Preparation of Engineering Senior Design Course: Global Learning Integration

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Abstract - **Engineering collaboration in today's interconnected global economy requires engineers who can understand, respect, and work collaboratively with different cultures around the world. Companies no longer design and build airplanes, cars and other technologically-intensive products within one country but through engineering and manufacturing capabilities wherever it can be economically utilized. Engineers must have skills for perceiving and adjusting for differences in culture needed in such global collaborations. This paper describes efforts to integrate global learning strategies into the ME 662 senior design course in the mechanical engineering design curriculum at Wichita State University. The goal is to develop a globally aware, culturally sensitive and adaptive engineer. Educators and researchers from engineering, education, and specialists in global learning are facilitating the process. The methodology includes implementation of the "cage painting" metaphor and accompanying simulator. Preliminary experiences from unique collaborations of local and international industry and academic institutions in the U.S., Russia, and India from the Spring 2006 are included in the paper.**

Index Terms – intercultural communication competence, global learning, engineering design

BACKGROUND: WHAT IS THE CHALLENGE?

"*No man is an island*" [1]

Engineering designers in today's global economy face new challenges. Modern communication devices are enabling more sophisticated approaches to international collaboration between industrial and educational organizations on a variety of projects. Such collaboration is driven by competition and includes coordination of technical design and production capabilities to minimize costs. Opportunities for obtaining new business and providing design services are maximized for those organizations that have the infrastructure and methodology to coordinate design activities between different locations around the world. The most successful companies in the global market place will be those which are able to facilitate a 24/7 design and development cycles throughout multiple time zones. This is driven by the need to minimize the time from concept to final production. Further, it is driven by globally dispersed talent and the requirement by customer countries for involvement in the design or manufacturing. Customer countries want to be a significant part of the value chain so that they share in the profits and employment stemming from the design and production. For example, Boeing can no longer sell aircraft to Japanese carriers without involving Japanese companies in the design and production of its new models [3]. Now Boeing provides greater responsibilities and involvement in the value chain to companies in other countries, including Japan, Russia and China. Design and production of products, such as large passenger aircraft involves multiple countries as well as companies. Companies and countries are driven by different priorities. Companies must ensure growth, profitability and improvement of shareholder value. Countries, or at least their governments, must attend to the needs of their constituents, such as employment, workforce skill development and trade balance.

Friedman [3] extended the idea of interconnectedness to a global scale from what he described as a "three-way convergence" of current world events and business trends. This consisted of the development of global internet connectivity, "horizontal value creation" with outsourcing (or insourcing) of business and engineering activities, and the emergence of India and China into the world business enterprise with their more market-based economies. Friedman maintained that this confluence has developed the, "creation of a global, Web-enabled playing field that allows for multiple forms of collaboration – the sharing of knowledge and work – in real-time, without regard to geography, distance, or, in the near future, even language" [3]. He concluded this opportunity would enable individuals, groups of individuals, or companies to connect with each other virtually, anywhere in the world and to collaborate on value-enhancing enterprises, which were previously the territory of vertically-integrated, multi-national companies.

As a result, as Friedman and others have observed, technologically-intensive products including airplanes and cars are no longer built within just one country, but are designed and built in multiple countries. The value added to a product is no longer limited to vertical development from the ground up, such as with the original Ford Model-T automobiles, for which nearly everything was built in one factory. Value can be added horizontally among multiple partners, who can share the design and development risk, such as for the new Boeing 787 Dreamliner. Gas turbine

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manufacturer–Rolls Royce–produces only 25% of the components that make up one of its turbine engines [3, 4].

A major challenge of the "Flat World" [3] is how individuals and organizations can coordinate effectively on collaborative endeavors such as engineering design and development, given the inherent differences in language, culture, and attitudes. The traditional methods of engineering collaboration have been mainly face-to-face among a relatively homogenous, white, European-heritage, male workforce. The local environment now involves both genders and many more ethnic and cultural groups. The global environment requires intercultural communication and collaboration. In turn, this must be underpinned by values of honor, respect, curiosity and courage and a more proactive approach to developing intercultural communication competence, through global learning. To meet this challenge engineering colleges must revise their curricula to better prepare new engineering graduates for work in a diverse and globally interconnected and interdependent world.

