Distant yet Near: Interdisciplinary Collaboration and Learning between Engineering and Business Students through Socially Responsible Projects

INNOVATION SUMMARY

With global specialization of work units within organizations, multidisciplinary virtual teams comprised of technical and business members are increasingly common in today's workplace. While higher education has responded by creating opportunities for remote teams to learn from collaborative work, opportunities for interaction between *remotely situated significantly diverse teams*, such as business and engineering, are few. Lecture and reading-based environments cannot adequately replicate the rich experiences necessary for such engagements. This manuscript describes a pedagogical offering built upon collaboration between undergraduate US-based business and UK-based engineering and product design students. The offering has been designed with four common goals:

a. Understand interdisciplinary dependence and related conflicts between **significantly diverse teams**.
b. Acquire skills necessary to successfully **develop and manage virtual project teams** using technology mediated face-to-face and asynchronous communications,
c. Understand cultural, temporal, and systematic **differences that influence invention and work**, and
d. Recognize the value of **socially responsible** business and technical engagements.

US-UK teams develop products for children with disabilities during Fall semester and renewable energy educational kits for middle-school children during Spring. The projects face both technical and business constraints, such as requirements for inclusive design to support children of various ages and abilities and for market viability including appropriate pricing levels. Students meet weekly via videoconferencing facilities for 20-30 minutes and supplement this with individual Skype sessions and asynchronous communication such e-mail and shared spaces. Faculty utilize the multi-faceted learning environment to introduce deliberate uncertainty and problem solving opportunities through the semester. The paper presents evaluations that evidence achievement of rich experiences as intended by faculty on all of the above goals. Additionally, among other lessons, insights related to institutional synergy, continuous improvement, promoting interdependent learning across such diverse teams are shared.

INTRODUCTION

With increasing global specialization of work, multidisciplinary virtual teams comprised of technical and business members are increasingly common in today's workplace. Employers stress the value of presenting students with educational opportunities to improve team and cross-disciplinary skills prior to entering the workplace. While higher education has responded by creating opportunities for remote teams to learn from collaborative work (see for example Adya, *et al*, 2008; Olson-Buchannan, *et al* 2007), engagements between significantly diverse disciplines, such as business and engineering, are few (Temple & Allen, 2000). Such remotely situated diverse teams must not merely foster trust, communications, and productive relationships but must also develop a mutual understanding of each other's disciplines despite potentially divergent goals, all via technology-mediated communications. For instance, project managers driven by temporal and budgetary constraints must comprehend and accommodate engineers' desire to develop most creative and complete applications.

Lecture and reading-based pedagogical environments do not replicate the complex and rich experiences desirable for developing a global and multidisciplinary workforce. While graduate students can gain exposure to such experiences through professional engagements, undergraduate students are severely limited in such opportunities. Recognizing this limitation, the authors, a US-based business faculty and two UK-based faculty in Mechanical and Electrical Engineering, collaborated to offer such an experience to undergraduate students. Since 2008, US business students enrolled in a Project Management course (hereon referred to as US teams) have collaborated with UK-based Mechanical and Electrical Engineering and Product Design students (UK teams) to design and develop socially responsible products for children. During Fall term, the US-UK teams jointly prototype and develop a marketing plan for activities for children with disabilities. In Spring, a different cohort of students design educational kits to teach children concepts of renewable energy. Having invested three years in developing and refining this joint offering, the authors welcome this award opportunity to share teaching strategies and related insights.

At one level, US-UK faculty have maintained independent learning objectives to comply with developmental expectations of their respective institutions and accrediting professional bodies. US-UK teams accomplish these in the context of this remote collaboration. Project management students learn to scope and plan a project, execute the project in accordance with plans, and manage constraints and teams. Engineering and product design students learn new product development, integrate mechanical and electrical components while maintaining safety standards, and consider efficient and cost-effective design principles. At a second and more critical level, each semester, both groups share the following objectives:

a. Understand the multidisciplinary but interdependent nature of their work engagement, specifically tensions that exist between business viability and technical creativity and in the information flow necessary for efficient and innovative product design and marketing.
b. Acquire skills necessary for working in virtual project teams and understand role of trust, communications, and effects of technology-mediated communications on team processes.
c. Recognize cultural, temporal, and systematic differences that influence invention and practice.
d. Recognize the value of socially responsible business and technical engagements.

With these objectives, the pedagogical environment reported in this work is innovative in bringing together (a) globally distributed, (b) significantly multidisciplinary teams, (c) with a common objective of socially responsible but viable product development, (d) using synchronous and asynchronous technology mediated communications and shared workspaces, (e) across a non-trivial engagement of 10-12 weeks. Reflecting our goals, from here on, the US-UK teams are referred to as "interdisciplinary." Rosenfield (1992) defines multidisciplinary teams as those that work *independently* in their own disciplines to solve a common problem and contrasts these with interdisciplinary teams that work *jointly*, but from their own perspectives, to address a common problem. Interdisciplinary teams are said to experience greater transformation through the collaborative engagement as compared to multidisciplinary teams.

In subsequent sections, we review existing pedagogical literature, highlighting the innovativeness of US-UK collaboration. This is followed by a description of the offering and its related outcomes as measured through student evaluations, reflective essays, and surveys. The concluding section outlines guidelines for transferability and recommendations for implementations in other domains.

REVIEW OF RELEVANT LITERATURE

Higher education has tended to provide highly specialized contexts for learning (Wojahn, *et al* 2009). While such contextualized delivery is efficacious considering the pragmatic constraints in teaching environments, it often results in compartmentalized knowledge and inefficiencies (Housely, 2003). Interdisciplinary and collaborative learning opportunities are an attempt to overcome such fragmented thinking (Klein, 1995) and "develop holistic modes of inquiry, decision making, and practice" (Housely, 2003, pp 1). Our interest in globally-focused multidisciplinary pedagogy led to examination of three aspects of existing literature – (i) the nature of interdisciplinary learning teams, (ii) engagement between remote teams, and (iii) the context of team work as defined by type of technologies used, length of engagement, and nature of joint project work. However, considering that numerous publications emphasize *research dimensions* of these elements (e.g. Van Der Vegt & Buderson's 2005 assessment of importance of collective team identification in multi-disciplinary teams), this work focused on *pedagogical* initiatives. The literature, summarized in Table 1, is by no means exhaustive, but is largely representative of what is reported in cross-disciplinary pedagogy.

In the past decade, there has been a steady shift towards interdisciplinary teaching environments. Ropers-Huilman, Carwile, & Lima (2005), for instance, used a service learning project to expose engineers to multidisciplinary and collaborative problem solving in engineering. Their teams represented two engineering sub-specialties that did not represent the significant diversity we posit herein. Metros (2005), in contrast, did establish diverse teams of visual designers and education students to design, develop, and deliver learning objects for high school students, particularly those with disabilities. Other such diverse teams are present in the literature as combinations of engineers and technical communicators (Dyke & Wojahn, 2000; Wojahan, *et al*, 2001), civil engineers and construction students (O'Brien, Soibelman, & Elvin, 2003), and product designers, pedagogy experts, and content experts (Winn &

Heeter, 2006) among others. Primarily, these studies reported that interdisciplinary teams experienced mutual learning (Dyke & Wojahn, 2000; O'Brien, *et al*, 2003) that was, in some cases, transformative (e.g. Metros, 2005). Studies also reported an increase in disciplinary team conflict because of such engagement (e.g. Winn & Heeter, 2006).

Learning environments implemented in collaboration with business, however, are less prevalent. Ford, *et al* (2004) and Okudan & Zappe (2006) paired co-located business and engineering teams to create designs and develop marketing plans for novel products while Maleki (2009) had business and engineering teams work on client projects. Other offerings, such as Ryssen & Goddar (2000), Olson-Buchannan, *et al* (2007), and Adya, *et al* (2008), paired business students, though with differing skill sets.

