AC 2007-2390: A PILOT PROGRAM ON TEACHING DISPERSED PRODUCT DEVELOPMENT IN COLLABORATION WITH AN INTERNATIONAL UNIVERSITY

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Introduction

Dispersed product development is becoming ever more prevalent across industries. Most multinational companies have research and development laboratories, design studios, manufacturing facilities, and marketing departments all over the globe. This global dispersion of talent often necessitates that highly skilled and often specialized workforce collaborates across time zones and cultural boundaries. To better prepare their students for this challenge, two prestigious universities from each side of the Atlantic, the "European University" and the "American University" have started a pilot program to jointly teach product development. We report on the structure of and lessons learned from this pilot program.

History of product development courses at the European University and the American University

Even before the start of the collaboration between the two schools, there were are number of key similarities between their respective programs: Both universities have a strong engineering ethos and a relatively long history of interdisciplinary product development classes; both classes are renown beyond the university environment; in both classes student teams must develop a product from concept to prototype during the course of the class; and both schools co-teach the course with a nearby school for industrial design. While evolving independently of each other, both courses have evolved similarly throughout the years and now follow "best practices" as reported by Meier[1]. Not surprisingly, key course objectives as reported by the faculty are also closely aligned between the two classes (Table 1).

Table 1 Course objectives of the Product Development courses at the European University and the American University (corresponding objectives on the same row)

European University	American University
Understanding of how successful PD is based on both traditional and modern methods and tools.	Competence with a set of tools and methods for product design and development.
Awareness of the quality of his or her own design, engineering, or marketing skills.	Confidence in your own abilities to create a new product.
Understanding of PD costs and economy	Awareness of the role of multiple functions in creating a new product (e.g. marketing, finance, industrial design, engineering, production).
Ability to work out project plan and schedules, manage resources, manage risks, complete a project successfully, and communicate and document effectively.	Ability to coordinate multiple, interdisciplinary tasks in order to achieve a common objective.
	Reinforcement of specific knowledge from other courses through practice and reflection in an action-oriented setting.
Understanding of the potential and the challenges of interdisciplinary teamwork.	Enhanced team working skills.
Ability to deliver high quality oral and written reports.	
Ability to negotiate and to deal with agreements, NDA's, and IPR's.	

The similar course objectives were crucial in the beginning to be able to share students between the two courses. We wanted to ensure during the planning of the collaboration that the students would meet the specific requirements of their respective degree programs.

Although the courses are similar, they are not completely identical. The following sections provide a brief overview of the two courses

European University

Product development is a popular major at the Department of Mechanical Engineering at the European University. This is partly due to the principal course in it – a project based course where groups of students develop products for industrial sponsor companies. This project based course first started at the European University in 1980 as part of another course and involved a small development exercise for an industrial sponsor. These exercises were very popular in both the school and among the sponsors, and in 1994 the exercise was separated as an independent course. For the first decade the theory of product development was taught parallel to the project course, but under a separate course code. However since starting the collaboration with the American University in 2003, the theory was woven into the project based course.

The course has evolved significantly over the decades and is continuously updated to keep the course current. Certain features of the course stabilized in 1997 into what is now called best practices. Nevertheless, the essence of the course has remained the same. Over 70 projects have been completed and 5 products have been commercialized since 1997. The team size has stabilized at approximately 10 students, of which one or two must be industrial designers. Usually, an additional one or two students are from other departments (e.g. electrical engineering, industrial engineering, school of management). The remaining six to eight students are product development majors or minors in the Mechanical Engineering department. A team is lead by a student project manager, who receives a short course on project management at the beginning of the class. The budget of the course has slowly been increasing. It started from around 5500 € and is now 10 000 €. The budget is paid for the teams by their sponsor companies who also give concrete product development assignments. All assignments are first negotiated with the professor.

The most significant changes in the last three years of the course have been the inclusion of international students both as distant and local members, the combination of the theoretical and practical courses into a single course under a single course code, an increased media publicity that has brought more students and sponsors, and the expansion of the tutoring team from a professor and assistant to laboratory personnel and graduate students.

