AC 2011-160: INCORPORATING GLOBAL AND ETHICAL ISSUES IN A FRESHMAN ENGINEERING DESIGN COURSE THROUGH COLLABORATIVE DESIGN PROJECTS

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Incorporating Global and Ethical Issues in a Freshman Engineering Design Course through Collaborative Design Projects

Abstract

Global collaborative design is a common practice nowadays due to the international nature and business scope of many corporations. More and more, the new engineers are working in concurrent design teams geographically disperse around the world. They are designing products and systems which have a broader impact due to the free-trade agreements and globalization effects that are making the national boundaries disappear in the global market. Future engineers will be also challenged to find solutions to problems outside of their social, cultural and economical environment forcing them to make responsible decisions in different settings. Besides that, the rapid developments of new products and the shorter life cycle of them, driven by the fast pace of technology advances and the increasing competition in the market, are creating new problems that are having a direct impact in the environment and ecosystems compromising the sustainability for future generations. The existing design solutions are satisfying immediate demands without considering future consequences. As a result, it is important to start educating students not only to be aware of the world with clear understanding of cross-cultural differences, but also with very high ethical standards and the ability to assess the local and global impact as well as the short and long term impact of their decisions during the design of products, systems and processes. This paper describes the approach used in a freshman Introduction to Engineering Design course to incorporate global and ethical issues through a collaborative design project carried out in collaboration with other students in Latin America.

Introduction

Globalization has had a tremendous impact on the way the companies are organized and are doing business today. The corporate world requires professionals aware of the cultural and political differences across the world, and with high ethical standards to be successful dealing with local and global markets, and making corporate decisions with a global scope. The international businesses and global ethics are not exclusive concepts. In fact, some authors consider that multinational enterprises have the potential to bring social benefits to deprived communities particularly in the Third-World. However, there is a tendency to obliterate the voice of the conscious corporations by the Western capitalism. This tendency has to be reversed by aligning international businesses and a system of global ethics. This can be achieved by preparing future professionals with the necessary knowledge and skills to succeed in the global workforce.
In the particular case of engineers, it is evident that they are required to be part of international structures in the corporate world where they have to interact with customers and colleagues around the world\textsuperscript{7}. They are also challenged to design more and more new products and systems for the global market\textsuperscript{8} at a very fast pace due to the dynamics of the markets and the rapid changes in technology. This phenomenon is forcing engineers to make decisions thinking in the immediate benefit ignoring sometimes the future consequences of these decisions or the broader impact of them in the communities and the environment. Therefore is important not only to prepare the future engineers with the scientific knowledge and the professional skills, but also with the attitude to be responsible and ethical world-class engineers.

The complexity of global ethical issues makes it a difficult topic to teach. People develop a set of personal moral values based on their cultural and religion background. They are influenced by education, cultural heritage, social milieu, and local laws and practices. As people is exposed to the world, ethical issues become global and more complex. Therefore, in engineering undergraduate education global ethics should be incorporated in the curriculum not as an isolated topic but as a crucial longitudinal concept that must be exercised when decisions are made in engineering. This paper describe a project-based learning approach used in a first year introduction to engineering design course to engage students in considering the global ethical impact of their decisions while solving a design challenge.

**Background**

It is important to expose engineering students to international experiences as part of their education from the very beginning in a consistent and productive manner so the students can start developing professional and global skills early in their careers. One of the most effective forms of doing this is through multinational global design projects\textsuperscript{9, 10, 11, 12}. This project-based approach allows the students to work with diverse teams geographically disperse while they solve an engineering problem. It follows the design methodology and gets the students immerse in their learning while they gain knowledge of concepts and become skilled in global competencies.

Recognizing the importance of this initiative, it was decided to incorporate multi-national design projects in the freshman Introduction to Engineering Design course. These projects are carried out each semester using a collaborative network with academic institutions from Latin America and the Caribbean. During the first five years of this initiative (2005-2009), emphasis was placed in problem solving, creativity, global awareness, diversity, global markets, technology for communication, and teamwork. However, the increasing awareness for green design, the environment, and social justice has opened new opportunities to revise the collaborative projects and include in them global ethics. As a result, these projects have been modified to introduce also students to ethical issues during the design process. The idea is to expose the students to
Global engineering challenges where they need to identify ethical issues, evaluate them and make
decisions based on ethical perspectives.