The context of virtual teams has been studied extensively in the literature (e.g. Powell, Piccoli, & Ives, 2004; Martins, Gilson, & Maynard, 2004). Much of this work, however, emphasizes *research* on virtual team effectiveness. For instance, research undertakings have examined trust among virtual teams (Coppola, Hiltz, & Rotter, 2004; Jarvenpaa, Knoll, & Liedner, 1998), leadership effectiveness (Kayworth & Liedner, 2002; Zigurs, 2003), conflict management (Mantoya-Weiss, Massey, & Song, 2001), and knowledge sharing and integration (Alavi & Tiwana, 2002). Pedagogically, however, few studies exist and when they do, the nature of engagement may not be truly remote. Olson-Buchannan, *et al* (2007), for instance, used co-located "virtual" teams that were not allowed to meet face-to-face during the project. Their interactions were facilitated by web-based learning tools. Several instances do exist, though, where teams are remotely, often internationally, located. Adya, *et al* (2008), Rusu, *et al* (2009), Ryssen & Goddar (2000), and Zavbi & Tavcar (2004) implemented international team projects though not all were interdisciplinary or may have exposed students to rich face-to-face communications as afforded by VC technology. Virtual teams in Adya, *et al* (2008), for instance, primarily utilized asynchronous communications such as e-mail and shared spaces to execute project work. The low-richness media may have impaired learning related to team development and awareness in these teams. Teams also potentially experienced lesser disciplinary tension events as both teams were from business school environments.

TABLE 1: Summary of Key Pedagogical Implementations in Multidisciplinary Remote Teams

Study	Disciplines Engaged	Remote Teams?	Nature of Engagement
1. Adya, *et al* (2008)	Project Management and Systems Analysis and Design teams, both in business schools	Yes – US and India respectively	System design projects defined by collaborating faculty
2. Chau (2007)	Sub-specialties of Engineering	No	Faculty designed sustainability projects
3. Dyke & Wojahn (2000)	Technical Communication and Engineering	No	Client-based projects
4. Ford, *et al* (2004)	Business and Engineering	No	Design a novel product and related marketing plan and documentation
5. Malecki (2009)	Business and engineering	No	Industrially defined collaborative projects
6. Metros (2005)	Visual Design and Education Students	No	Design, deliver learning objects for school students, particularly those with disabilities
7. Miller & Olds (1994)	8 engineering sub-specialties	No	Industrial and government driven projects
8. Newell, *et al* (1999)	Engineering and Communications	No	Open-ended design projects sponsored by faculty
9. O'Brien, *et al* (2003)	Civil Engineering and Construction Teams	Yes – US only	Facility design project defined by faculty
10. Olson-Buchannan, *et al* (2007)	Only Management Principles	No	Unclear
11. Okudan & Zappe (2006)	Manufacturing Management and those in Engineering Entrepreneurship (graduate)	No	Two faculty defined design projects
12. Ropers-Huilman, *et al* (2005)	Biomedical Engineering students	No	Service learning projects
13. Rosca (2005)	Business and Engineering	No	Software development for HR firm
14. Rusu, *et al* (2009)	Software engineering	Yes – US-based	Government-driven design project
15. Ryssen & Goddar (2000)	International Marketing	Yes – US and Belgium based	Write a term paper analyzing markets for a particular product
16. Temple & Allan (2000)	Business and Engineering teams	Yes - Europe	System design projects defined by faculty
17. Wellington, *et al* (2002)	Engineering, Marketing, Accounting, and Industrial Design	No	Industrial driven projects
18. Winn & Heeter, (2006)	Product Design and Education	No	Design game concepts for students from 7-9th grades
19. Wojahan, *et al* (2001)	Technical Communications and Engineering	No	Industrial and government driven projects
20. Zavbi & Tavcar (2004)	Engineering sub-specialties	Yes – Slovenia, Swiss, Netherlands	Faculty defined product development projects

IMPLEMENTATION OF THE US-UK OFFERING

Since Fall 2008, US-UK teams have collaborated twice a year during Fall and Spring semesters. A total of 71 product designers and 190 engineers in the UK and 206 business students in the US, comprising 63 interdisciplinary teams, have taken this joint offering. Their engagements have been non-trivial as Fall term work typically lasts from end-September to early December and Spring projects begin in mid-January and end March. The implementation of this offering is described in detail next:

Socially Responsible Projects: In alignment with the authors' institutional missions of service-based learning, US-UK teams engage in socially responsible projects in both terms. During Fall, they jointly develop a fully-costed, viable design of a product prototype for a recreational activity for children with disabilities. Fall teams must work with the following product constraints: (a) inclusive design i.e. both able and disabled children must be able to use the product, (b) intellectually stimulating i.e. both able and disabled children should be equally challenged, (c) non-computer-based activity but with interfacing to support a range of possible disabilities, and (d) market viability i.e. price and features that make the product saleable. Spring semester projects involve renewable energy. Teams must design an educational kit for middle school children to teach power generation from any one of the following renewable sources – air, water, or solar – under the following constraints: the kit must be (a) easily assembled and understood by targeted children, (b) accompanied by an easy to understand user manual, (c) packaged attractively, and (d) viable in the chosen market. Table 2 below summarizes the two offerings.

Positive Inter-dependence among Teams: Co-operative learning is most effective when collaborating teams are positively interdependent upon each other (Millis & Cottell, 1997). The US-UK learning environment and project objectives easily facilitated such interdependence:

a. *Joint Responsibility for Managing Communications*: US - UK teams engage in communications via videoconferencing (VC) facilities, shared spaces, and e-mail, all facilitated as part of the class offering (Figure 1). Weekly VC sessions are mandated while e-mail and shared spaces are to be used at the discretion of teams. Faculty are only responsible for enabling weekly the VC sessions; the

TABLE 2: Overview of US-UK Fall and Spring Offerings

	Fall Offering	Spring Offering
Duration	Mid-September to Early December	Mid-January to End-March
Goal	Inclusive activity for children – disabled and able	Educational product to teach about renewable energy to middle school children
Examples of Projects	- Connect-4 style game with eye tracker to control movements - Remote controlled car operable by eye tracking device	- 4-room doll house with LED lights that work on solar power - 4-wheeled car powered by solar energy
Market	World	US or UK
US Team Constitution	Business and Project Managers	Business and Project Managers
UK Team Constitution	Mechanical Engineers Electrical Engineers Product Designers	Mechanical Engineers Electrical Engineers
Information exchange		
US Teams	Require product development information (manufacturing route, costs and materials) from UK Teams	
UK Teams	Require number of sales expected and price to be targeted, market scope from US Teams	

activities and conduct of the actual VC sessions are left to the two teams. US teams must e-mail agendas to UK teams 48 hours prior to the VC session, to which UK can add agenda items up to 12 hours prior to the session. US teams are also responsible for creating minutes of meetings and sending them to UK teams within 24 hours of the VC session. Both agendas and minutes are graded. Beyond this, teams can use Skype to augment "face-to-face" interaction in their own time; most teams do so, often close to delivery of final documents. As anticipated, complex communications such as brain storming, choosing final product, discussing marketing plan, etc. are left to VC; shared spaces are mostly used as document repositories; and e-mails are utilized primarily for sharing meeting agendas and minutes and to trigger reminders and short notifications. Such use of communication media most often result from team evolution and reflection with little or no faculty directive.

b. *Common Outcomes*: Beyond their individual course requirements, US-UK teams deliver three shared outcomes upon which both teams are evaluated – (a) a feasible fully-costed design for the product as per requirements, (b) companion business case, and (c) joint presentation pitched to potential