American University
The product design and development course at the American University started in the early 1990s in the larger context of addressing the dwindling competitiveness of US manufacturing throughout the 1980s. An ambitious project between the American University's Engineering Department and Business School and major American manufacturing companies aimed at educating future leaders in the manufacturing area and to conduct research on manufacturing processes. Product development was soon determined as a principal driver of manufacturing capabilities, giving rise to the product development class at the American University. The class soon became an essential building block in its manufacturing curriculum. Being offered both, as a business class and an engineering class, the class also helped strengthen the ties and collaboration between the engineering department and the business school.

From its inception, one of the key tenets of the class was to generate and select student ideas and, over the course of a semester, transform these ideas into tangible products. Teams of six to eight students from both the business school and engineering department would receive a budget of $1,000 to do this. Initial funding was provided by the industry partners of the newly minted manufacturing program. Later, funding was provided by individual companies who would suggest a product development challenge to one of the teams. The latter funding mode is still the principal source of funding today.

The lack of industrial design talent at the American University lead in 1995 to a collaboration between the American University and the nearby School of Industrial Design. Since then, the course is also listed at the School of Industrial Design and at least one industrial design student is now on each product development team.

All classes are taught at the American University, primarily by the lead American University faculty. An instructor from the School of Industrial Design is specifically allocated to this class and takes partial teaching responsibility. Classes are designed to illustrate the product development *process* and the tools necessary for the students to perform principal tasks. Typical class size is 80 students, half of which are usually from the interdisciplinary manufacturing program. The other half consists in general of equal numbers of students from (mechanical) engineering, the business school and the school of industrial design. Finally, each year a few students from other departments (ore even universities) such as sociology, psychology, or architecture are also admitted to the class. More details on the history of this class can be found in Eppinger and Kressy[2]. Table 2 summarizes the key features of the courses at each university.

Table 2 Key features of Product Development courses at the European University and the American University

	European University	American University
Student mix	Engineering, Industrial Design, Management	Engineering, Industrial Design, Management
Team size	8–10 (incl. a project manager)	6–8 (no project manager)
Student age	21–28	25–40
Course length	2 terms	1 term
Project types	Direct company sponsorship and project initiation.	Indirect company sponsorship. Primarily student initiated projects
Budget per team	10,000 €	$1,000
Goal	Working prototype	Works and looks like prototype. (Sell concept to possible investors)

Structure of the student exchange pilot program

In 2003 we started a pilot program, where the idea was to practice working in a dispersed team, where 2 out of 10 members of the team would participate as distant members. In 2003–2004 two American University students participated in the European University version of the class; and similarly two European University students took part in the American University version of the class. The program is continuing today. The distant members are advised to travel to work with the rest of the team locally 2–3 times during the course. The recommended times are (1) the very beginning, (2) during major decisions such as final concept selection or concept refinement and testing, and (3) the final building of a prototype for the end gala presentations.

As the program continues, each year 2-4 students from one side of the Atlantic are teamed up together with a team of approximately 8 students on the other side. The distant students consist of 1-2 engineering or management students and 1-2 industrial design students, depending on the type of project and student participation. Originally we had two teams on both sides of the Atlantic and managed two parallel dispersed teams. Due to logistical and administrative reasons, we have since then moved to having just one dispersed team; typically 2-4 American University students joining a team in the European University,. We have, however, not excluded the option of returning to the two sided exchange in the future.

The pilot was originally financed from the private funds of the faculty on each side. Since the first year's success, the industrial sponsor has picked up the costs for the exchange. We budget approximately $2,500 for each student. It is up to the student to decide how to distribute that money between travel, communication, and other expenses related to the exchange.

Building the pilot through teaching principles

We use multiple pedagogical principals in building and teaching our courses from basic lecturing and independent readings to guest lectures. The main philosophy used, however, is problem-based learning, which includes project-based learning and learning by doing.

As discussed by de Graaf and Kolmos[3] problem-based learning is one of the most popular teaching philosophies, partly because of the high degree of motivation of the students. This motivation is also clealrly evident in the courses at the European University and the American University. The students often work more than the required hours for credit and they do so out of interest toward the course and the excitement of seeing something build by their own hands. The prospect of issuing a patent under their name and, in the context of the class at American University, the prospect of reaping future financial rewards from their development, further add to their dedication. This motivation encouraged us to try adding an additional level of difficulty to the courses.