In this paper, we first introduce the senior design course in the Mechanical Engineering Department, then we describe the integration of global learning experiences into this course, and finally we describe an example that involves interactions between Moscow, India and Wichita during the spring of 2006. In conclusion, we share what was learned from this experience and make recommendations for future integration activities.

SENIOR DESIGN COURSE IN THE MECHANICAL ENGINEERING DEPARTMENT

The senior design course has traditionally been a "bridge" from academic studies in engineering, mathematics, science, and supporting studies in the liberal arts and humanities, to the product- and profit-driven realities of engineering practice in industry.

The ME 662 Mechanical Engineering Practice course at Wichita State University was designed to integrate these learned skills through synthesis of designs applied to a design project proposed by a local company or organization, such as the American Society for Mechanical Engineers. Student teams approach the design project using a project management approach, defining and researching the problem, formulating the approach, work tasks, and scope of the work, as well as developing a schedule. Several preliminary design options are presented to the sponsor for their consideration and after approval a final design is adopted for development and evaluation. The class is modeled after a design-consulting firm, in which the instructor served as the design supervisor, and the project teams coordinate through status reports, as well as background, preliminary, critical, and final design reviews.

The objectives of the class reflect goals of the ABET (Accreditation Board for Engineering and Technology) Engineering Criteria 2000 program outcomes for engineering graduates Accreditation [5]:

1. The ability to apply the knowledge and tools learned in the undergraduate curriculum;
2. The ability to apply problem solving skills independently to new problems not seen before;
3. The ability to design and conduct mechanical engineering experiments in support of design or development (not all projects will require physical experiments, they will use analytical iteration instead);
4. An ability to solve engineering problems
5. The ability for self-education by doing research on new topics;
6. Effective communication skills, including interpersonal, written and oral;
7. Functional project management skills, including task and schedule development;
8. The ability to function in teams; and
9. An awareness of the complex environment involved with practice of the profession, including the issues involving safety, ergonomics, product liability, ethics, global learning, and entrepreneurship.

The specific recommended outcome (h) of the ABET Criteria relates directly to recognition of the need for a global perspective in engineering, calling for "the broad education necessary to understand the impact of engineering solutions in a global and social context." By incorporating global engineering collaborations into the design class, the education provided is going beyond mere knowledge of the collaboration process to understanding derived from experiential learning acquired during completion of the design project. Wagner [6] identified life-long learning, adaptability to work place changes, professional registration, and international collaborative skills as being essential for professional success in a global design and manufacturing environment. He recognized that traditional methods of engineering collaboration have changed in a highly interconnected global economy and require better methods for understanding, respecting, and working with different cultures around the world. This recognition blurs the distinction between academia and industry. Georgia Institute of Technology, in its recent Quality Enhancement Plan [7], identified improvements in global competence and undergraduate research opportunities as two main areas for enhancing its academic excellence in engineering education. Boeing, a company with established international business collaborations, has distributed its product design and manufacturing tasks among many international partners as a means of tapping specialized engineering skills, reducing development costs, improving time to market and sharing cost and technical risks [3]. As a result, Boeing and its partners recognize the need for greater intercultural communication and collaboration competences from engineering graduates [8]. Indeed, a vice-president of the former Boeing Commercial Airplanes Division in Wichita remarked that he looked forward to hiring the first global graduate in engineering [2].

INTEGRATION OF GLOBAL LEARNING STRATEGIES

The Development of design and collaborative skills in a global environment is essential for engineering graduates to compete successfully with others throughout the nation and world. To this end, the senior design course ME 662 Mechanical Engineering Practice was transformed to incorporate global collaboration using communication technologies, so our students have the opportunity to develop global perspectives on engineering design and culture. An additional learning outcome of the course is to develop an awareness of the complexity of the global design and manufacturing environment through experiential learning.

