ideas by the PTC website was difficult. The uploading of materials on to this collaborative site was new to us and took some time loading. This led to a lag in agreeing on concepts. We would ask for an idea, and wait up to a couple days to get a response. The response would show up on the website and for us to answer. We would deliberate as the US half of the team and then respond in the same time frame. This means we have let four days go by without even making a decision. It will take a few more days to discuss through emails the pros and cons of the different ideas presented. To get a consensus on an idea would take us at least a week. More complicated issues take longer, and some were just ignored.
>
> This also caused a few troubles during the modeling of the trolley. There were a few times when new parts were added to a model that wasn't current. I know that once or twice Jeff and I got a model from the PTC website with a new French part and sadly the base model to which they had attached the new part was not the updated one we were using. This forced us to do a lot of modeling all at once to get the model posted on the same day we were working on it. If we didn't, one or the other parts of the team might have been working off of an old model. We also had to spend some time reassembling parts to different bases to get things back together.

In the beginning, the American students and their French counterparts had different ideas about the project's goals. Spending time on alleviating these differences slowed the progress of the design activity.

> Also, it should have been made clear that all suggestions, opinions, and changes were to be constructive criticism, always made to come closer to the team's goals. All too often, pride and the fear of 'losing face' made working together more difficult and less effective. (Group 3)

Since the cultures differed within a team, the patience in communicating needed to be high.

STUDENT FEEDBACK ON THE WORTHINESS OF THE INTERNATIONAL COLLABORATIVE EXPERIENCE

The main approach used by the co-authors to motivate the students to face the project challenges was to emphasize the value added to the design process and to the students' educational experience. As the French and American students work together, the design problem is stripped from the constraints imposed by the local culture and new constraints are added, since the design now has to meet the requirements of operation and to meet user needs in two different environments. Participation in a global collaborative project added a new dimension to the design process.

> The experience with the French students in our group was very beneficial. The main consideration from this standpoint is to get your organization and collaborative direction early. If there is not an agreed upon direction from the start of the collaboration, the progress will be slower and more frustrating. This is not to say there shouldn't be any room for changes along the way, just that with the main concepts in place the rest of the project can progress from there. (Group 1)

Group 6 (fall 2001), consisting of A. Willamon, G. Westwate, T. Hecquet, and T. Drapeau, explained:

> Additionally, when the timing was correctly established, amazing progress could be made. While one half of the team was sleeping or 'off work', the other half of the team was able to make progress. The work could then be handed off, allowing progress to be made nearly 24 hours a day.
>
> Finally, since the team members came from two different classes with two different instructors, each half had a slightly different focus on some parts of the project. As team members evaluated the design process from different perspectives, new ideas and refinements developed that may not have otherwise been included.

The collaboration experience between the American and French engineering students enhanced the design process efficiency. Group 7 (fall 2002), consisting of B. Mueller, E. Schaffer, M. El Ghomari, and X. Rolland, explained:

> Different views were obtained in the analysis of the design. Work on the project could be completed in a timely manner. Progress excelled when the teams agreed upon a specific design. Once the design was agreed upon, the workload was distributed evenly between the teams. This accounted for an easier transition between development of the design to construction of a solid model of the prototype. The experience allowed for a successful model that accomplished the intended tasks.

THE INSTRUCTORS' EXPERIENCE

Online international collaboration is as challenging for the course instructors and teaching assistants administrating the course as for the students. At the course instructor's level, issues such as trust, respect, and personality agreement are extremely important to maintain a collaborative program. The initial introduction between the course instructors seeking collaboration is usually sufficient to initiate the international collaborative program. However, to maintain the program 'a sense of friendship' has to evolve between the course instructors.

In addition to the challenges presented by the asynchronous communication and cultural differences, course instructors will experience the pressure of: 1) managing and streamlining the students' collaborative efforts; 2) resolving conflicts between team members (local and international); and 3) maintaining software and computer system support for the project.

The co-authors' experience with the project resulted in the belief that the factor most damaging to maintaining an effective collaboration is a sense of discouragement. The co-authors are also certain that course instructors will experience that feeling while conducting such a project. The threat rests mainly in the possibility that the course instructors might not recover from the sense of discouragement and may start to direct their time and efforts to other responsibilities. Conducting an online international collaboration project at undergraduate level requires commitment. International collaboration projects are fragile. One experience of failure is all it will take to prevent future continuation of the project. Collaborating instructors will find it difficult to work beyond a failed project offering.

As course instructors become more experienced in conducting an international collaborative project, they also become more experienced in watching for and quickly recovering from potential pitfalls. The instructors' goal is to have their students experience the disagreement between their work habits, language, social attributes, design approach, computer software and hardware, and yet come out with a single design configuration per group, and a single CAD model per group. An international teaming project is about building the resilience and tolerance necessary to bring engineers from different engineering education backgrounds and social cultures to communicate, resolve conflict, and commit to a unified path.

CONCLUSIONS

Although the co-authors have been conducting their online international collaborative design project for five years, they are far from reaching a steady-state mode of operation. It is almost impossible to reach that stage, since the environment of operation is dynamic: the project runs for three months per year; CAD software and collaborative software is either updated or replaced; the topic of the project is changed frequently; the personality and attitude of the students taking the course are different from one year to another; and, within a given class, different groups will vary in performance.

To ensure the success of an international collaboration experience, course instructors must influence the students' perception of the importance of our ability to 'work together across cultures' rather than submitting to saying: 'What can we do? We simply cannot agree.'

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Bruno Ramond has been a Professor at the University of Technology of Compiegne since 1987. After completing a Ph.D. in Material Sciences, he oriented his research and teaching toward mechanical design and computer tools for design. He introduced CAD tools into the mechanical engineering curriculum in UTC. In 1990, he participated in the creation of a new UTC engineering curriculum based on Concurrent Engineering, Mechanical Design, Project Management and CAx tools. During this time, he has developed student projects and international collaborative projects with ISU (USA), where he was able to study how people and their behavior can influence the design process and the product. His main interest is collaboration in design and the effects of culture on the design process. Bruno Ramond is the Director of the Mechanical Systems Engineering Department.