As we built the pilot, and as we continue improving it, problem based learning is eminent throughout the course and for each individual learning target. The students identify their project goals and draft their own project plans and schedules. The only restrictions or guidance comes from the budget available, the class schedule, and in case of a sponsored project, some sponsor provided guidelines. The students with their respective skills are introduced to the distant members, but other than that, the inclusion in the project is left to the students. The students face multiple design choices along the project forcing them to seek information and to rely on each others' expertise, which results in high degrees of learning and appreciation of both own and team members' skills, as evidenced in the course feedback. With the completion of the projects, the students have been able to lead a project from an idea to a prototype and gained hands-on experience in achieving this.

In addition to problem based learning, we have noticed that students learn through teaching and peer-to-peer interaction as well. In practice, we have the students present certain class topics to the rest of the class and introduce and defend their product concepts. This peer-to-peer feedback is appreciated by the students and often leads to further product refinements.

Data collection

In order to evaluate the success and usefulness of the pilot program, we interviewed all 26 students of the three dispersed teams from 2003–2005. We used an open-ended interview guide to obtain comparable answers while still allowing the students to voice their other possible concerns freely. The students were interviewed separately and by persons not involved in grading to ensure truthful answers. In addition, we interviewed the professors in charge of the program as well as the industrial sponsor in the 2 European University projects.

As the program continues, we are moving to more formal monitoring of learning and use a standard student feedback form. Data from one year (Academic year 2005–2006) is included in this report. The first formal student feedback was completed by 40 students, five of which participated in the European-American collaborative project. We compare these answers to the non-dispersed students' answers to investigate how the dispersed team enhances or hinders learning.

Experiences and assessment

A first conclusion from the interviews is that the pilot program has worked well at both universities. The project results were at least as good as those of projects with no distant members. In addition, both the students and faculty at all universities were satisfied with the class. According to the students the most satisfactory part of the class was the international team experience and hands-on work. The distant members agreed with the rest of the team and added that the main motivator for their participation was to learn how the same topic is taught at a different university. Further, the industrial sponsor was also satisfied and is continuing to sponsor the dispersed team.

The dispersed teams faced more problems in the project definition phase than the purely local teams. This was due to the added communication effort and difficulty of building the team when the team could not meet face to face in its entirety. The project scheduling was not experienced difficult because of the distant members. This was even though the project was built around the distant members' traveling schedules.

The dispersed team made the everyday communication and coordination of meetings more difficult than if the team had had no distant members. This problem was mentioned independently by practically all participants. In addition, the students emphasized that the distant members must be chosen prior to the start of the class, which would also improve the students' understanding of the distant members' roles in the project. The excess effort for communication and coordination also added workload compared to the other teams as mentioned by over half of the students. In general, however, students found that the extra effort was worth it.

During the interviews students mentioned many obstacles they had faced that could have easily been solved by a faculty member. These included issues with team dynamics, a space for teleconferencing, and help in finding a file sharing software. Unfortunately the students did not feel comfortable voicing these problems during the course.

The cross-Atlantic cooperation also brought new cultural differences to the project. Since both universities have a highly international student body to begin with, the perceived cultural difference was mainly attributed to the different working habits at the two universities. This, however, was not considered a problem by most of the participants. The bigger differences were felt, in general, between management and engineering students as well as industrial design and engineering students. These cultural differences lead both to disagreements and positive learnings as the following three comments illustrate:

> "They have this attitude of being extremely effective and cheery saying 'Come on team! Come on guys!' but it doesn't help the real work. They act effective but are not. For me it was uncomfortable." *An engineering student at the European University describing 2 distant members*.

> "We were supposed to figure out something and us local members thought we should just try experimental methods but [a distant member] wanted to take a theoretical approach." *An engineering student at the European University describing a distant member*.

> "[An engineer] did not understand what we were doing in the beginning. [An industrial design student] was leading a meeting, [the engineer] was wondering why we were doing it, starting it from so far away. He was perhaps worried about the time. This really shows the difference between industrial designers and engineers!" *An engineering student at the European University*.

