Teaching Design Through International Collaboration

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Abstract — *There is a growing need for engineering graduates to have an appreciation for the issues that must be addressed when working on international collaborative projects. By combining this appreciation with the experience of working in virtual teams, students can develop skills that will enable them to perform effectively in such settings. This paper describes a collaborative effort involving an industry-sponsored design project that was common to the introductory design course in mechanical engineering at University of Leeds and the introductory design course taken by almost all engineering students at Penn State University. Various forms of information technology were used for the collaboration and at least one hour of overlap was scheduled for team audio–visual conferencing each week. In this project the attitudes of the students to international virtual teams and the collaborative technologies were tested. The project reported here is part of an ongoing initiative between the two universities with the goal of establishing cost-effective mechanisms by which large numbers of students can experience and benefit from working as members of international teams.*

Index Terms ¾ collaborative tools, design education, global economy, virtual teams

INTRODUCTION

Information technology has made virtual teams possible, and they are attractive because of the comparative advantage of deploying the best human resources without the need to assemble them all in one place. Although such teams may be only national in scope, whether or not they are global is constrained only by differences of time and culture. This paper is about preparing students not only to work in virtual teams but also to work in global virtual teams. Students with this experience will be prepared for work in the growing global economy through their exposure to differences in culture and time as well as the work dynamics of virtual teams.

Information technology may be used in several different ways for internationalizing the engineering curriculum. These include lectures and discussions by and with engineers, faculty, and students around the world and also forming multinational teams, as we discuss in this paper. Variations in modes for running multinational student design teams include whether or not there are multiple teams formed within a regular class [1], or whether a single team is formed outside of the usual class setting [2]. The latter is likely to be long duration and the in-class setting is likely to be short duration. Another variation is how many countries are involved, that is, whether the collaboration and communications are point-to-point or multi-point [3].

A consortium has been established of seven universities in four countries dedicated to preparing engineering students for the global economy with the academic focus of global product design and development. Called PRESTIGE, it is comprised of The University of Leeds, École Centrale de Lyon, Universidad de Navarra in San Sebastian (Tecnun), the IUT of the Université d'Artois in Béthune, the University of Washington, Arizona State University, and The Pennsylvania State University. PRESTIGE will prepare (in English, French, and Spanish) a series of web-based modules for use in teaching and students will engage in in-class and out-of-class cross-national design projects facilitated by the use of information technology (IT). Some students will also travel for study abroad and work experiences.

The trial experience described here was designed to get a sense of what is needed to establish and run the cross-national virtual teams in point-to-point and multi-point modes. Both partners came into the trial with some experience, but this trial focused on the information technology that neither had used extensively yet. This article discusses the first attempt at student collaboration between the University of Leeds and Penn State University by forming multiple teams using students in similar introductory design classes.

BACKGROUND

The University of Leeds and Penn State University have an ongoing initiative with the goal of establishing cost-effective mechanisms by which large numbers of students can experience and benefit from working as members of international teams. The project reported here is the second year of design project collaboration between the two universities. In the first year, students at Penn State and Leeds participated in a common design project but there was no direct communication between the individual teams. Instead, the teams were encouraged to exchange questions and answers via a website. In the second year, the

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collaboration involved students collaborating through conventional web-based communication techniques. They were encouraged to exchange ideas and help each other solve problems encountered during the design process. It was anticipated that the differences in design process used at the two institutions, along with the cultural differences, would encourage the students to generate ideas they would not have otherwise.

THE DESIGN PROJECT

The project was run with 22 students in the first-year introductory design course in the School of Mechanical Engineering at Leeds and 31 students in a section of the introductory design course taken by almost all engineering students at Penn State. The 5 teams came from volunteers at Leeds and one of 14 sections at Penn State.

The project all five groups were undertaking was the design of an assembly process for the timing chains in a Harley Davidson engine. The students were not told how Borg Warner, the chain's manufacturer, currently assembles the chains in order that the concepts they generated were fresh and original and not influenced by knowledge of the current assembly process. To provide technological context, the students were given a presentation by a Borg Warner engineer that was posted on the project website for students at both universities to see. In addition, a video on the 5-year development of Harley Davidson's V-Rod 1000—fortuitously produced by the Discovery Channel in the United States [4]—was shown to students at both universities. Samples of the timing chains and chain components were also provided to all teams.

Although the students were working on a common design problem, the requirements set by the two universities differed slightly, with emphasis placed on different elements of the problem and differences in the final deliverables.