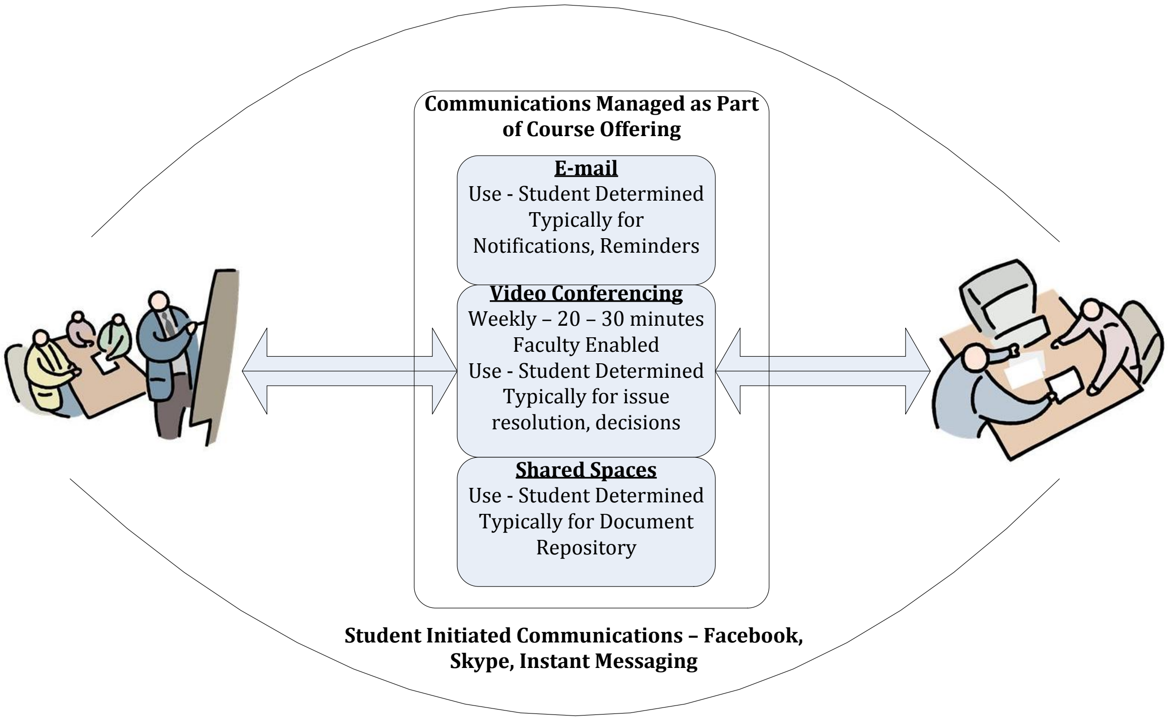


Figure 1: US-UK Communications

investors (faculty and invited guests). Students are encouraged to consider these elements as joint, rather than having engineering and business components. Interdependent work processes, described next, aid this.

c. *Interdependent Work Process* – The complementary skills across US and UK teams enable creation of highly interdependent work processes (Figure 2). UK teams meet to discuss initial ideas for the product subsequent to a product brief from their faculty and their research on target customer needs. Meanwhile, US teams conduct a preliminary market review to identify state of competition, typical price range, and features of competitive products. This information is used to jointly brainstorm ideas during their first two VC meetings. Both US - UK must use decision criteria to agree upon one idea to develop further. Over the next several weeks, UK teams refine the concept, develop mechanical and electrical requirements of the product, and define the manufacturing process to construct it. This is iteratively reviewed and evaluated by US teams who must give due consideration to product marketability and costing. As the product evolves, US teams begin writing the business case to present to potential investors (see Appendix for business case format).

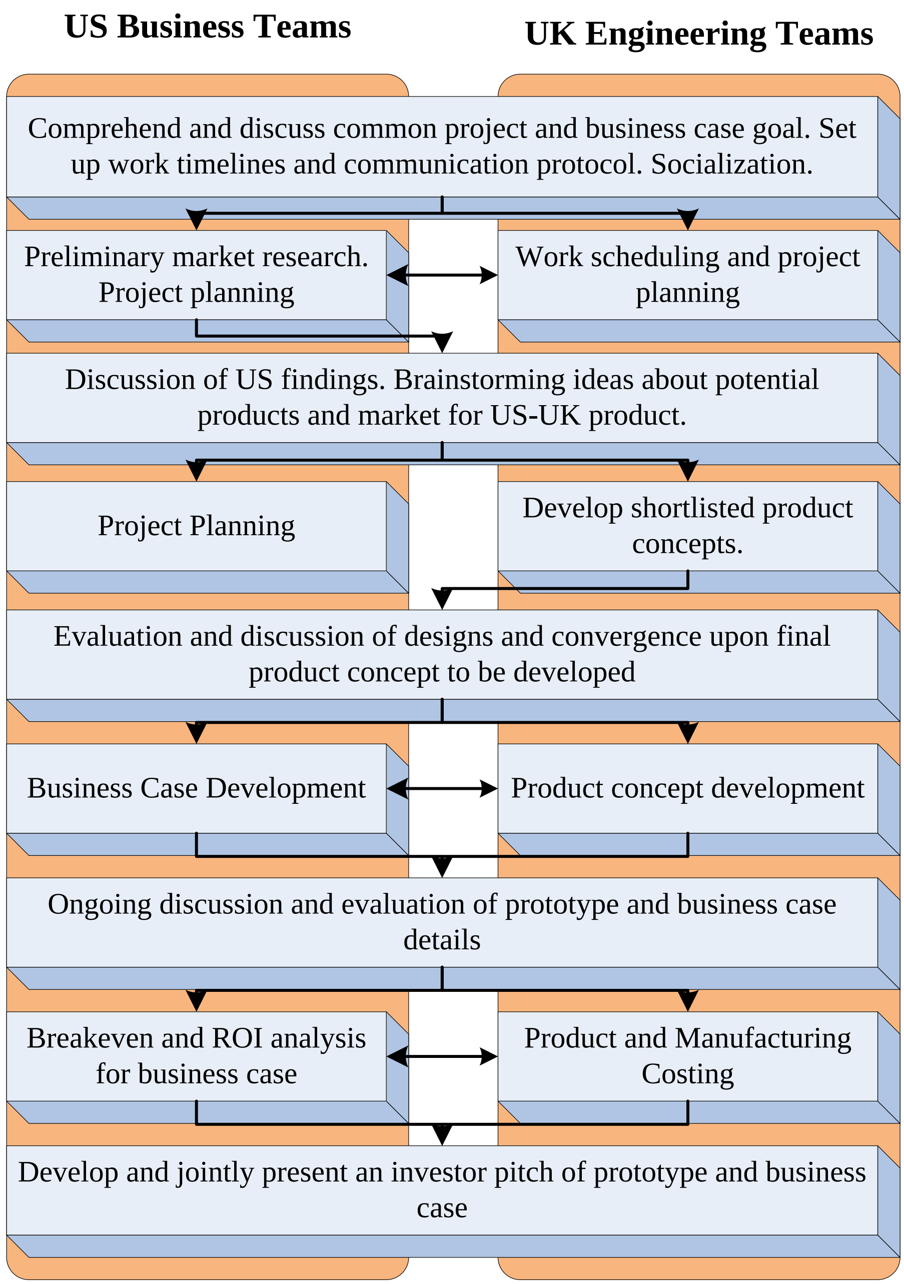


Figure 2: Overview of US-UK Interactions

While US teams are largely responsible for executing the business case, they need manufacturing costs from UK teams to conduct meaningful costing, pricing, breakeven, and payback period analysis. Their risk analysis should reflect product and manufacturing related risks, information that UK teams are best suited to provide. Further, the business case requires a brief overview of the product and its technical specifications that UK teams develop. In contrast, US teams must evaluate the product routinely to ensure market viability as well as cost and requirements control. As UK teams are partially judged on the market viability of their product, they depend upon US business teams to evolve product features, determine pricing, and design effective marketing plans.