> "I learned a lot about teamwork and [industrial] designer's position in product development. I believe and now with experience I can say that [an industrial] designer is essential to every product development project. I would do lots of things differently. First I'd like to see better working between all designers, engineers, and marketing people." *An industrial design student at the European University*.

As to whether the distant members were truly part of the team, the opinions were split. About half felt that the distant members contributed as much or even more than the local members. The other half, however, felt that the distant members merely needed to be kept informed about the project while contributing to the project occasionally. The perceived motivation of an individual distant member affected the opinions of the individual local members. The main lesson learned from this and the earlier comment about the early definition of the roles of the distant members is to choose the distant members carefully based on their motivation and commitment.

The principal learnings, in addition to developing a product, reported by the participants, were related to importance of communication and coordination among the dispersed team. In addition, many students appreciated the chance to practice for future work – many felt that it is an important skill to be able to work in dispersed product development teams. The latter was mentioned especially by the distant members interviewed in 2003–2005. After introducing the recommendation listed in at the end of the paper, many local members (AY 2005–2006) also commented on the value of learning to work in dispersed product development teams.

We also asked the students about the structure of the course and how they would like to modify the course if they were in charge. The most popular suggestions were related to the selection and communication with the distant members. Almost all called for an earlier selection of the students and mandatory 2–3 scheduled trips to work locally with the rest of the team. Another popular improvement suggestion was to assign an assistant to help with the communication between the team members, especially in the beginning. Further, it was suggested that the roles of the distant members should be defined more clearly together with the faculty in the beginning. The last part is against the planned problem based approach, but due to the large number of comments, more advice and support is needed in forming of the dispersed team.

The pilot program teams consisted of approximately 2 distant members and 8 local members. We asked the students' opinions on having the dispersed team be evenly split between the two engineering schools, but this was generally not supported. A few members actively suggested it, but the rest deemed it too expensive, and most of all, feared that then the team would split into two distinct projects. The same concerns are shared by the faculty at both universities.

Based on the interviews, we find that the students learned about product development as much as the other teams with no distant members. The distant members' learning is tied to his or her motivation and how proactive he or she is. The members, who the other team members saw as an active member, felt they learned from the project, whereas the members who were not as proactive, felt that they would have learned more if they had participated in a local team.

On the more practical side, we observed that email and internet phone, such as Skype, were considered the best ways of communicating daily issues among a dispersed team. Also instant messenger was recommended, particularly by the distant members who likened it to passing a team member in a hall. For file sharing, a shared internet workspace was recommended. The students never tried videoconferencing and only a couple mentioned the need for it. The true need for videoconferencing is unclear and must be further investigated.

Overall, the projects went very well and 22 of the 26 students felt that the project benefited from the dispersed product development team. The benefits were primarily ascribed to the added expertise the distant members brought to the table, but not to the fact that they were not local members. This reflects common practice in industrial projects, as teams are not merely dispersed for the sake of being international but due to specific expertise needed in a project. Most students would or did recommend the experience to their friends. Only two students would not recommend participating in a dispersed team to a friend.

Two years into the program, we started using a formal student feedback form to follow the student learning. The results related to the dispersed program from the first year of the formal feedback form are reported. We compared the dispersed teams' answers (n=5) to the non-dispersed teams' answers (n=35) on four topics: (1) Learning and meeting of course objectives, (2) Causes for difficulties or failures, (3) Success factors, and (4) Teamwork. The following table (Table 3) summarizes the results.

Table 3 Results of student feedback questions related to the dispersed product development program

	Non-dispersed team average	Dispersed team average
Learning and meeting of course objectives (1 = disagree, 4=agree)		
the course had marginal value for me	1.9	2.0
the goals of the course were unclear to me	1.4	1.8
one does not learn that much new during the project	1.7	1.4
I put so much effort for so little learning outcome	1.9	1.2
Causes for difficulties and failures in our project (1=no problem, 4=major challenge)		
organizational challenges with 10 individuals	2.3	2.4
language and/or cultural problems	1.5	1.8
project planning, scheduling	2.5	2.8
understanding of students from other study directions	1.6	1.4
conceptual design phase	2.0	1.6
detailed design phase, fighting with CAD	1.8	1.6
purchasing, manufacture and assembly	2.5	1.4
decision making and related issues	2.5	2.6
Most important success factors (1=disagree, 4=agree)		
thanks to the past engineering studies	3.1	2.6
thanks to the industrial design skills in our team	3.0	2.8
thanks to our brainstorming and creativity	2.9	2.8
understanding the customer needs and marketing issues	2.8	3.2
persistence - we just never gave up	3.0	3.0
Teamwork (1=disagree, 4=agree)		
mission impossible: scheduling of team work and individuals	2.4	2.0
there were too many meetings, tutoring sessions, etc. with little value	1.8	2.4
non-functional team dynamics	1.8	2.0
my respect to students of other disciplines increased during the project	2.9	3.0

