

## **AC 2007-1188: FORMING GLOBAL ENGINEERS: A FRESHMAN ENGINEERING DESIGN COURSE WITH A MULTINATIONAL DESIGN PROJECT INVOLVING LATIN AMERICAN INSTITUTIONS**

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# Forming Global Engineers: A Freshman Engineering Design Course with a Multinational Design Project Involving Latin American Institutions

## Abstract

The establishment of new regional economic alliances beyond the frontiers of a single nation has required that engineers be prepared to work in an economy that is now best seen as essentially international in nature. It is evident that future engineers should have a better understanding of the global economy, awareness of cultural diversity, and appropriate training to work in multi-disciplinary and multi-national teams. This paper describes an adaptation of the first year Introduction to Engineering Design course at Penn State that has been tailored not only to teach the basic concepts in design, innovation and creativity, but also to introduce in experimental sections the concept of global design, and expose the students to other cultures through multi-national projects. Students are required to work in global design teams with students from institutions in other countries. They are challenged to solve a design problem and to use effectively the available technology for communication. This multinational project provides students the opportunity to work in a global distributed team, learn the value of different ideas from different cultures, gain knowledge of design opportunities in other countries and become skilled at how to use collaborative tool effectively.

## Introduction

The growing integration of economies and societies around the world, better known as globalization, has been one of the most hotly-debated topics in international economics over the past few years.<sup>1</sup> Its advantages and disadvantages have been discussed in many forums and both sides, in favor of and against globalization, have presented clear and strong ideas. Beyond the economic point of view, this international integration has multiple implications in the interaction between the different constituents. Understanding globalization means studying the changes in population, human resource flows (migration), the changing distribution of design and manufacturing/construction work, urbanization, diseases, resource management, environmental degradation, economic integration, knowledge dissemination, information technology, biotechnology, nanotechnology, conflict, and governance.<sup>2</sup> Therefore, the best way to conciliate both pro and against positions is to understand the unavoidable changes and take the necessary steps in minimizing their impact in the society.

These rapid changes in the world entail a change in the role of engineers in the global economy and, as a consequence, in the engineering education. There is an increasing perception of the need to educate competent engineers for the global market; an engineer who must understand and accept diversity; be able to work in multi-national corporations; be able to work in multi-cultural teams; be creative in the solutions of problems impacting a wider and more diverse population; be able to communicate and socialize with people from different cultures; be knowledgeable in other language; be able to use the technology to exchange ideas, solve problems and present solutions; be a leader, an excellent team member, and an ambassador. The list of competences for the global engineer might include these and more attributes besides the technical knowledge required for each major, so the question is if the industry is expecting a

super engineer for the new millennium, or if the academia is prepared to deliver the global engineer.

One reason to do this in the United States is to create resistance to outsourcing of engineering skills. The main response to the production of very large (but typically exaggerated) populations of engineering graduates in India and China who work for far less than their European and US counterparts is to stress quality.<sup>3,4</sup> Quality means high academic standards, creating global competencies, and, increasingly, a capacity for innovation.<sup>5</sup> There is little developed countries can do to restrain outsourcing of routine engineering work beyond maintaining healthy employment patterns for engineers in the their domestic economies largely in national defense and civilian infrastructure. Conversely, within Caribbean and Latin American countries there is an opportunity to compete aggressively with high quality, bi-lingual, relatively low cost graduates who can function effectively throughout the Americas.

In 2005, eight international prestigious universities, chaired by TU Darmstadt, started participating in an initiative to conduct the first worldwide scientific study on “Global Engineering”. The results of this study lead to four recommendations: (1) Global competence needs to become a key qualification of engineering graduates; (2) Transnational mobility for engineering students, researchers, and professionals needs to become a priority; (3) Global engineering excellence depends critically on a mutual commitment to partnerships, especially those that link engineering education to professional practice; and (4) Research on engineering in a global context is urgently needed.<sup>6</sup> These recommendations suggest that the engineering curriculum should be modified to include global competences, and that the educational institutions and the private industry around the world should collaborate among them to provide mobility, internships, projects, and research initiatives to the faculty and students in a global context.