TABLE 3: US and UK Deliverables

<table>
<tr><th>US Business Deliverables</th><th>UK Engineering/Product Design Deliverables</th></tr>
<tr><td>Project Management Documentation
• Project Charter
• Project Plan including communications, resource, risk, schedule, quality plans
• Lessons learned and project documentation updates
• Weekly agendas and minutes</td><td>Product Development Documentation
• Product ideas
• Product concept
• Refined product
• Drawings of the product
• Manufacturing route/costs</td></tr>
<tr><td>Course Reflection
• Individual - Periodic (1-2 week) reflection on team-based and interdisciplinary learning
• Team – Project lessons learned</td><td>Course Reflection
• Individual - Reflection at end of project on team-based and interdisciplinary learning
• Individual – Reflection on technical merit of the product</td></tr>
<tr><td colspan="2">Joint – Prototype and Business Case (see Appendix for specific details and format)
• Final prototype concept
• Breakeven analysis, payback period, and ROI
• Marketing plan</td></tr>
<tr><td colspan="2">Joint - Investor Presentation
• UK teams present product details, respond to questions on business analysis
• US teams present business analysis, respond to questions on technical details</td></tr>
</table>

The joint presentation, delivered during the final VC meeting, lasts about 30 minutes with 20 minutes devoted to product and business case description and 10 minutes to questions. Typically, UK teams present product details while US teams deliver the business aspects, including cost and investment analysis. However, **in order to ascertain the degree of knowledge exchange, questions posed to the teams address topics of their international partners**, i.e. US business faculty asks UK engineers questions related to the business case, such as cost and investment analysis and marketing plan proposed by their US partners. Engineering faculty, similarly, query US business teams about choice of materials, size and weighting, electrical and mechanical elements, and other engineering decisions. Teams are given advance notice of this format and, therefore, need to ensure that they are comfortable with choices made by their partners. Lack of knowledge exchange, consequently, becomes evident in this deliverable. For instance, during Fall 2011, joint presentations between US - UK had to be cancelled two hours prior to delivery (6:00 AM US time) due to a crippling ice storm in Europe. US teams that had been actively engaged with their UK partners were better prepared with technical details and were able to respond to engineering and product design questions with greater confidence than those that did not. Similar differences were noted in the UK teams.

Controlled Certainty and Deliberate Uncertainty: A multi-faceted learning environment, such as the one described herein, lends itself well to managed uncertainty. US - UK faculty create some level of surety by providing course-related structure, imposing challenging but reasonable project constraints, setting up VC communications, and managing consistent communication of goals and processes across the two locations. However, once the remotely situated teams begin collaborating for prolonged periods of time, group dynamics, interactions, and trust can change unpredictably on a weekly basis. This is particularly so during key points in the project such as agreeing upon a product concept, determining the best market (e.g. US or UK) to initially target, keeping production costs low while producing a marketable product, and identifying the quantity of products to be manufactured to meet projected market demand (which impacts the manufacturing route and costs). This aspect of student interactions is deliberately left unmanaged so as to enable active problem solving and engaged learning. Students are tasked with resolving these interdisciplinary tensions. They may escalate issues to faculty but must demonstrate at least three prior attempts to resolve the issue themselves. Faculty, they are told, are available to serve in consultative roles but ultimately students themselves are answerable for project success. Most students recognize that they are responsible for group development and maintenance and cannot let conflicts impact project communications, decision making, and conduct.

Reflective Evaluation and Continuous Evolution: Both student teams and faculty engage in periodic reflection, minimally at the end of the course (see Table 2 above). Every 2-3 weeks, US students complete an individual reflective assignment wherein they ponder on their learning, contributions to their UK team's learning, factors that have aided collaboration, and aspects that they need to improve. Additionally, each team must present three lessons learned during final week of classes. UK teams meet with faculty every week to assess progress and consider next steps. Additionally, they submit an end-of-semester detailed reflection on the overall learning process. These graded reflections provide routine contemplative opportunities to incite teams to adjust behaviors during project execution.

Faculty also significantly benefit from regular reflections that facilitate continuous improvement. We utilize a combination of three elements to evolve this course offering to a point where, we believe, we have a stable and effective offering in place. First, VC is used for an end-semester debrief to identify aspects needing improvement in the next offering. For instance, in Fall 2010, we agreed through such a debrief, that lack of a common business case template impeded the speed with which teams understood the nature of their project interdependence. In response, US faculty created a business case template which is now used as reference for both locations while discussing requirements. Second, and more significantly, faculty routinely utilize VC to discuss modifications to be made ***during*** the collaborative term and, consequently, are able provide an agile response to issues that might hinder learning. In Fall 2011, for example, we realized that by using different sets of class materials on manufacturing costs and pricing, faculty might potentially cause greater conflict among teams than desirable for such a project engagement. Both faculty immediately shifted to using slides and class content from UK. Thus, following pro-active reflection, both locations have benefitted from interdisciplinary engagements at faculty level.

Third, US - UK faculty examine outcomes from reflective assignments, course evaluations, and discussions with students after course completion to identify specific issues to be implemented before next term. While student discussions are self-selected i.e. not all students engage, they do elicit issues related to team size, benefits of this course offering beyond completion, and employer assessment of the module offerings. The authors wish to raise an important issue at this point: participating faculty must be actively engaged in this ongoing assessment and improvement. Without equal commitment from all, such joint collaborations are ineffective. It is also important to point out that such engagement is evolutionary in nature. A conscious and conscientious effort at continuous improvement is critical to sustain both the institutional relationship as well as an effective learning environment. In Table 3 below, the effect and effectiveness of such continuous improvement on the maturing of the course offering are described.

TABLE 3: Continuous Improvement in US - UK Offerings

Year	Key Changes Made in Response to Continuous Evaluation		
	Project	**Deliverables**	**Communication**
2008-2009	Socially responsible	Project documentation, Product design	VC and e-mail (no shared spaces)
2009-2010	Socially responsible	Project documentation, ***Marketing Plan with low level cost analysis****, Product design, Reflections	VC, e-mail, ***shared spaces**** (Blackboard)
2010-2011	Socially responsible	Project documentation, ***Business case with extensive cost analysis****, Product design, ***Reflections****	VC, e-mail, ***shared spaces**** (Blackboard, SharePoint)
2011-2012	Socially responsible	Project documentation, Business case with extensive cost analysis, Product design, Reflections	VC, e-mail, ***shared spaces**** (student choice e.g. Google+, Box.com, Dropbox.com)

*items in bold/italics indicate changes from previous year's offerings

INNOVATIVE ASPECTS OF US-UK OFFERING

Pedagogical innovation can emerge from numerous sources – creative exercises and content in a specific area or topic, innovative delivery mechanisms such as through use of new technologies, and creative structuring of the classroom environment. The innovation embedded in our approach lies in the last category where the authors have engaged in an overall reconstruction of two course offerings at two institutions across the world in ways that engage students with their respective content areas while recognizing the pragmatic and challenging aspects of interdisciplinary global teams.

Interdisciplinary Perspectives: As the earlier literature review suggests, few prior studies have synergized business and engineering teams in a prolonged engagement of the sort reported. Not only are these areas diverse in terms of lack of a common disciplinary language, they face-off in terms of inherent disciplinary tension stemming from divergent goals. Business students must examine product viability, pricing, and promotional structures. They want the best possible product with least amount of cost and high profit margins to demonstrate a quick return on investment. Engineering students should accommodate safety and quality standards, production processes, and materials to ensure reliability and product longevity. They must design to the cost and sales volume determined by the market and must plan manufacturing processes to achieve a target date for launch. This is not always simple since sales volume and product pricing are determined following a marketing process, yet design decisions influence these targets. There is, consequently, a dilemma right at start of the design process. Equally, business teams need to have early sight of product cost in order to determine profitability, yet detailed costing emerges only after completion of the design process. This dilemma may be resolved by careful use of approximations, a subject not often taught at universities.

Socially Responsible Engagement: Students must recognize a third level of tension added through the socially-driven projects. While this project often binds students with greater commitment towards a common intrinsic goal, they do experience pressures of cost management even further. Teams must base their decisions by considering the constrained environment confronting their target market, e.g. financial limitations faced by parents of children with disabilities or by public school systems. Interestingly, the project context forces students to examine some real-world social entrepreneurship initiatives to understand how some of their business models could be adapted to their own projects.