**Global and Ethical Issues in Design**

Globalization implies new challenges for engineers and industries. The information technology
and the logistic networks are facilitating the production and distribution of products around the
world. This might create the perception that product design is simplified by producing uniform
products that appeal to all customers around the world\(^{13}\). Even though some products have been
accepted worldwide, engineers have been forced to redesign other products to meet local
requirements. This is known as localization which is the process used by engineers to adapt
designs to meet the language, culture, and technical requirements specific for particular
markets\(^{14}\). Then the dilemma appears when corporations are interested in global standardization
to produce high volumes of units at lower cost, and the local adaptation that increases the cost.
To deal with this dilemma, two concepts have been proposed: glocalization and homologation.
Glocalization implies that products are first globalized (standardized) and then localized
(adapted) to local requirements. Homologation implies to reach regulatory compliance with local
legislation\(^{14}\).

Globalization is changing the way corporations do businesses around the world. Outsourcing and
offshoring have become common practices; therefore, engineers are required to work the
problems with a broader perspective. They have to recognize the companies as globally
dispersed organizations with material, information and people moving across the national
boundaries\(^{14}\). This has created a new way to design and realize products and systems forcing
engineers to be located anywhere in the world as required by the business\(^{14}\) and working with
international partners and suppliers around the world. Therefore, global design implies to work
in multi-national multi-cultural teams geographically dispersed using the technology for
communication. This means having more diversity and creativity in design and the ability to
better reach new markets. The relocation of engineers and the international collaboration also
contributes to go through the processes of glocalization and homologation mentioned before
since cultural differences can be brought early in the design process making the local adaptation
process easier later on.

This global business model brings an important challenge that affects all the stakeholders: ethics.
Ethical behavior is a critical issue in the corporate world and particularly interesting in the global
business.

Ethics is defined as the set of standards, rules and guidelines for moral or socially approved
conduct and is based on the idea of what is right and wrong. Individuals’ ethical behavior is
influenced by: (a) personal ethics, the set of one’s commitments learned at home and religion
training and modified later by reflection; (b) common morality, the set of moral ideas shared by most members of a culture or society; and (c) professional ethics, the set of standards adopted by professional organizations.

The four basic frameworks for ethics are: (1) consequence-based thinking, based on the notion of doing what is best for all affected; (2) duty-based thinking, based on the notion of doing what you would like everyone to do; (3) virtue-based thinking, based on the notion of doing what a virtuous person would do; (4) care-based thinking, based on the notion of exercising appropriate virtue in every case. Even though each framework capture something that is ethically relevant no frame work captures everything; so all of them should be used to find not the right but the best answer to an ethical issue.

Understanding that individuals’ ethical behavior is greatly influenced by culture, religion, society, and local practices, ethics in a global context is a complex issue. Ethics relativism, which claims that actions are morally right within particular society when they are approved by law or customs of that society, is false because it might justify moral horrors; ethics absolutism, which claims that moral principles have no justified exemptions, it fails to take into account how moral principles can come into conflict. Ethical pluralism is an acceptable practice in the global context since it claims that there is more than one justifiable moral perspective.

To act ethically in the global setting, engineers must develop cultural awareness and broad their knowledge in geography, business, international laws and practices, trade agreements and regulations, intellectual property, and ecosystems and environmental issues. Cultural awareness and international experiences will allow engineers to enhance their sensitivity to cultural differences, and expand their respect for persons from different societies and backgrounds. This sensibility and the non-technical knowledge mentioned above will provide the foundation to deal with a global ethics framework based on global justice and sustainable development. The global justice framework asks ethical questions on a global scale and has three main dimensions: the market model, Rawl’s principles of justice, and basic needs. The market model calls for efficiency that makes everyone happy or better off. Rawl’s model is based in two principles of justice: (1) each person is to have an equal right to the most extensive basic liberty compatible with similar liberty of others; (2) social and economic inequalities are to be arranged so that they are both reasonable expected to be to everyone’s advantage, and attached to positions and offices open to all. The basic needs model is based on the effects on people’s access to basic resources. The sustainable development framework basically calls for extending the moral imagination to include non human living species, future generations and the environment in our ethical considerations. This framework covers those areas which are not considered in the traditional frameworks. For example, traditional frameworks are focused in the wellbeing of human beings ignoring other living species or even the environment. They also ignore future generations and decisions are based on what is convenient now without considering the impact in the future. The
world is changing and the ethical frameworks should also change and respond to the new realities.