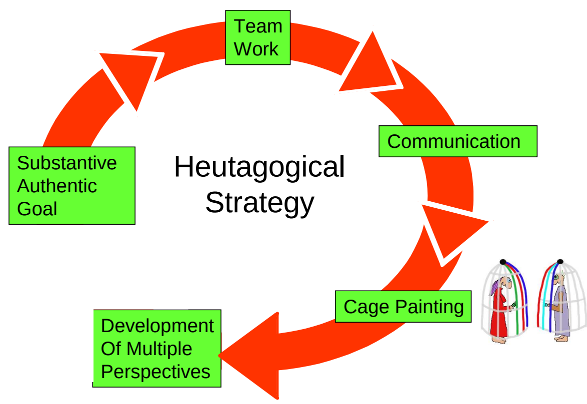

Figure 1. The heutogogical (self-directed learning) strategy for global learning.

The development of multiple perspectives and development of strategies for improving intercultural communication competence cannot be taught didactically. It has to be learned experientially. The conditions for this type of self-directed learning include the setting of a substantive and authentic goal, such as developing an engineering design. Itg can only be achieved through teamwork and this depends on good communication [Fig. 1]. Intercultural communication is improved through cage painting or making explicit the perspectives of each participant.

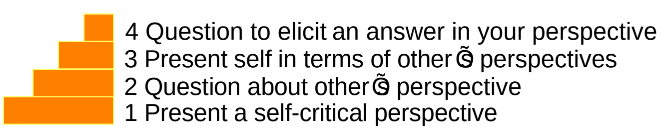

Figure 2. 4 steps representing levels of cage painting.

Cage painting involves at the most basic level, sharing a self-critical perspective and asking about the perspective of others [Fig. 2]. At a more advanced level, it comprises sharing about oneself from the other's perspective and asking others questions that result in an answer in one's own perspective. This type of interchange represents a high level of intercultural communication competence that will help eliminate misunderstandings in this type of global learning project.

Achieving this additional learning outcome involves more than just using technology to provide a connection with sponsors and students in another country. This is only a means to be able to interact with people from another culture. A systematic approach is needed to develop strategies for learning about each other's culture and how it affects the engineering design process. First the students are exposed to the views of industry so they realize that this is an activity that is vital for their education. A keynote presentation by the then Vice President of Boeing Commercial Airplanes (now Vice President of Spirit Aerosystems) was shown to the class [2]. Further, the process and benefits of global learning were shared with the class, including an activity called "cage painting" [8]; [9]. The students were then given the opportunity to use a computer simulation game in which they had to meet certain goals by practicing "cage painting" or improved intercultural communication. Following this, they participated in a "mock" global communication session with international students using a videoconference to another part of the building. After this preparation, actual international connections were then conducted with students from an engineering school of a different country (India). Then one student team began work on their senior design project for a sponsoring company in Moscow, Russia.

The global project team had access, in the design laboratory, to a PC-based, Polycom Viavideo unit along with Polycom PVX software for synchronous communication and for asynchronous communication they used a combination of email and the Blackboard, web-based course management system. The expected outcomes of this modified course include the development of engineering graduates with:

- a global perspective on collaborative product design and manufacturing;
- respect and appreciation of different cultures and attitudes, and their effect on collaboration;
- experience with global learning and strategies for improving intercultural communication; and
- understanding and experience using modern communication technologies.

COLLABORATION BETWEEN MOSCOW AND WICHITA COMPANIES AND UNIVERSITIES IN THE SPRING OF 2006

The Boeing Company and companies in its supply and value chain, such as Spirit Aerosystems in Wichita and Progresstech in Moscow are currently involved in the design of the Boeing 787 Dreamliner. The Dreamliner project involves collaboration between many companies around the world, but for the Spring of 2006, we concentrated on the links between Wichita, Kansas and Moscow, Russia to provide an opportunity for students at Wichita State University (WSU) and at the Moscow Aviation Technology Institute (MATI) to participate in a global learning project with sponsors in Moscow and Wichita, respectively. A team of 3 students at WSU worked on a design for Progresstech, whose engineers are on contract to the Moscow Boeing Design Center (MBDC), while 4 students at MATI worked on a design for Spirit Aerosystems in Wichita. Plans are under way to expand the number of opportunities for student teams and to extend involvement to companies and institutions in other countries.