In this hemisphere, the Engineering for the Americas (EftA) initiative is an academic, industrial and government grass roots effort that has evolved over the past five years. Its aim is to enhance engineering and technology education in the Western Hemisphere, and to strive for mutual recognition of engineering graduates across national boundaries and cross-border trade agreements, facilitating the flow of work and human resources throughout the hemisphere to optimal locations for distributed economic development.<sup>7</sup> The IV Summit of the Americas recognized the importance of this initiative and the Organization of American States (OAS), Engineering for the Americas (EftA), the U.S. Trade and Development Agency (USTDA) and World Federation of Engineering Organizations (WFEO) organized the Engineering for the Americas Symposium at the end of 2005 in Lima, Peru. The Symposium focused on the needs of the productive sector for engineering graduates and capacity building; quality assurance in engineering education; and national planning for financing of upgrades to engineering education. The 2005 Engineering for the Americas Symposium final report<sup>8</sup> calls for educational reforms at the regional level that include the needs of the productive sector and preparing new engineers with attributes certified by transparent accreditation systems, which will further professional mobility, investments levels, and therefore economic development. The final report urges the academic sector to boost its collaboration with industry to develop a change in paradigm to educate the engineers of the 21st Century, which they describe as world class engineers, leaders, visionaries, and entrepreneurs, committed to the social environment and with a clear sense of the

common good. In the U.S., the National Academy of Engineering was asked by representatives of the U.S. Senate and House of Representatives to formulate strategies that policymakers could propose so the U.S. can successfully compete, prosper, and secure the global community of the 21<sup>st</sup> century. In 2004 the National Academy of Engineering published *The Engineer of 2020*<sup>9</sup>, followed in 2005 by *Educating the Engineer of 2020*<sup>10</sup> in 2005. These reports stress the impact of globalization on the practice of engineering and the need for U.S. engineers to focus on innovation and creative aspects of the profession to be globally competitive. This concern is taken further with the latest NAE report, *Rising above the Gathering Storm*<sup>11</sup> published in 2006. As noted earlier, some of these reports are an overreaction using inflated and inaccurate numbers, but some (informed) concern is merited.<sup>3</sup>

This urgent call for a change in paradigm in engineering education to create the Global Engineer, and in particular the Engineer for the Americas, is coming from all sectors: government, industry and academia. This change clearly requires coordinating efforts, and defining and facilitating experiences that would result in the Global Engineer. Because of this, the academic programs should offer the students the opportunity for international experiences where the students can obtain the global competences as they learn their majors skills, so they can effectively be prepared for the global economy.

One of the multiple challenges faced by the academia is to educate creative thinkers and innovative engineers capable of working in multi-disciplinary teams in a global context. It has been shown that one of the most effective ways to expose the students to an international experience is through multinational design projects as can be seen in several publications.<sup>12,13,14</sup> This type of initiative allows the students to work in diverse teams geographically disperse around the world while they are solving a real engineering problem. This experience allows the students to exercise the creativity and innovation skills while they solve the problem, and to acquire the international competences while they interact with their international partners. The earlier the students are exposed to multinational teams the easier for them to understand diversity, to become familiar working in multi cultural scenarios, and to build the necessary confidence to be part of an effective team. The new technology available for communication has facilitated the implementation of multi-national projects with teams disperse in different countries. Small or large institutions as well as institutions in developing countries can incorporate global design projects in their curriculum without compromising big amount of money. Other venues for global engineering skills are communities of practice within student organizations such as ASME,<sup>15</sup> and IEEE.<sup>16</sup> This includes participation in international competitions such as ASME Latin America Student Sections competitions,<sup>17</sup> Mondialogo Engineering Student contest,<sup>18</sup> and the Society of Hispanic Professional Engineers NTCC design competition,<sup>19</sup> and student exchange programs such as the Latin American and Iberian Resources Study Abroad program.<sup>20</sup>