Introduction to Engineering Design

Before getting into the details of the collaborative projects, it is important to put in perspective globalization and ethics in the introduction to engineering design course.

This is a freshman engineering course required by all the engineering students entering to Penn State. This course put emphasis in the design methodology and students are required to solve two design projects during the semester. The first project is a redesign of a product where students take a product, do the reverse engineering and go through a design process to propose a redesigned product. The second project is an open problem where students have to explore the solution going through the design process. This project will be discussed in more details in the next section since this is the project used for the multinational collaboration and to include global ethics issues in the design process.

This course is also used to introduce topics related to professional skills in the curriculum such as teamwork and ethics. Both topics are introduced in class and have assignments associated with them before they are practiced in the projects. Globalization and ethics are presented in class in a simple and practical form to get the students interested and motivated. It is not the intention of this class to substitute humanities or social studies courses but to embed humanities and social studies topics in engineering so students start appreciating the relation between technical and non-technical studies. In the case of ethics, two case studies are analyzed and discussed in class before the projects. This is with the intention of having the students to start identifying ethical issues and discovering their own personal values and their stance in ethical issues. The second project has been modified to guide the students through an ethical thinking process.

The freshman Introduction to Engineering Design course has been structured as a project-based course and, therefore, a multi-national global design project has been easily incorporated on this course. This project is used not only to develop important skills such as project management, teamwork, global design, creativity, innovation, and problem-solving abilities but also to foster cultural awareness, understand diversity, master the use of technology for communication, and more recently to promote global ethics issues in engineering design.

Collaborative Design Projects

There are different types of international projects that can vary from a very simple case study where a team reports a final result of a design to their opposite group to a more complex integrated team project where students from multiple countries work together on a joint design
The criteria to select the appropriate type of collaboration depend on the general objective, the level and content of the course, the commitment of faculty and the students, and the resources. The scheme structure selected for this collaboration 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 collaborative network used during the Fall 2010 is shown in Fig. 1. As can be seen, five clusters were formed with 19 teams from six different institutions from four different countries. The geographic distribution is as follows:
- Colombia: two institutions and six teams
- Dominican Republic: two institutions and three teams
- Ecuador: one institution and five teams
- USA: one institution and five teams

![Figure 1](image1.png)

**Figure 1 Collaborative network for global design project Fall 2010**

The assigned project for all the teams was to design a machine to produce charcoal briquettes from sugarcane bagasse. The machine was to be manufactured and operated in Latin America, and to be used by people in small and deprived villages. Teams should keep in mind the limited access to energy in the villages where the machine would be used. Following the parallel design projects scheme, students were allowed to work independently on each location and share information and data with their international counterparts to enrich the project and to nourish with diverse ideas the final solution.

The project under consideration was global in scope and students were asked to consider all ethical implications involved in this project by asking questions along the design process that stimulates teams mind in the ethical dimensions of the problem. Figure 2 shows the design methodology for the project and Table 1 shows the chronogram of activities.
Figure 2 Design methodology for the project

Table 1 Chronogram of activities for the collaborative project

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Assign the project</td>
<td>10/6</td>
</tr>
<tr>
<td>2</td>
<td>Understanding the project locally</td>
<td>10/6 – 10/11</td>
</tr>
<tr>
<td>3</td>
<td>Test equipment for AV conferences</td>
<td>10/6 – 10/11</td>
</tr>
<tr>
<td>4</td>
<td>Understanding customer needs</td>
<td>10/11 – 10/18</td>
</tr>
<tr>
<td>5</td>
<td>AV-1 Conference: Establishing personal relations</td>
<td>10/15</td>
</tr>
<tr>
<td>6</td>
<td>Advance Report I: Design tasks and customer needs</td>
<td>10/22</td>
</tr>
<tr>
<td>7</td>
<td>AV-2 Conference: Discuss design tasks and customer needs</td>
<td>10/22</td>
</tr>
<tr>
<td>8</td>
<td>Functions and specifications</td>
<td>10/18 – 10/25</td>
</tr>
<tr>
<td>9</td>
<td>Advance Report II: Function analysis and design specifications</td>
<td>10/29</td>
</tr>
<tr>
<td>10</td>
<td>AV-3 Conference: Discuss function analysis and design specifications</td>
<td>10/29</td>
</tr>
<tr>
<td>11</td>
<td>Concept generation</td>
<td>10/25 – 11/1</td>
</tr>
<tr>
<td>12</td>
<td>Advance Report III: Conceptual design ideas</td>
<td>11/5</td>
</tr>
<tr>
<td>13</td>
<td>AV-4 Conference: Discuss concept ideas</td>
<td>11/5</td>
</tr>
<tr>
<td>14</td>
<td>Concept selection</td>
<td>11/1 – 11/8</td>
</tr>
<tr>
<td>15</td>
<td>Progress Report</td>
<td>11/12</td>
</tr>
<tr>
<td>16</td>
<td>Develop 3D model and final concept</td>
<td>11/8 – 12/8</td>
</tr>
<tr>
<td>17</td>
<td>Prepare final report and presentation</td>
<td>11/8 – 12/8</td>
</tr>
<tr>
<td>18</td>
<td>Submit final report and presentation</td>
<td>12/10</td>
</tr>
</tbody>
</table>
Table 2 illustrates how this project was modified to include global ethics. The table shows a comparison between the previous approach and the modified approach to incorporate global ethical issues into the project.