The variables between the projects were the difference in design processes taught, culture, and education systems. The collaborating students were required as part of their assessed work to state what they had learned from their foreign counterparts and which parts of their designs came from collaborative efforts. They were asked to complete a survey at the end of the project asking what they thought about the project and whether the collaboration had made a difference to their final result.

The project was introduced to the students with the following rationales:

- The students can expect to work in multi-cultural teams for multi-national organizations, including virtual teams and this project is their first chance to prepare for it.
- Leeds and Penn State has an old and successful exchange program so the students may wish to avail themselves of it if their interest is aroused by the collaboration.
- Diversity can be viewed as creating inhibitions and conflicts based on a fixed view in immature minds, or it can offer new ways of doing things with and for new populations of people. This project followed the latter idea, i.e., that it is an enrichment process in terms of the design outcomes and the marketability and utility of the product.

Although the two universities supposedly share a common language, the diversity experienced even between the staff was immediately apparent when common phrases used in exchanges were not familiar to or understood by the teams on the other side of the Atlantic. These language differences were quite manageable however, and of some amusement to the students.

LOGISTICAL CONSTRAINTS

There are very obvious constraints when running these projects and the largest of them is generally logistics. Logistical challenges include calendar differences; international time differences and scheduled class hours; different class structures and student incentive systems; and information technology facilities and their availability. Only insofar as you can solve these problems can you get to the value-added activities of the design process and the cultural differences revealed in it. In this first attempt, the logistics almost swamped the project, but enough was accomplished that many valuable lessons were learned not just about the logistics but also about the technologies and the assessment tools that can be used for these projects.

Timescales

There were many logistical details that had to be finalized before the project could begin. The first difficult problem that had to be overcome was the different term schedules at the two universities.

Some planning was done in late 2001, at which time it was decided to use the industry-based design problem that would be used in the spring semester at Penn State. Difficulties arose immediately because the details of these projects as well as resources are often developed in the first month of the semester and the problem is not fully ready to go until about week 4 or 5 of the semester. This works for the Penn State course, which runs the industry-sponsored design project during the last 8–9 weeks of the course. At Leeds, the students have Easter recess for four weeks from the end of March until the end of April and the Penn State students have a one-week Spring Break in the beginning of March. The Penn State course ends the last week of April. This left a maximum of 5 weeks of overlap in which to run collaborative activities and, in actuality, there were only four weeks of collaboration in the end.

Assessment Criteria

Another issue that must be considered are the different assessment criteria used at the two institutions involved. The variation in assessment criteria at the two institutions was not seen as a problem for this collaboration since the teams were assessed separately in their courses and, in fact, the criteria and weights were very similar.

The assessment criteria had to align in some manner so that the students were not working at cross-purposes and with differing aims. As the "core" of the project was the same at both universities this was not anticipated to be a difficulty. However, it was recognized that for future collaborations this problem would have to be addressed.

Resources

A third logistical issue encountered was the limited time available for the collaborative meetings. The Leeds students were participating on a voluntary basis so the meetings were not taking place during class time, unlike the Penn State students who had meetings during class. Each team was given 20 minutes on the multimedia PC available for the collaboration. When the teams were well prepared and had information to share this time proved insufficient for them and they were forced to cut short discussion. Any continuation of these discussions was asynchronous via email. The problem stemmed also from the limited computer facilities available at Leeds where only one PC was equipped for multimedia use.

This limited availability of IT equipment proved to be the major logistical problem. Although the computing facilities available at Penn State were excellent, those at the Leeds were limited as there had been no previous need for multimedia PCs accessible to groups of first year students. There was only one computer available and this was not well suited to the task. The teams' access to this computer was limited to the 20-minute session and even then there were difficulties with the connection. The students at both universities did not have time to experiment and become familiar with the tools prior to the meetings and as a result much time was wasted while they familiarized themselves with the software.

STUDENT COLLABORATION

The use of web-based collaborative tools is becoming increasingly widespread as these tools become more diverse and easier to use and obtain, with many of them available free and downloadable. The improvements in communication tools, such as the ones used in this project, have encouraged many engineering companies to allocate tasks to teams of employees that are distributed rather than co-located. The virtual teams formed allow organizations to take advantage of the particular skills and expertise of workers without incurring travel or relocation costs [5]. University faculty and students could enjoy similar benefits, but use of these tools within an academic setting generally has been more limited. Although student exchanges have been popular for a while now, the numbers of students exposed to the advantages of international contact can be significantly increased using collaborative tools. The value of such collaboration is not only that it facilitates discussion between students with different social, cultural, and educational backgrounds, but that any disagreements that occur will promote growth on the path to understanding.