This work describes an adaptation of the first year Introduction to Engineering Design course at Penn State that has been tailored not only to teach the basic concepts in design, innovation and creativity, but also to introduce the concept of global design, and expose the students to other cultures through multi-national projects. Students are required to work in global design teams with students from institutions in other countries. They are challenged to solve a design problem and to use effectively the available technology for communication. This multi-national project

provides students the opportunity to work in a global distributed team, learn the value of different ideas from different cultures, gain knowledge of design opportunities in other countries and become skilled at how to use collaborative tool effectively. The general idea of having an introductory course for engineering design where students are exposed to international experiences has been disseminated through institutions in Latin America as a result of this international collaboration. Examples of successful experiences working with institutions in Latin America are presented as an effective means of providing opportunities for the formation of world-class engineers for the Americas starting from the first year. In new trial initiatives students are exposed to learning more about the world and the way that engineering and design are practiced in the global economy. While the world is very diverse, the global economy tends to create monoculture which is a threat to diversity that needs to be monitored. However it is also a medium through which engineers around the world may communicate and engineering students in the US and in Latin America may be learning very similar things about global engineering. If not, those differences should enrich the dialogue that occurs in the cross national teams. The end result, we hope, is that we produce engineers who are both world class and engaged with the world.

## **Background**

Penn State is a multi-campus university geographically dispersed that has the main campus situated in State College, in the center of the state, and nineteen other campuses across the state of Pennsylvania, and four special-mission campuses. Penn State offers baccalaureate engineering degrees in 14 undergraduate majors at University Park (UP), and associated and selected baccalaureate degrees in engineering technology at various other locations. More than 50% of the engineering undergraduate students begin their education at one of the nineteen other campuses where they traditionally complete the first two years and they transfer later to UP or to another granting degree location in the Penn State system to complete their engineering program. Most of the campuses outside State College are commuter campuses where the student population is formed primarily by local residents who are non traditional students. These students hold part-time or full-time jobs while they are attending the school.

As most of the major universities, Penn State has had a variety of international programs in all the disciplines, including engineering. However, it was detected years ago, that none of the international initiatives involved engineering technology faculty and students, few have involved faculty in any discipline at locations other than the main campus, and only limited opportunities have existed for faculty involved in introductory engineering courses.<sup>21</sup> Additionally, the opportunities for international experiences for freshman students at commuter campuses were very limited since most of them cannot afford the traditional “semester abroad” studies or even some short trips abroad as part of a course.

The necessity of providing the future engineers international experiences and having these opportunities available to a wider student population and at a very early stage in the engineering curriculum brought a group of professor from UP to start exploring options to incorporate international experiences early in the engineering curriculum at UP. In 1994, Penn State started collaboration with The Université d'Artois at Bethune, France with exchanging faculty. In 1996, a Memorandum of Understanding was signed by both institutions outlining a broader range of

interests and activities. These included the exchange of students, the development of common course components or modules, cooperative videoconferences, and the exploration of the use of new information technologies for teaching, learning and distance education.<sup>21</sup> In 1997, the relationship established by these two institutions lead to the introduction of multinational design projects in the curriculum using a first year introduction to engineering design course for this purpose. Since then, this practice has continuously growth and has evolved to other and more advance courses.

In 2004, Penn State became member of the Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) and set as priority to promote the idea of global design projects in this part of the hemisphere. This was an excellent opportunity also to incorporate Penn State's commuter campuses to this practice. That year, a general invitation was submitted to professors members of the consortium for the international collaboration and instructors from two institutions Universidad Autónoma de Occidente from Colombia and Universidade Federal Juiz de Fora from Brazil accepted to participate in this initiative. In the Spring semester 2005, the first global design project took place involving two campuses from Penn State (UP and Delaware County), and two institutions from Latin America. The number of participating institutions from Latin America has growth and nine universities from six different countries have taken part of the global design projects with the participation of more than 150 students in the last two years.