**Table 2 Modified design approach for multinational design project**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Previous Approach</th>
<th>Modified Approach</th>
</tr>
</thead>
</table>
| Understanding customer needs | 1. Identify the customers.  
   2. Gather information from the customers (consider the information from your international partners).  
   3. Translate customer needs into product requirements. | 1. Identify stakeholders (all people with interest in this project or might be affected for this project).  
   2. Identify non-human living species that might be affected by this project.  
   3. Gather information from stakeholders (consider the information from your international partners).  
   4. Translate stakeholders desires into product requirements  
   a. Can you include requirements for the non-human living species?  
   b. Can you anticipate an environmental impact during manufacturing, operation, service, and final disposal of this product? |
| Functions and specifications | 1. Function analysis  
   2. Create a black-box model  
   3. Create a transparent-box model  
   4. List product specifications | 1. Function analysis  
   2. Create a black-box model  
   a. Can you anticipate in or out flows that might have a negative impact (consider short and long term impact)?  
   3. Create a transparent-box model  
   a. Can you anticipate internal flows that might have a negative impact (consider short and long term impact)? |
### Concept generation

| | 1. External search  
|---|---|
| | a. Patent search  
| | b. Benchmarking  
| | 2. Internal search  
| | a. Basic methods (intuitive)  
| | b. Direct methods (logical)  

| | 1. External search  
|---|---|
| | a. Patent search  
| | b. Benchmarking (can you identify safety or environmental issues in existing products?)  
| | 2. Internal search  
| | a. Basic methods (intuitive)  
| | b. Direct methods (logical)  

(consider alternatives that are safe and has a minimum impact in all living species and the environment during manufacture, assembly, use, service and final disposal)

### Concept selection

| | 1. Use decision matrix for concept selection  
|---|---|

| | 1. Use decision matrix for concept selection  
|---|---|
| | a. When evaluating alternatives take into consideration not only the business aspect of the product but also the sustainable aspect and the impact in the society.

### Conclusions

The simple set of questions shown in Table 2 are used with the intention of promoting ethical thinking and broadening the context of the problem during the design process. One important change in the design approach is to broadening the scope during the stage of understanding customer needs. First, it is critical to move from the customer definition where usually the customer is considered solely as the primary user of the product to the stakeholder definition where all individuals with interest in the product, users and those who might be directly or indirectly affected by the product, are considered. Additionally, it is also important to consider non-human living species and state their requirements as they might be affected by the product at
any stage of its life-cycle. This first stage of defining stakeholders in a very broad manner and understanding their requirements sets an important foundation for ethical considerations in the design process since solutions should be sought to satisfy stakeholders and non-human species requirements in a responsible way. The concept generation phase is the one with less intervention since fostering creativity is another important objective of this course; however, it is critical to promote creative and sustainable solutions in engineering and minimize the negative impact of new products and systems in the society and the environment.

The problems used in this class are all related to Latin American communities. This provides not only the global component but also a challenge in finding ethical and sustainable solutions. For example, in the last project, one of the constraints was the limited access to energy and another constraint was that the product would be used in deprived communities. This forces students to find solutions in a setting and constraints they are not familiar with. Even though this project is solved in teams and the final solution is not known until the final presentation, some issues are discussed with the entire class and more questions might come up during the class discussion to trigger students thinking.

Bibliography