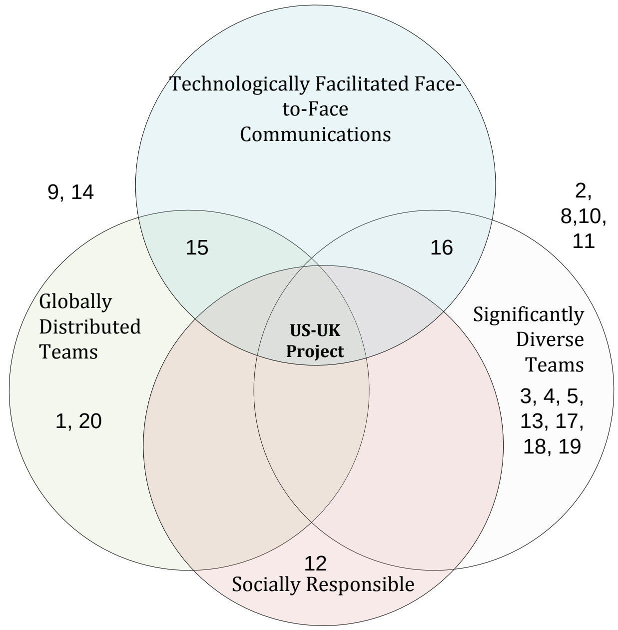
Cultural Differences: These disciplinary challenges are intensified by cultural and time zone incongruity. While both groups speak a common language, they must deal with differences in accents and cultural nuances such as use and interpretation of humor. UK teams contain UK nationals as well as international students from Asia, Africa, and South America, adding complexity to the cultural mix. Further, during project execution, teams must be careful about planning around time zone differences and conversions between metric and US systems, especially when dealing with technical specifications and costing.

Distant, Yet Face-To-Face: Unlike some other pedagogical implementations, US - UK teams must meet face-to-face weekly through VC. At one level, this is a luxury that facilitates development and maintenance of team relationships, but at another, it adds greater complexity to student communications. Cultural and social cues are enhanced. Students are forced to be accountable to each other for unaccomplished work from the past week. Consequently, they must not only have ways of encountering awkward gaps in communications but also be prepared to deal with questions about unanswered e-mails or incomplete assignments. Quite rapidly, students recognize the strong interdependency between their assignments the frustration caused because of missing assignments from partner teams.

Figure 3 illustrates how these four dimensions above mesh to create the unique US-UK experiences. In this figure, we juxtapose studies from Table 1 next to ours, highlighting the uniqueness of our offering. Interdisciplinary pedagogical environments offer numerous opportunities for co-operative learning where competencies stem not merely from books or lecture-based delivery but more significantly from active student engagement in content, issues, and relevant skills (Millis & Cottell, 1997). Without such an environment, there was a significant likelihood that PM students at US and engineering students at UK would have learned the science and techniques of their respective domains without experiencing the delicate negotiations involved in balancing disciplinary tensions. Similarly, both teams may have *inferred* the challenges and benefits of working across time zones and culture without having direct experiences to relate back to.

EFFECTIVENESS AND SPECIFIC BENEFITS OF LEARNING PROCESS

Finding a common set of assessments has been one of the challenges of this joint venture. Traditional university assessment focuses on specific in-class learning objectives and faculty evaluations. Finding such commonality across business and engineering is not easy. While it is possible to use the quality and content of business case and final presentation as a potential measure, considering that students follow a



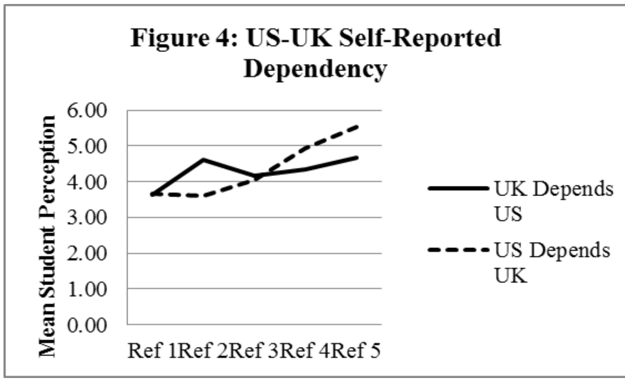
Numbers in the figure map to reference numbers in Table 1

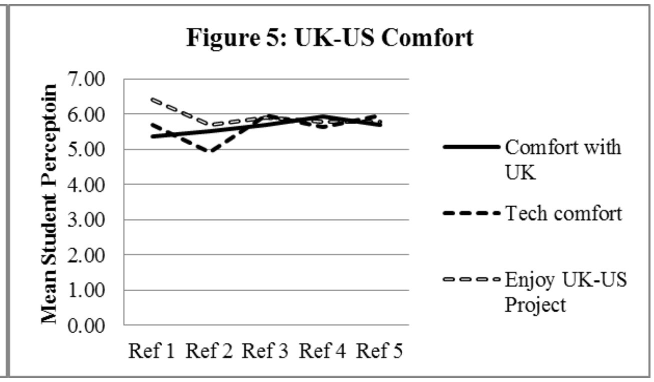
Figure 3: US-UK Offering at the Core of Global, Socially Responsible, and Multidisciplinary Pedagogy

structured format and templates, this deliverable will mostly reflect class requirements rather than interdisciplinary learning. Consequently, we have relied on three primary sources of evaluation: (a) student reflections, (b) faculty evaluations, and (c) informal communications from students and employers post-completion. In addition, student employability and course popularity are examined as alternate measures. Earlier in this document, four common teaching objectives, shared between US and UK, were identified. In the following sections, we evaluate our effectiveness along these four dimensions using the sources is described above.

Understanding and Accommodating Interdisciplinary Tensions: We routinely assess whether students (a) recognize and attempt to accommodate disciplinary dependencies, and (b) experience conflicts stemming from disciplinary differences. Success of their accommodations has not formally been measured as these can be artifacts of communications, team personalities, and group processes. To assess (a) above, Fall 2011 US students were asked in their reflections to indicate on a scale of 1-7 (1 = strongly disagree and 7 = strongly agree) their perceived dependence on UK teams as well as perceived dependence of UK on them. Figure 4 below provides means from their reflections (Ref 1 to Ref 5).

As the time series suggest, students start out (Ref 1) perceiving equal dependence. During the first few weeks (Ref 2 & 3) as US teams research markets, competition, and assess ideas for potential products,





they perceive UK teams to have greater dependence on them. In contrast, towards end of the project, US teams begin relying more on UK teams for detailed technical designs and manufacturing costs in order to develop a meaningful business case. Note also that perceived mutual dependency continues to rise during the semester, suggesting a growing realization of the interdisciplinary nature of their engagement.

Open-ended reflections and communications from teams provide evidence of disciplinary tension. As an illustration, below is an issue raised by a US student via e-mail:

Hello Dr. _US Faculty_,
Last week we discussed the problems with the costing and profitability of our project. I attached the cost of our solar car that [UK] provided. Summary of discussion:

[UK] wants to sell 60,000 units, and our group is forecasting approximately 2,000 units. [UK] based their number off the total population of 11 to 13 year old students in the United States. Our group based our numbers on the amount of middle schools multiplied by average unit per school demand.
We have recently discovered that the solar panels are going to cost $12.55, instead of $5. The fixed cost structure will drastically increase because the fixed cost are divided by 60,000 units. Finally, we were expecting to sell the kit around $75 to $100 per unit, but based off the aesthetic value, it appears that it will be difficult to sell the kit over $50, which makes it difficult to include overhead and administrative costs in the project.

All in all, it has been difficult to explain to our [UK] group that the feasibility of profitability on this project is slim.

This team was advised to revisit the assumptions underlying their calculations and if they held ground, to present objective data to their UK teams and convince them. The US team identified an issue with their assumptions, modified their sale potential to 40,000 units, and presented this data to their UK partners. The teams jointly reworked the analysis via VC to settle on a projected sales volume of 43,000 units. This is the nature of deliberate tension we have wanted to see between the two teams such that they question their assumptions and decisions when misalignments occur. While the above relates to one incident, such issues arise numerous times over a semester. Most teams soon recognize the value of this interdisciplinary conflict and related learning opportunities, as highlighted by student reflection below.