### **Global Design in an Engineering Freshman Class**

As mentioned before, the world is changing rapidly. Regional economic alliances and major corporations working in a global market and dispersing their operations around the world are changing the role of the professionals. Human and social capital are increasingly seen as a critically important resource of organizations and when those organizations are global, as most are, the most desirable features of the human capital changes accordingly. The profile for the new engineer includes knowledge of different languages, cultures, resources, markets, and how to manage social diversity. Additionally, some regions are losing their own identity and the products are now designed for wider and more diverse customers as compare to years ago when markets were more localized and the products impacted a population with similar backgrounds. Furthermore, the use of new technology in communications, in particular the Internet, is facilitating the formation of distributed design teams over the world.<sup>22</sup> Therefore, the academic programs have to adjust the curriculum to respond to those changes the students are facing. Global design collaboration is an excellent opportunity to allow the students and faculty to work with multinational teams and different cultures in the solution of worldwide engineering problems. This international experience can be easily incorporated in the traditional engineering curriculum.

Design in engineering can be defined as the process of generating, analyzing and synthesizing ideas for the solution of problems for the benefit of the human community. Then, designers face several implicit constraints in the design process since they have to deal with different aspects impacting the solution and the community such as: cultural issues, politics, standards, environment, aesthetics, and so on. This is the traditional designer working for a particular community. But the globalization has forced the products to reach and impact different communities in different ways. It may involve, for example, designing a product in North

America, manufacturing it in Asia, and selling it in Europe. Even services, such as telecommunications, cross national boundaries with ease. Now, designers deal with a broader community in developing and servicing consumer products. Therefore, global design is playing an important role in the design process. But, what is global design? Global design means to use the new technology in computers and communications to form teams distributed in different locations in order to design products for a global market. Using teams distributed in different locations over the world implies that the design team is representing a broader and diverse community and, therefore, making more significant, creative and widely accepted contributions to the final product. Global design also implies a commitment to create safe consumer products to benefit the international community, protecting the global environment, supporting cultural diversity, and respecting international agreements and standards.

It is evident that if the world is changing the academic programs should change also to reflect the new tendencies the future engineers are going to be facing. Most of the engineering programs have a design course or a capstone project requirement in the curriculum. Those courses or projects can be found at different levels depending on the institutions and the program itself. It is there where the global design experience should be introduced to start preparing the future engineers to work in the global market. The international design collaborations have different type of structures that will be discussed later as well as how to incorporate them in the courses. What is significant at this point is to reinforce the importance of the international experience in the curriculum. Many universities around the world have already established successful programs to expose the students to the international experience. The new instructional technologies have the potential to be used to internationalize the curriculum in innovative ways even without leaving the home institution can save money and traveling time.

The educational part of this initiative is probably one of the major challenges. International collaboration means students might be dealing with a number of concepts that should be properly addressed in the classroom such as design process, standards, basic technological issues, and communications. However, the global design and the international collaboration becomes a self-learning experience by nature. Creativity and innovation cannot be taught: different concepts and systematic methods can be provided by the instructor in the classroom but students decide how to proceed to generate, analyze and synthesize the ideas for the solution of the problem; cultural differences can be addressed but they have to be discovered by the students; communication problems might be anticipated but they have to be solved by the students. Students will decide also at which extend they will discuss a specific idea. Therefore, the teaching model has to be changed since the whole experience becomes more a coaching rather than a teaching experience<sup>22</sup>. Becoming a coach implies to guide the student and to provide them the necessary information they might need, the technological tools they might need and set a feasible chronogram for the project but allow them to develop their maximum creativity potential.

### **Multinational Design Project**

The multinational design project was introduced in the introduction to engineering design course at Penn State with the purpose of providing to freshman students their first opportunity to:

- Work in multi-cultural teams in an international setting.