Project Structure

There are many different ways of running an international design project requiring varying levels of commitment from staff and students. There are also varying levels of international commitment: insertion of an international element into a class, inclusion of an international dimension into a course's structure, and student exchanges to immerse the student in a foreign environment [6]. These levels of commitment are usually built year-on-year. The different methods of structuring international collaborations have been described as [7]:

- Case studies—the single reporting of the final result of a design project to their opposite group. This would be a one-time, in-class experience.
- Show and tell—the students in the two countries work on separate design projects and come together to progressively explain to their opposite group how their work is developing. This would be a short-term, in-class experience.
- Parallel teams—the student groups in each country work independently on the same design proposal, working separately but being encouraged to share data and ideas. This would be short, multi-teamed projects run as part of a regular module. This is the model used for the project reported in this paper.
- Integrated teams—the students in each country work together on a joint design project. These are long duration, out-of-class professional projects, usually involving a single team with high levels of staff and student commitment. The teams can be single or multi-disciplinary.

Leeds and Penn State have both been involved several of such schemes involving one other university and are planning to extend their experience to multi-point collaborations.

Collaboration Tools

This project was designed to be a short, parallel teamed approach run as part of one of the students' regular classes. Since there were 14 sections of the Penn State course, one section was chosen that had a two-hour morning session at a time when the students at Leeds were available (in the afternoon). The students held web-based meetings with their international counterparts once a week for 4 weeks. As part of the project a variety of web-based collaborative tools were used and assessed. Although both universities had access to video conferencing facilities it was decided to focus of web-based capabilities, as these are cheaper and more accessible by the students. The software tools used were:

NetMeeting allows chat, voice, file transfer plus video and application sharing (needs camera, sound, mike on PC);

Alibre Design allows discussion of imported drawings in chat and voice (Alibre is presently offering free software to our universities and a number of others);

Groove for collaborative working and planning; and

WWW and email were also encouraged, as they are available to all students.

As a result of experiences, both with and without the students, a preliminary typology was prepared for collaborative functions in virtual teams and some of the free technologies available for realizing these functions. Table I below summarizes the functions available in the various tools, also included for comparison is MSN Messenger.

TABLE I:
FREE, ENTRY-LEVEL COLLABORATIVE TOOLS AND COLLABORATIVE FUNCTIONS

Collaboration Tool	MSN Messenger	NetMeeting	Groove	Alibre Design
Network Capability		✓	✓	✓
Chat	✓	✓	✓	✓
Transcript of Chat	✓	✓	✓	✓
File Transfer	✓	✓	✓	✓
Project Management			✓	
Audio	✓	✓	✓	✓
Video		✓		
Whiteboard		✓	✓	
Application Sharing		✓		
Shared CAD Env.				✓
Shared Archive			✓	✓
LAN Security		✓	✓	✓
Mode	TCP/IP	TCP/IP or ISDN	TCP/IP	TCP/IP

Of the available "free" tools listed above, some tentative conclusions were reached:

1. Sending messages and transferring files is not a problem, perhaps managing the volume is.
2. Chat and chat transcripts may be realized through many software modes but the instant "messenger" software that is becoming very popular among US students is not at all popular with LAN administrators for security reasons. Some students preferred using the "chat" function of NetMeeting to discuss ideas as it meant they had to explain their ideas clearly. Further, chat is real time and slow compared to email (asynchronous) or voice (real time but fast). Faculty need to gauge whether using this mode is the best way to spend their time and, if so, what rules of discourse will optimize the efficiency of the transactions.
3. NetMeeting offers chat and chat transcript recording and is free with Windows 2000 and XP. It also is the best means of free AV conferencing. If a multi-media PC is not available, some modest costs are involved for a PC camera, mike, and sound system. It is not good quality for converting to room system use, but it can be done and room systems like PicTel are quite costly for the equipment and for the ISDN line costs. NetMeeting is very easy to use for point-to-point communications. For multi-point connections, a server will need to be established on a computer, but this can be done on a desktop PC.
4. NetMeeting also allows whiteboarding and application sharing. Whiteboarding is useful for displaying images and sometimes for simple messages like "We can see you, but we cannot hear you." Application sharing is remarkable. You may boot an application in CAD, or Word, or Excel, and then share the application with your remote partner. Further, you may turn control over to your partner so they, for example, may edit the drawing or the document or add data to a spreadsheet. If you turn your desktop over to them they will control your computer. However, you may get control back at any time. Groove also has a whiteboard capability used in a similar way to the NetMeeting version. Groove has its own version of application sharing, in that it allows both users to move about, open, and modify documents and a web-browser. The difference between Groove and NetMeeting being that the document or web browser has to open within the Groove shared space.
5. None of the tools examined in this project seemed very good for project management. Further, it needs to be established what elements of project management are wanted for projects of this kind. It is possible to put contact information, project information, team structure and roles, timelines, shared files, and a calendar on a website. If necessary, this may be password protected. It is easy to do and may be accessed from any on-line computer. Most of this can also be done using Groove as any member of a group can enter the shared space, which can include a calendar for project planning and an address book for contact details. This project did not use Groove from the start and the students were not familiar with all its functions so they could not integrate it into their team management.
6. Alibre has a special niche. It is targeting a large desktop market with a modestly priced CAD package that has excellent collaborative tools. The concept is something of *lingua franca* idea. Produce your CAD drawings in any popular CAD system and then, when working in virtual teams where partners have different CAD systems, everyone agrees to import their drawings into Alibre to discuss and annotate them there. It is very attractive software and extremely portable: you may