> *…, without the skills of engineers and product designers the project would never have the technical skill to be successful. Some of the challenges stem from the advantages. Since people have different ways about thinking about things, this can cause conflict or misunderstanding between differences. Also, the gap between engineering technical knowledge and project management knowledge sometimes makes it hard to understand the other discipline.* [Fall '11 student]

> *… working with engineers, although challenging at times, is also a great benefit. It provides a sense of realism into the academic process which is very refreshing. The most difficult part of the process is helping the [UK] team understand the common business vernacular. Additionally, some cultural differences have been difficult, such as the definitions for robust, sustainable, and durable.* [Fall '10 student]

Acquiring Skills for Working in Virtual Project Teams: Mostly, US and UK teams do not have previous experience on virtual team projects. Nevertheless, it takes only a few sessions to relax towards mediated communications, as Figure 5 above illustrates. In the first two sessions, teams are overwhelmed by the VC room Polycom facilities that use two large projection screens, sophisticated cameras and microphones, and integrated presentation equipment. However, this soon gets resolved (Ref 2) as teams get involved in setting up connections, document exchanges, and screen sharing. Teams also continue to reflect high levels of enjoyment and sustained comfort with the US-UK project (see Figure 5).

When the project began and teams were assigned, I was defiantly apprehensive about the project, worrying about what skills I could bring to the table, how my skills compare to those of different disciplines and how I would factor in this module on top of an already mounting workload.[UK student]

A positive virtual presence seems to emerge early as teams from both locations recognize the value of VC in facilitating communications. There is also a degree of social responsiveness among teams engendered by the desire to work successfully with remote teams. However, this is a fragile entity relying, as it does, on mutual trust and many teams feel the need for a larger number of face-to-face communication points.

On reflection more video conference time or skyping would have helped both groups and the team over all. A more relaxed relationship could have been formed; also team members who weren't really contributing may have opened up in a more relaxed situation.[UK Student]

As technology fades into the background, students begin focusing on the normal logistics of teamwork, such as identifying communications liaisons and processes, planning work, allocating responsibilities. Social cues are experienced despite technology mediation, as reflected below.

It became evident that "X" had become the team coordinator for team USA. We agreed that anything that required to be dealt with the week before our meeting would be relayed to the local teams via me and [team member]. [UK student]

While VC sessions are most significant in these early interactions for developing team trust and communications, students gradually demonstrate the use of multiple levels of communication media to shift focus to maintaining relationship. Technology seems to recede into the background. In the comment below, a US student relates her team experiences with only minimal reflection on technology:

Our relationship has definitely gotten better even though it has been beneficial and positive from the beginning. There are several reasons for this growth. One is both team's ability to work hard and put out quality work at deadlines … Another reason is that we respect each other. I think from the first meeting, we established a friendship which led to mutual respect. We are always receptive to each other's ideas for improvement as well, and have never had intense conflicts. One more reason growth has occurred is because we have active communication between groups between video conferences. We set clear goals and expectations that are taken care of before group meetings so we can move forward in our work when we actually see each other.

Teams, however, also realize that technology mediated communications can only have limited effectiveness as compared to local team interactions, as was reflected in a UK comment below:

The relationship with our American colleagues wasn't as good as the relationship maintained within our side of the group (UK Members) and I believe this was due to only meeting our American colleagues once a week for a brief 20 minute period through the video conference software. I felt the relationship wasn't as good as we didn't see our American colleagues daily where as we saw our side of the group members daily in classes etc.

The rich project experiences are frequently reflected in student course evaluation comments such as from US below. While it is infeasible to provide a listing of such comments, they are extensive and consistent:

I felt that this may have been the most relevant class I have ever taken when comparing my schoolwork to what I will be doing after graduation. The skills I gained from this experience has vastly improved my abilities to operate in a virtual team and I would recommend that all IT majors take this class.

Understand Cultural, Time Zone, and Systematic Differences: While teams are mostly focused on developing common understanding and trust in initial meetings, we observe that they pick up on cultural and national differences early in the process. However, the impact of time zone and metric system differences on team work only dawns on them as project work goes into full swing, often around key deliverables and always around changes in daylight saving times (since US and UK are on different schedules). Teams quickly realize the need to adjust their work strategy with UK teams in light of time zone differences. As a US participant indicated:

I always had to think a few days ahead about what had to get done. [UK] had to be informed a few days before the meeting what was expected of them, and we had to accomplish our tasks ahead of time in case we had any questions for [UK] before deliverable date. Because reaching them was not immediate, last minute questions were not an option. I did not think about this before the project started. I could get away with last minute changes to group projects at [US], but definitely not with [UK].

In class, students learn about the Mars Rover project where metric system differences resulted in a disastrous outcome. Working on the US-UK project reinforces this learning further. During product costing, students recognize through their mistakes the need to align metric systems.

One way it is definitely challenging is developing a product for two different countries; costing is in different currency, target markets were hard to develop, and risks increased. [US student]

Although cultural differences confront teams most often in the form of accent and language, subtle distinctions such as perceived value of time and deadlines emerge as teams worked together over prolonged periods. As expected, these occasionally result in frustration, as expressed by a US participant:

I think the ease of communication has improved, but I have become increasingly frustrated with the lack of precise deadlines on the [UK] team. I believe this is due partially to cultural differences and the lack of stress placed on deadlines that [team mate] and I have set forth.

Once again, student evaluations emphasize how students value working with international teams. While most students gain significant benefit from it, providing a uniformly positive learning experience is not always feasible. Teams faced conflict and while some emerged from it with positive outcomes, not all were able to transition similarly. This occasional contrast is evident in course evaluations below:

This class was extremely beneficial. It provided me with a real life application of what we would learn in class. Having to work with the group from [UK] seemed to be a bit intimidating in the beginning but I felt that it provided me with a great experience of working with people internationally. I enjoyed the class.

I appreciate the idea of working with an off-shore team, [UK], but in reality, it was unnecessarily frustrating and there was little collaboration that actually took place until the final weeks of the semester.

Recognize the Value of Socially Responsible Business and Technical Engagements: It is challenging to identify a specific measure for this aspect of the project. Socially responsible undertakings are a part of the mission for both involved institutions. Most students engaged in service learning projects with local non-profit organizations are evaluated by the client. We, however, have no opportunity for such external evaluations. To this end, the nature of discussions and research conducted by students are considered. For instance, Fall semester students recognize financial and healthcare pressures on buying power of parents of disabled children while Spring term students factor in tight middle school budgets and related resource constraints on investing in renewable energy kits. Anecdotally, the research required for this study, specifically market demographics, existing competitive products, understanding renewable energy or specifics of the disabilities the teams would support, such as cerebral palsy or spinal cord injury, increased awareness of these societal issues. As part of our continuous learning initiative, it is intended in future course offerings to explicitly measure this aspect of the learning, specifically by using an evaluative score for the business case that integrates proposed cost of product, marketing plan, and recognition of constraints around socially responsible projects.

Student Employability: Both UK and US students have benefitted significantly with regard to their ability to execute successful interviews, employability, and workplace benefits as a result of their experience with this project. Course evaluations and personal e-mails to faculty highlight this.

Very awesome class that provided real-world experience and something AWESOME to talk about in interviews. [Student emphasis in course evaluation]

Another student wrote in an e-mail about a year after graduation:

I'm really benefiting from the project management class you taught. After that I took a position at PMO office…. On my first project I had an opportunity to lead a [details withheld] team from both onshore and offshore. (Thanks again to the class project background)

Finally, as students graduate, employers appreciate the value of this offering through interviews with students, promotional materials, or new hires. As one employer from a US consulting firm mentioned:

Now if we come across a student who has graduated from your program and has not taken this course, we question them why.