- Work in virtual teams around the world.
- Foster cultural awareness and understand the importance of diversity in the design and development of new products.
- Apply the design methodology in the development of concept solutions in a global context.
- Use web conferencing tools in a professional setting.
- Establish an international collaborative network.

There are different types of international projects that can be implemented<sup>23</sup>. The scheme structure selected for collaboration in the freshman class consists of a parallel design project in which students at each institution work independently in the same project but they are encouraged to share and discuss data and ideas in the solution of the problem.

The global design project is part of the first year Introduction to Engineering Design course. This course is structured to have two projects during the semester. The first project is a local re-design project for the students to start using the design methodology in the solution of open ended problems. The second project is the global design project in which students are required to interact with international partners in Latin America. The project is assigned to the students in the different countries simultaneously. Pairs of collaboration are formed among the institutions participating so each team has a corresponding partner in a foreign institution. Figs. 1 to 4 show the collaboration network from Spring 2005 to Fall 2006.

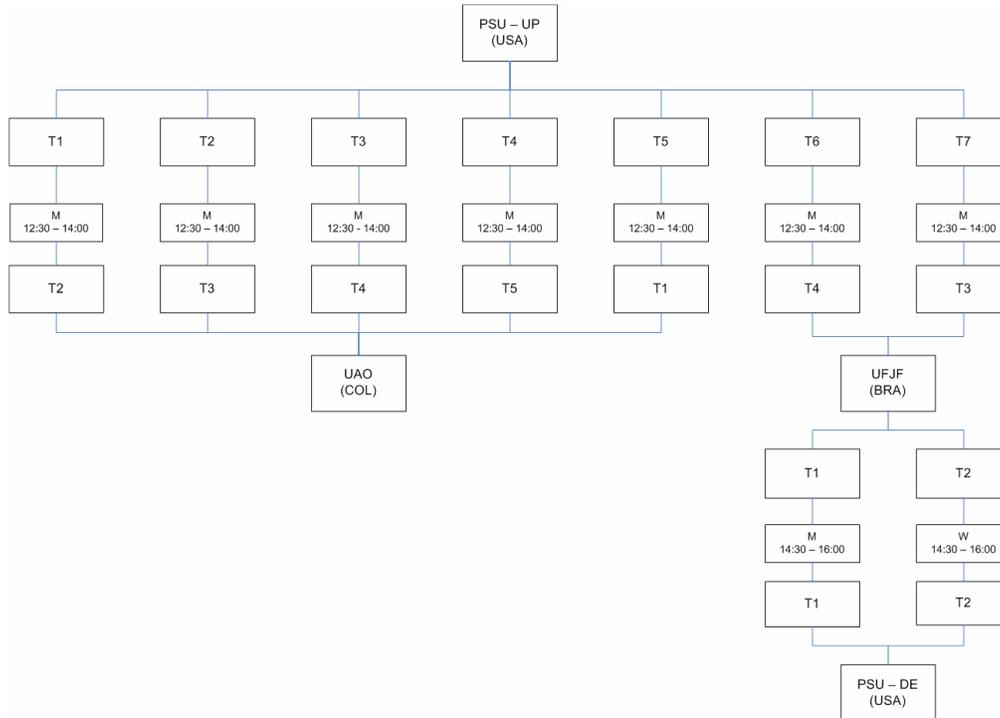
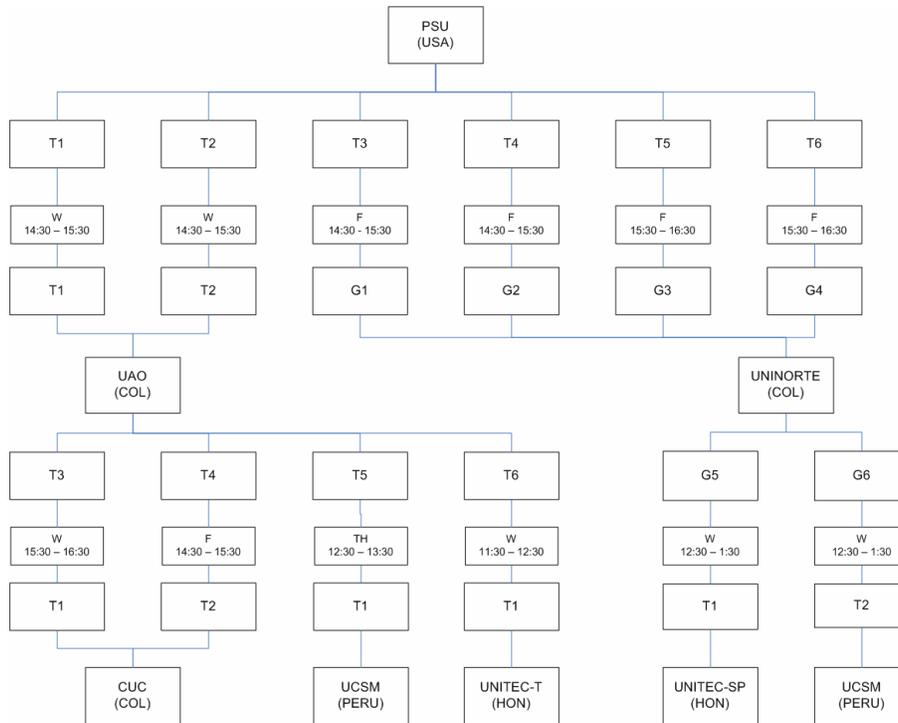
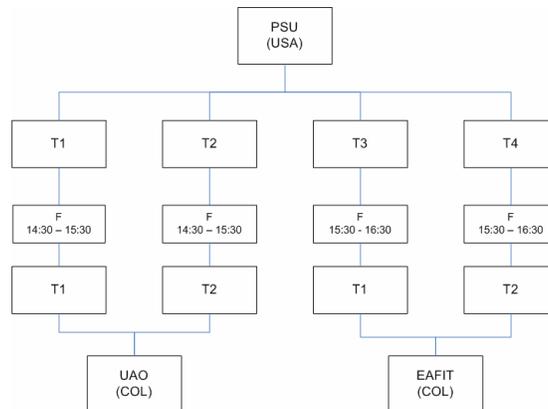