download it, and use Alibre servers if you need to, from any on-line computer anywhere. It is limited by the non-standard nature of export/import protocols like STEP, and they have to keep up with whatever is available. Also, there are limits on what can be exported/imported and the reverse. Most CAD systems now have their own collaborative tools, which are one option, and application sharing using NetMeeting is another option. Nevertheless, Alibre still looks like it has a niche in the market and they have been providing it free to many universities.

STUDENT FEEDBACK

The students were asked to complete a questionnaire at the end of the project in which they were asked their opinions on the value of the collaborative tools used, the project as a whole, and any changes in their interest level for working abroad. Considering the very compressed time scale and the difficulties of learning new software, getting to know each other, getting ideas across, disorganization, etc., the students on both sides were remarkably positive about their experiences.

Although nearly all agreed that the experience had been interesting and fun, there was disagreement over whether it had been useful. This disagreement was reflected in the varying levels of involvement the teams said they had from their international partners. Several students commented on the collaborations being too short and most wanted a longer experience and would like to do it again. They were particularly positive about the use of such collaborations for getting new ideas. The students were asked whether differences between the students at Leeds and Penn State were due to individual personalities, cultural differences, or differences in what they had learned at their universities. Most thought the differences were educational, but many thought they were cultural. This is the sort of question that would be interesting with a larger data set based on a much longer collaboration. About a quarter of the students felt they were more likely to travel for work or pleasure as a result of the experience and none said they were less likely.

The students also reviewed the software tools they used. They were asked to assess how useful they had found the tools and how potentially useful they were. Most students gave the tools used in this project positive reviews. The exceptions were Groove and Alibre. Both of these were recognized as having good potential but as there was little time for the students to learn them properly they did not find them very helpful in this collaboration.

The students agreed that many of the ideas they generated were the same as their foreign partners and that the other team of students positively influenced them. Comments included *"They had some new perspectives and challenged us to think"* and *"Mostly, we already had an idea similar to theirs."* However, for some teams the input of the group at the other university was not significant, for example, *"We couldn't understand their ideas, so they weren't very influential."* This highlights one of the cultural differences the staff involved expected to encounter during this project and the importance of communicating well. Some students commented on this cultural difference, the differing criteria, and the different design process used by students at the other university. One student said, *"We did have some different approaches to design, and they were probably due to different educational backgrounds."* Most students said they would repeat the experience and that it had made the project more interesting, for example, *"I think the international communication is a great way to introduce students to what it may be like working in industry some day for an international company. It made the project seem better/more significant as well. There were only a few minor problems with it, but overall, I think it was a good practice worthy of repeating."* If the students went away from the collaboration having learnt this, then, at one level, it can be deemed a successful experiment.

FUTURE COLLABORATIONS

In future international collaborations where global teams are formed between students at the two universities, the project will be better integrated with the same aims, objectives, and deliverables. The communication tools will be more sophisticated and the level of collaboration among the students is expected to be higher. When working on an industrially based global design project such as this one, it is expected that the students will:

- learn abut working in diverse teams;
- learn about working in global teams with differences of time and culture;
- learn about working in virtual teams;
- learn how to use collaborative tools: NetMeeting, Groove, Alibre Design, etc.;
- carry out an industry based engineering design project;
- become familiar with a series of contextual engineering topics that are related to the design problem.

It is anticipated the future collaborations will be tested by comparing experimental and control groups of students at both universities to see whether such international collaborations lead to better design, and to more positive attitudes towards other cultures and working in the global economy.

RECOMMENDATIONS

Our recommendations are given below. They are not costly and probably face greater constraints from local turf issues and space allocation. The recommendations are just that and are simply a guide for getting started. The software we use will certainly change over time. Note that computer-based team meetings in labs allow other students to continue with their work uninterrupted, which is not the case with room system AV conferencing.