Faculty Evaluations and Course Enrolments: Faculty evaluations, though not a reflection of student learning, is often the standard measure for success of a course and teaching effectiveness. Faculty evaluations for this offering have been well above the college and department average for each semester. Furthermore, enrolments have steadily risen from about 15-17 students a semester in 2007 to full capacity and a normal waiting list of 8-10 students by end of registration. Within the UK syllabus, useful ness of team interaction has been recognized and the supporting module is being enlarged in scope.

TRANSFERABILITY AND IMPLICATIONS FOR EDUCATORS

The previous section describes in detail execution of our collaborative offering. Supporting course materials such as templates, presentations, and reflective reports can be made available to colleagues interested in providing similar sorts of engagement. In addition, we share several relevant insights.

(a) ***Committed Partnership***: A committed and synergistic arrangement between collaborating faculty is the most critical element of this undertaking. Both must share responsibility for success of the learning environment and its continuous improvement. Collaborators must be responsive. Goals and objectives must be realigned while accommodating each other's individual disciplinary needs. UK-US partnership was initiated through a posting on ISWorld, a listserv maintained by the Association of Information Systems (AIS). Although the first author received numerous global responses to the post, UK faculty responded most proactively by setting up a phone meeting within the first day. Once initial interests were exchanged, a series of e-mails and calls were used to detail out the collaboration. This set the tone for long-term engagement. Despite having met only via mediated communications, faculty are responsive and there is strong trust, exemplifying good practice for students. Others considering such initiatives might leverage existing partnerships or communities of practice to identify potential partners.

(b) ***Design and Process is not as Challenging***. Two elements often raise concern about transferability of this initiative – its design and supporting processes. At one level, the concerns are valid. Greater coordination is required among faculty who must agree on interdependent pedagogical goals, design mutually synergistic roles for teams and themselves, provide non-conflicting communications to students, and be more responsive than normal. This takes work. Based on our experience, significantly diverse teams have a greater potential for design of interdependent processes as compared to similar teams. The UK and US offering was developed such that teams needed to be positively dependent upon each other. Such interdependency may, for instance, occur between industrial engineers and supply chain majors in designing logistical or inventory management solutions. Marketing or finance teams may work with engineers in the same role as our project managers did since the project involved elements of both these majors. Medical students could collaborate with engineers and/or business students to develop solutions to healthcare needs. If faculty are committed to continuous improvement, after about three offerings, the design falls into place and faculty can continue to fine-tune.

(c) ***Technological Transferability***: Not all institutions may have access to extensive VC facilities. However, a range of new technologies are now available to facilitate team and class communications. For instance, desktop-based Polycom roundtable, active speaker cameras can manage large group VC sessions using Skype or Microsoft Lync. Adobe Connect and Net Meeting can provide other economical alternatives. Most now enable desktop sharing to more effectively simulate a team-based VC environment. We have successfully used these as alternates to large conference-style VC facilities. Today, it is easier to achieve economical technological compatibility across remote locations than ever before.

(d) ***Consider Executing Small Projects First***: To ease into an extensive offering, faculty could consider starting first with a small team task and evolve towards a full project. For instance, virtual teams could initially work on a small presentation developed jointly over a 1-2 week window, such as analyzing national marketing and product development strategies of a global firm (e.g. GE, Apple). The following semester, this could be phased into a 3-4 week engagement, and so on. This will also enable faculty to test and evolve working relationships, technological feasibility, and course level synergy.

(e) ***Manage Student Expectations Early But Provide Guidance*** – A significant aspect of faculty communication must be directed to to preparing students to work independently from faculty. These expectations should be managed early in the term. While describing the project during early weeks, we often highlight our inability to control significant aspects of the project e.g. team personalities, trust and comfort, effectiveness of technology mediation. Students, in such circumstances, become willing partners in identifying opportunities for continuous improvement in a non-invasive manner. Faculty must, however, be prepared to play a greater advisory role for students as compared to traditional classes.

(f) ***Highlight Business and Engineering Synergy Outside the Project***: Most students recognize interdisciplinary differences in their interactions such as one below:

… I just sort of assumed that everyone has a business mindset and understand when certain pieces of the process fit in… I thought engineering was a completely separate function who developed models, determined feasibility, and selected materials, but now realize they need to understand certain aspects of their market before they can even begin to develop ideas. Similar to my thinking, our [UK] team did not realize how much customer analysis must take place in order to develop a product.

However, not all students recognize this quickly enough. To this end, faculty must reinforce through case studies and news items how these synergies are integral to the business and engineering worlds and critical to success of many products consumed by students. Such discussions trigger greater reflection among students about how their own projects have evolved, or should evolve to be successful. Faculty might assign students a particular product to discuss or write a brief on how business and engineering integrate to make the product a success. Failed products are equally effective in driving home the point.

CONCLUSION

Pedagogical innovation is critical to providing students with relevant skills. For this, faculty must also continue to reinvent themselves and demonstrate the entrepreneurial spirit expected of students. To this end, the US-UK course offering has been a deep learning experience for both faculty and students. While the transformational experiences for US-UK teams are still emerging, we expect that with commitment to continuous learning, this offering can continue to deliver value. It has, however, been also exciting for us to observe that **these collaborative improvements have enhanced our individual course offerings**. Even if, for some unanticipated reason, this collaboration dissipates, both offerings in US and UK have matured to where they are stronger in their own right than when the collaboration began in 2008. Faculty must continuously seek such synergistic improvements that significantly improve individual offerings.

APPENDIX A

Engineering Module Handbook – Fall Semester Offering

Group Work
This is a group project. The group will comprise some team members in [UK] and additional members in [US]. Interaction between the two segments of the group, in [UK] and [US], are the responsibility of the team. Regular video conference facilities will be provided but other interaction is at the teams' discretion.

The sub-group in [UK] will be expected to:

a. meet regularly,
b. provide evidence of development of the project through minutes logged on the [UK] Blackboard (Bb) site for this module,
c. give a group presentation of the outcomes of the project and
d. write an individual reflective log to demonstrate their individual understanding of their place within the team and their development through team working.

There will be peer assessment, where each group member will evaluate the performance of their team mates, including themselves.

The Project
As a team you must

a) undertake a feasibility study on a new product to match the design brief outlined below. The documentation provided at the project end will comprise a product specification and a commercial justification for its further development.

b) provide a *reflective technical study* about the new product and the pathway you chose to arrive at a conclusion.

You should work as a joint team, i.e. not only with colleagues in [UK] but also in close collaboration with your international team-mates. Make sure that you understand the relationship between your part of the project and theirs. You should:

1) Devise several possible concepts for the product, then create a detailed concept design for the product and have it fully costed. This will include materials, manufacturing process and labour needed to make it.

2) Decide the commercial potential of the product, identifying selling price and sales volume

The product brief: "Inclusive Design".

An ethical company has been approached to develop a toy that can provide physical and cognitive development for disabled children. The initial product is aimed at a child who has cerebral palsy. The condition means that the child has full brain functions but is unable to speak and unable to control their limbs. Children with this condition do, however, have control of their head and are able to move their head in different directions as they need to. This will allow the child to use the head to "control" the actions of the toy through interacting with two sensors. A 12 year old child has limited ability to control body movements, they have macro control of head movements but not micro control.

The child sits in a chair with a headrest that forms a 'U' around his head. Sensors could be mounted in this 'U'. Your brief is to devise an electro-mechanical game, preferably for two or more players, that will allow the child to develop and to enjoy a more normal interaction with other children and adults. Ideally the activity developed could be adapted to cater for other disabilities by suitable re-design of the sensor interface.

One restriction: the product to be invented should not be a computer game, as these are already available and require little in the way of electro-mechanical design.

Note: during the product specification the team will have to take into account and understand the interests and capabilities of 6 year old children.

Deliverables:

1. **Presentation -** Worth 20%.

This presentation should sell your product idea as it were, in a dragon's den situation. It should demonstrate equal contributions from the team members.