Figure 1 Collaboration network Spring 2005

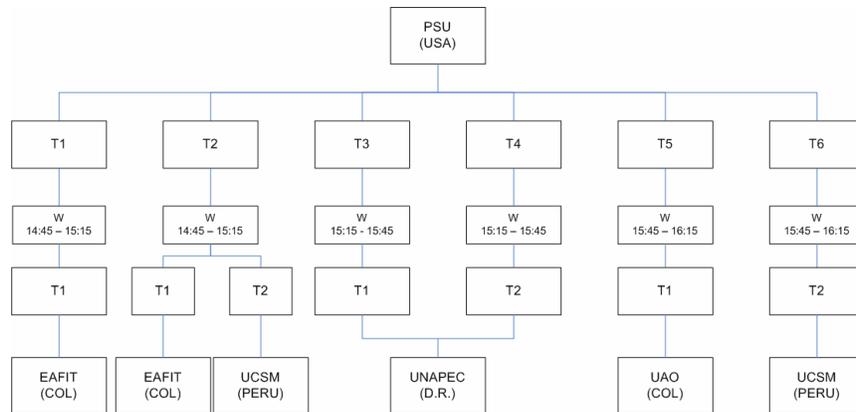


**Figure 2 Collaboration network Fall 2005**



**Figure 3 Collaboration network Spring 2006**

The multinational projects are structured to last seven to eight weeks were the international interaction is required to take four to five meetings using audio-video conferences. However, students are encouraged to keep the international communication via e-mail or audio-video conference beyond the minimum required number of interactions. Participating students discuss the design methodology and the project at a local level first and then they are asked to start sharing information with their international partners to enrich the final solution of the problem. A typical chronogram of activities is shown in Fig. 5.