At a minimum, each partner in such collaborations should have enough on-line, multi-media PCs for each student group to hold simultaneous virtual meetings. Using only one or two PCs for the virtual meetings will severely restrict the length of those meetings. Using several PCs allows for multiple teams to be communicating at the same time, and hence for longer, as well as allowing for some redundancy. Additionally, this number of PCs facilitates testing the multi-point connectivity of software like NetMeeting. The project personnel should likewise have a multi-media PC on their desktop. These computers should be under the control of the personnel who can provide both the multi-media PCs loaded with the software needed, and the access to and support of those PCs when needed. Having the PCs under the control of project personnel allows the participants to easily try out new software as well as change their use schedule as needed. The Penn State unit in this collaboration has long had team computer desks with four PCs. (To view these in action, go to http://www.cede.psu.edu/). They have two computer labs with at least 8 such desks and are currently installing one multi-media PC at each. Thus each team of four students will have access to collaboration with external partners when using the facilities.

The PCs should be running Windows 2000 or XP. The participants should expect to use a browser, email, NetMeeting, Groove, and Alibre for communications, all of which may currently be obtained for free. Similarly, all participants should be looking for new software tools since they are continuously appearing on the market.

CONCLUSIONS

International design projects such as the one described in this paper are an important way of teaching engineering students how to operate in the modern global climate. Although the trial was very limited in scope and some elements of this project were not entirely successful, it was a valuable experience for both the staff and students involved.

The many logistical problems encountered include teaching schedules, computing facilities, team sizes, and assessment criteria. The easiest of these to overcome is the problems with computing facilities. While our recommendations for computer facilities will allow for more and longer virtual team meetings, it is still true that these meetings must be well planned and well prepared so that their efficiency is optimal. One aspect of planning must be the efficient use of drawings and of simple and direct language in communications. The latter becomes even more critical in bi- or multi-lingual communications where interpreters and second-language skills are in play.

The most difficult problem to solve was the difference between academic calendars. We view comparison of calendars as the first step in any such collaboration. Plentiful computer facilities allow for intensive periods of collaboration that can offset the calendar constraints. Alternatively, one group can subcontract to the other for a limited period, or there can be a total design hand-off from one team to the other.

In order to benefit the most from the international diversity, a thorough review after the idea-generation stage would force students to recognize the impact of their international partners because is this is where the best payoff is likely to occur. This is a good idea even without the international collaboration, since "solution lock" occurring within a few hours of the start of a project is often a problem with student design teams. (The term "solution lock" comes from Professor John S. Lamancusa, the director of the Learning Factory at Penn State, http://www.lf.psu.edu/.) Many ideas should be generated and clearly documented. They should subsequently be discussed in terms of their tradeoffs. All this should take place before the concept selection occurs. A thorough review before the selection might reduce the tendency to lock on a single solution and carelessly add a few alternatives just to meet the requirement. It should also be used in international projects to reveal the more diverse and creative contributions that are generated by cooperative international teams.

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REFERENCES

[1] Devon, R, Saintive, D, Hager, D, Nowé, M, and Sathianathan, D, "Alliance by Design: An International Student Collaboration," *Proceedings of the American Society of Engineering Education 1998 Annual Conference,* Seattle, 1998. Also, see, http://www.ecsel.psu.edu/alliance/

[2] Henderson, M, de Pennington, A, Baxter, J E and Wells, V, "The Global Engineering Design Team (GEDT) Transatlantic Team-Based Design for Undergraduates". *Proceedings of the American Society of Engineering Education 2000 Annual Conference,* St Louis, 2000

[3] http://www.engin.umich.edu/alumni/engineer/01SS/global.html "Going Global; Educating Michigan Engineers for a Worldwide Marketplace"

[4] Discovery Channel Original Productions, LLC, "Harley Davidson – Birth of the V-Rod", *Discovery Communications, Inc*, 2001

[5] Thomas, P J, Ramirez, B, Leech, S C, McKay, A, Blair, G and. Baxter, J E "Prototyping the Future: Developing a Virtual Design Office Exploration Programme", *to be presented at TTI 2002 Conference*, 10-12 July 2002, Birmingham, UK

[6] Holland, N and Vasquez de Velasco, G, "The internationalization of undergraduate programs: A model program," *FIE Conference 1998, IEEE/ASEE.*

[7] Jenkinson, L. R., Page G J, Marchman, J F, "A model for international teaming in aircraft design education," *Aircraft Design*, vol. 3, 2000, pp 239–247.