2. **Reflective technical assessment -** Worth 40% of your marks.

To be submitted on or before [date]. Late submissions will have marks deducted at the rate of 10% per day. A specification will be placed on Bb by the end of [date].

3. **All project information**, including the presentation to be lodged on Bb by [date]. Marks awarded for the information on Bb:
   a. quality of the information in the group pages. 15%
   b. quality of the analysis, based on the information, that is placed on Bb. 15%
   c. your own personal contribution to the material on Bb 10%

In assessing the actual mark, note will be taken of the timely addition of the material to Bb. Deposition of material and analyses overly skewed to the end of the project will be considered unfavourably.

APPENDIX B
Format of Business Case[1]

1. 1-page executive summary
2. Problem statement
3. Goals and Objectives
4. Expected Benefits
5. Expected Limitations
6. Customer Characteristics
7. Competitor Analysis
8. Project Plan including project schedule and resource requirements
9. Costs and Pricing
10. Breakeven Analysis
11. Major Risks
12. Marketing Plan (1-2 pages)
13. Appendix which must include product images, technical details, and details of cost analysis.

[1] Full Business Case template can be obtained from the first author

REFERENCES

Adya, M., Nath, D., Sridhar, V., & Malik, A. (2008). Bringing global sourcing into the classroom: Lessons from an experiential software development project. *Communications of the AIS*, Vol. 22 No.2, 2008, pp. 33-48.

Alavi, M. & Tiwana, A. (2002). Knowledge integration in virtual teams: The potential role of KMS. *Journal of the American Society for Information Science & Technology*, Vol. 53, No. 2, pp. 1029-1037

Chau, K.W. (2007). Incorporation of sustainability concepts into a civil engineering curriculum. *Journal of Professional Issues in Engineering Education and Practice, ASCE*, Vol. 133, No. 3, pp. 188-191

Coppola, N., Hiltz, S.R. & Rotter, N. (2004) Building trust in a virtual teams. *IEEE Transactions on Professional Communication*, Vol. 47, pp. 95-104.

Dyke, J. & Wojahn, P. (2000). Getting "dissed": Technical communicators in Interdisciplinary Engineering. *Proceedings of the IEEE Professional Communication Society International Professional Communication Conferences & Proceedings of the 18th Annual ACM In International Conference on Computer Documentation: Technology & Teamwork*, Cambridge, MA. pp. 7-23.

Ford, R.M., Goodrich, J.G., & Weissbach, R.S. (2004). A multidisciplinary business and engineering course. *34th ASEE/IEEE Frontiers in Education Conference*, Oct. 20-24, Savannah, GA.

Housely, W. (2003). *Interaction in multidisciplinary teams*. Ashgate Publishing Co. Hants, England.

Jarvenpaa, S.L., Knoll, K., & Leidner, D.E. (1998). Is Anybody Out There? Antecedents of Trust in Global Virtual Teams. *Journal of Management Information Systems*, Vol. 14, No. 4, pp. 29-64.

Kayworth, T. & Leidner, D. (2002). The global virtual manager: A prescription for success. *European Management Journal*, Vol. 18, pp. 183-194.

Klein, J. T. (1995). Interdisciplinary and adult learners. *The Journal of Graduate Liberal Studies*, Vol. 1, No. 1, pp. 113-126.

Maleki, R. A. (2009) Business and industry project-based capstone courses: A reflection on the performance of student teams. *Industry and Higher Education*, Vol. 23, No. 2, pp. 103-110.

Martins, L.L., Gilson, L.L., & Maynard, M.T. (2004). Virtual teams: What do we know and where do we go from here? *Journal of Management*, Vol. 30, No. 6, pp. 805-835.

Metros, S. E. (2005). Visualizing knowledge in new educational environments: A course on learning objects. *Open Learning*, Vol. 20, No. 1, pp. 93-102.

Miller, R.L. & Olds, B. M. (1994). A model curriculum for a capstone course in multidisciplinary engineering design. Journal of Engineering Education, Vol. 84, No. 4, pp. 311-316.

Millis, B. & Cottell, P. (1997). *Cooperative learning for higher education faculty.* Series on Higher Education, Oryx Press, Phoenix, AZ.

Montoya-Weiss, M., Massey, A. & Song, M. (2001). Getting it together: Temporal coordination and conflict management in global virtual teams. *Academy of Management Journal*, Vol. 44, pp. 1251-1262

Newell, J.A., Marchese, A.J., Ramachandran, R., Sukumaran, B. & Harvey, R., (1999). Multidisciplinary Design and Communication: A pedagogical vision. *International Journal of Engineering Education*, Vol. 15, No. 5, pp. 376-382.

O'Brien, W., Soibelman, L., & Elvin, G. (2003) Collaborative design processes: An active-and-reflective learning course in multidisciplinary collaboration. *Journal of Construction Education*, Vol. 8, No. 2, pp 78-93.

Okudan, G.E. & Zappe, S.E. (2006). Teaching product design to non-engineers: A review of experience, opportunities, and problems. *Technovation*, Vol. 26, No. 11, pp. 1287-1293.

Olson-Buchanan, J.B., Rechner, P.R., Sanchez, R. J., & Schmidtke, J.M. (2007), Utilizing virtual teams in a management principles course. *Education & Training*, Vol. 49, No. 5, pp. 408 – 423

Powell, A. Piccoli, G. & Ives, B. (2004). Virtual teams: A review of current literature and directions for future research, *The DATABSE for Advances in Information Systems*, Vol. 35, No. 1, pp. 6-36.

Ropers-Huilman, B., Carwile, L., & Lima, M. (2005). Service learning in engineering: A valuable pedagogy for meeting learning objectives. *European Journal of Engineering Education*, Vol. 30, No. 2, pp. 155-165.

Rosca, D. (2005) Multidisciplinary and active/collaborative approaches in teaching requirements engineering. *European Journal of Engineering Education*, Vol. 30, No. 1, pp. 121-128.

Rosenfield, P.L. (1992). The potential for transdisciplinary research for sustaining and extending linkages between health and social sciences. *Social Science and Medicine*, Vol. 35, pp. 1343 – 1357.

Rusu, A., Rusu, A., Docimo, R., Santiago, C., & Paglione, M. (2009). Academia-academia-industry collaborations in software engineering projects using local-remote teams. *SIGCSE*, March 3-7, pp. 301-305.

Ryssen, S.V. & Godal, S.H. (2000). Going international without going international: Multinational virtual teams. *Journal of International Management*, Vol. 6, No. 1, pp. 49-60.

Temple, B.K. & Allan, M. (2000) Engineers and Business – Spanning the divide by means of cross-disciplinary activities. *British Journal of Engineering Education*, Vol. 1, No. 1, ISSN 1470-4692

Van Der Vegt, G.S. & Buderson, J.S. (2005). Learning and performance in multidisciplinary teams: The importance of collective team identification. *The Academy of Management Journal* , Vol. 48, No. 3 (Jun., 2005), pp. 532-547.

Wellington, P., Thomas, I., Powell, I., & Clarke, B. (2002). Authentic assessment applied to engineering and business undergraduate consulting teams. International Journal of Engineering Education, Vol. 18, No. 2, pp. 168-179.

Winn, B. & Heeter, C. (2006). Resolving conflicts in educational game design through playtesting. Innovate, Vol. 3, No. 2, (http://www.innovateonline.info/)

Wojahn, P., Dyke, J., Riley, L.A., Hensel, E., Brown, S.C. (2001). Blurring boundaries between technical communication and engineering: Challenges of a multidisciplinary, client-based pedagogy. *Technical Communication Quarterly*, Vol. 10, No. 2.

Zavbi, R. & Tavcar, J. (2005) Preparing undergraduate students for work in virtual product development teams. *Computers & Education*, Vol. 44, No. 4, pp. 357-376.

Zigurs, I. (2003). Leadership in virtual teams: Oxymoron or opportunity? *Organizational Dynamics*, Vol. 31, pp. 339-351.