**Figure 4 Collaboration network Fall 2006**

The design projects considered for the international collaboration can be suggested by any participating institution and discussed for all participants for adoption. When more than two projects are under consideration the final project is selected by consensus. The design projects considered so far are summarized below:

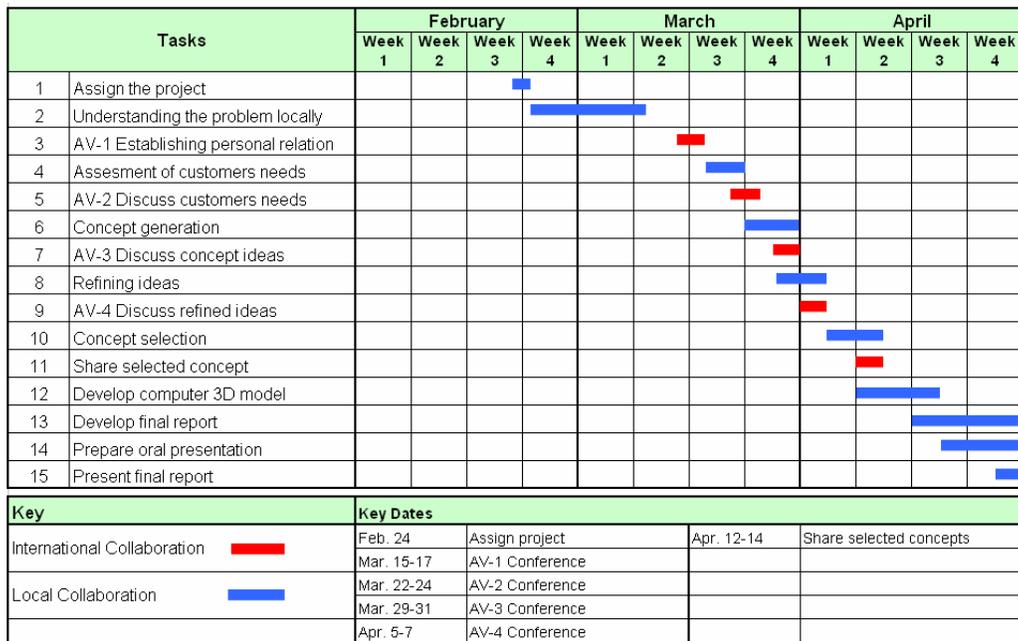
- Spring 2005: Design of a mounting (support) system for a portable electronic warning sign for road emergencies which is easy to carry in a car's trunk.
- Fall 2005: Design a portable and folding bicycle that can be store in a backpack and carry by a person without any inconvenience.
- Spring 2006: Design a lifting wheelchair capable of providing vertical displacement of one meter above the floor and rotation of 180° for the user.
- Fall 2006: Design a wheelchair accessible refrigerator with a minimum capacity of 18 cu. ft.

### **Difficulties and Benefits**

Some difficulties appear in the implementation of the multinational design projects at a freshman level. They emerge from different sources but the most critical ones are due to inexperience working in multinational teams and the use of technology for communication. However, the benefits of this international collaboration exceed by far the difficulties. The most common difficulties and benefits identified while implementing the global design projects are summarized as follows:

#### *Difficulties:*

- *Time:* Coordinating time is a real challenge during the planning process. Length and dates for the semester vary for the different institutions involved. Additionally, there are different time zones that need to be coordinated, and the daylight saving time change that occurs during the collaboration has to be taken into account for the schedule of the meetings.
- *Language:* Language appeared as a significant difficulty at the beginning. English is used as the official language for the meetings but could be a challenge for some students in Latin America, especially speaking. Writing communication works very well.