The opportunity for involvement in the pilot global learning project with Moscow sponsors was offered to the ME 662 class and 3 students chose this project from among others with local sponsoring companies. After preparatory exercises, described above, they met via telephone conference with their sponsors in Moscow. They also swapped information about themselves including photos. As their project proceeded, they exchanged emails with the Moscow sponsors. Just after mid way through the semester, both student teams, one from WSU and one from MATI met with their respective sponsors and company officials for a combined videoconference between the MBDC and Spirit Aerosystems. Toward the end of the semester, at the presentation day for projects at WSU, a videoconference link was set up at Progresstech so the Moscow sponsors and MATI students could observe presentations by the WSU student team and other teams from WSU. The WSU team presented a written report, a PowerPoint presentation and a poster. During the semester, WSU students were asked to write reflective journal entries on their experience. The Spring 2006 semester constituted Phase I of this overall initiative.

The plan is for this initiative to proceed in four phases:

Phase I:
Semester: Spring ’06
Opportunities: WSU student team with MBDC/Progesstech; MATI student team with Spirit Aerosystems

Phase II:
Semester: Fall ’06
Opportunities: Add an opportunity for a combined WSU/MATI student team with a sponsor in a third country

Phase III:
Semester: Spring ’07
Opportunities: Add teams and sponsors from more countries (India and UK)

Phase IV:
Semester: Fall ’07
Opportunities: Expand to include other areas of engineering (electrical, computing, aerospace, manufacturing)

The WSU student team worked on a project concerned with the design, analysis, and optimization of an anisogrid lattice shear web that would serve as a floor beam of an aircraft. This was essentially a more research-oriented project than the usual projects for ME 662. The challenge was to optimize design elements such as diagonal angles, number of vertical supports and thickness to ensure adequate shear strength, while minimizing weight. The team had to produce and execute a detailed project plan, with different tasks and deadlines allocated to each team member. The project was cost-estimated on the basis of a notional hourly rate for each member. They used a combination of 3D design and modeling software as well as software to compute deformation due to shear stresses. During the presentation, they included the total hours of work needed along with the total cost.

LESSONS LEARNED AND FUTURE RECOMMENDATIONS

The ME 662 Instructor during the Spring 2006 semester made a number of observations. The first was that not all students in the class (not in the pilot global learning team) accepted that the incorporation of global learning was relevant to their career, compared to the other aspects of the course, such as project definition, project management, preliminary and final design development and submission of written and oral reports. All students were required to view a 2003 WSU Global Learning Conference video, which was meant to establish the need for global learning by industry, as well as attend a lecture by two Spirit engineering managers, who explained the methods and challenges of global coordination. Students were asked to keep a journal after each global learning exercise share their perceptions of global learning. Only a few students (not in the global learning team) made journal entries during the semester. This may be partially due to the low percentage of grade (<5%) that was assigned to global learning participation, as well as the multiple demands of the course. Lucena [10] noted that this resistance may be due to technically-directed students having to learn the non-technical, political aspects of global learning in international design collaboration. This non-participation may be overcome by increasing the allocation of marks or by closer integration of global learning into the course activities.

Increasing the opportunities for global learning remains a challenge. Of the 7 projects offered during the Spring 2006 semester, six were with local companies or organizations, with only the one global project. Global learning lectures, cage-painting simulation and practice may give an idea of global learning, but not the experiential learning required to give global learning its significance. On the other hand, local companies and organizations do provide very challenging and useful projects and it is important to continue to have good relations with them. One solution may be to include at least one student from an overseas university in each team to collaborate on a locally or internationally sponsored project. An initial connection with an Indian engineering school in Karnataka state made during the Spring of 2006, may provide opportunities for such collaborations.

It is important to make sure that the global student teams have ready access to a variety of communication technologies so they can establish communication early in the project and maintain regular communication through to completion. Computer terminals with software for email, web-based discussion and interactive chat sessions are essential as is the provision of at least one videoconferencing system. It should be capable of simultaneously sharing voice, video and design software data during a session. The students should be encouraged to use this technology to initially establish informal contact so they can share information about culture with their sponsors. This helps with subsequent communication sessions.

A further observation is that it is important that the design project definition be open-ended without defining problem solutions upfront. Providing general project specifications will lead to the need for ongoing communication and hence the need to improve their cross-cultural communication competence. If the design is too well specified, there will not be the need for communication that provides practice in cross-cultural communication, or the opportunity for meaningful design experiences.

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