As it can be seen in Table 3, the averages for both the non-dispersed teams' students and the dispersed teams' students are close. The only significant difference ($p<0.05$) is the question regarding the effort put into the project. The students in the dispersed team felt the effort they put into the project was definitely worth it. The difference could also be due to more motivated people selecting the dispersed team. In either case, we gladly notice that the pilot program does not seem to over-burden students. The only other question, where the averages differ somewhat significantly ($p=0.06$) is in the question related to purchasing, manufacture, and assembly problems. These were less of a problem with the dispersed team, but this is likely due to the type of project rather than the fact that the team was dispersed. In general, we conclude that since the student feedback from the non-dispersed and dispersed team is identical, the pilot program can continue without unfairly disadvantaging students. We will continue to monitor the progress and collect more qualitative and quantitative data as the program continues.

Recommendations

Based on the experiences from this pilot program we are planning and recommend the following improvements for the coming projects:

1. The team structure of the dispersed team and the roles of the team members must be carefully planned.
2. The distant members must be chosen prior to the start of the class.
3. The students need more support on communication. It is not enough to mention that faculty can help with e.g. tele/videoconferencing, but the faculty should actually participate in the initial conference.
4. Reserve class time with no specific content to enable group meetings (to keep schedules clear and no overlapping classes).
5. More faculty and/or staff consulting/encouragement to help with resolving issues both with the project itself and team dynamics.

The first two recommendations are based on the strong feedback by most of the students. Without timely selection of distant members, that is *prior* to the beginning of the semester, the projects cannot be scheduled to accommodate the distant members' schedules (specifically their ability to travel). Moreover, without knowing the specific expertise of the (not yet chosen) distant members, assigning tasks to team members is either delayed or causes downstream integration problems of the distant members.

The third recommendation addresses the difficulties the students experienced with communication. This is listed as the biggest hurdle in the beginning but also as one of the key learnings in the end. To expedite the learning, and to prevent project delays due to communication issues, we consider it beneficial for a faculty member to schedule and sit in early tele (or video) conferences. Similarly we recommend (#5) faculty to be proactive about helping the teams with the projects and team dynamics. We found that students are sometimes afraid to ask for help in fear of a lower grade.

Finally, if the university has a mandatory attendance policy in their lectures, as was the case for the American University, class time must be reserved to enable group meetings. Because the students come from different departments, their schedules tend to be very different and overlapping times to meet are hard to find during the work week. This results in scheduling meetings during the weekend, which is sometimes impossible for students with families. Thus we recommend reserving some class time for group meetings.

Also based on our experience the following practices worked well and will be continued next year:

1. Continue the dispersed team practice. Surprisingly the dispersed team did not only bring coordination challenges but also resulted in being able to perform certain tasks better than without distant team members.
2. Roughly an 8/2-4 ratio between local and distant team members. Too many distant members risk the group splitting into two.
3. Timing of the distant members visits: (1) in the very beginning, (2) at a major point of activity such as final concept selection or concept refinement and testing, and (3) the final project presentations. These times in general involve major decision points, and provide good

opportunities for the distant members to be truly involved. These particular visiting times seem to be good for the student motivation – for both distant and local members.

Conclusions

We have described a new course to help students prepare for the global work environment in product development. We set up a collaborative course based on earlier experience of over a decade at both the European University and the American University. This experience enabled us to choose the teaching principles, namely different aspects of problem based learning that best improve student learning and motivation. The pilot program of dispersed product development teams was a success and is continuing today. We highly recommend similar programs to other schools as well.

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