**Figure 5 Typical chronogram of activities for the global design project**

- **Technology:** Initially MSN Messenger and Skype were used for the Audio-Video conferences, with limitations in quality and connectivity. During Fall 2006 the web conferencing package from Adobe was used. Some problems appeared in Latin America using this package due to limitations in the connectivity to the web. The new package brings also the challenge of creating and maintaining updated the meeting rooms on the web.
- **Resistance:** Resistance from the freshman students to work with other teams. They simply do not know how to work in a team in the same classroom which makes even more difficult to interact with students from other countries and cultures.
- **More Work:** This type of projects demands more work from the instructors planning the collaboration and assisting the students during the international interaction.

*Benefits:*

- **Global Design:** Global design means having more diversity and creativity in design and the ability to reach international markets. The freshman engineering students have the opportunity to be exposed to and international experience by solving a design project which is enriched by multicultural ideas. They learn by doing the importance of diversity in creativity and innovation and its role in reaching new and different markets.
- **International Collaboration:** The globalization of the economy requires engineers to be prepared to design and work for a more diverse community. This initiative provides an excellent international experience for the engineering students at a very early stage on their careers.

- *Cultural Awareness:* This collaboration is important to foster cultural awareness in the engineering students. Besides that, it is a great opportunity for them to learn the value of different ideas from different cultures in the design process.
- *Teamwork:* Students learn how to work in a team and how to share ideas and look for better solutions with multinational colleagues.
- *Communication Skills:* Students are challenged to communicate in a very professional manner and to use the appropriate vocabulary and graphics techniques to maintain the contact with their international partners.
- *Collaborative Tools:* Students have the opportunity to use the technology for communication using web conferencing packages, and features of other software for distance collaboration.
- *Fun into Engineering Courses:* This idea changes the concept of many students who think that engineering courses are boring.
- *Recruitment and Retention:* International programs have been used extensively as a recruitment and retention tool.
- *Inexpensive:* This is an excellent practice to provide international experience for freshman students without incurring in all the expenses necessary for other international experiences like study abroad.

## **Final Remarks**

The overall response of the students participating and the effort of the instructors coordinating this initiative have contributed to a flourishing practice. Informal assessments of these experiences show the success of these projects from the students and faculty perspective.

Generally speaking, most of the students participating have evaluated positively the multinational collaboration through multinational projects. They highlighted the richness of the experience and its innovative character. Most of them coincided in placing this first experience as a starting point for other collaborative experiences. Students feel that when international collaborations in global design experiences occur, they are very interesting and pleasurable; they foster learning about other cultures, and other universities. Besides that, they provide a first hand experience about design practice in disperse teams, and the opportunity to think in a different language, and to establish a wider field of acquaintances and friendship. Many students have shown interest in doing more projects like this, and consider this kind of experience will help them to work in distributed teams in the future.

The instructors participating have found this initiative as an excellent means to teach design concepts but also to expose the students to international experience at a very early stage in their careers. Besides that, it has provided a broader view of engineering education and how engineers are educated in other cultures. Additionally, the multinational projects have created links between the instructors in different countries that are being used to exchange ideas, and explore collaboration opportunities in research projects.

The idea of educating global engineers is becoming very important worldwide. Many organizations and institutions on this hemisphere have started promoting the Engineers for the Americas which is the response to the necessity of forming engineers with the adequate competences for the global market. This is the driving force behind the movement promoting a change in paradigm in engineering education. The new engineering curriculum should provide the students the opportunities to develop the necessary global competences. This new educational model clearly requires coordinating efforts, and identifying and facilitating the best practices that would result in the world-class engineer. Providing the students international experience through multinational projects at a freshman level is an excellent practice to start developing global competences. However, it is important to continue exposing the students to the global competences along their career. The international freshman experience is just the foundation of a long term plan that should be continued until the senior year.

The number of faculty, students and institutions participating in this initiative has grown significantly. In total, faculty and students from ten campuses, from eight institutions, in six different countries have participated. It is important to have more institutions involved in this practice. Some of the difficulties, such as time zone and language, can be minimized if institutions in the Americas with similar time zone and language start incorporating this experience in their engineering curriculum.

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