AC 2007-123: INCORPORATING GLOBAL ISSUES INTO FRESHMAN ENGINEERING COURSE

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Incorporating Global Issues into Freshman Engineering Course

Abstract

This paper documents the redesign of a freshman engineering concepts course to incorporate various global/intercultural issues that our students will face if they stay in an engineering career. Today's engineering students graduate in a world that is becoming highly competitive as geographical barriers are being eliminated, and engineering activities are truly global in nature. To remain competitive, students must develop global skills and competencies to be leaders and participants in cross-cultural engineering teams. This extension of students' skills is very compatible with ABET initiatives. ABET has established requirements for professional skills outcomes that are directly fulfilled by cross-cultural/global studies. However, many of our engineering curricula do not address globalization for all students. John Brown University (JBU) is integrating global issues into all years of a student's educational experience. This task starts with the redesign of the freshman course.

The original course structure follows the basic philosophy of providing the student a broad knowledge of what engineering is and the various disciplines that can be chosen to meet career desires. One of the key objectives is to provide sufficient information about various engineering disciplines so that a student can make an informed choice of a major. Students are informed regarding the ABET Engineering Criterion 2000 and how it will affect their educational experience. A key element of modifying the course to include global issues was to maintain current objectives, introduce them from a global perspective, and not overload this introductory course for either the student or the professor. This paper will describe the resulting course with assessment and lessons learned for improvement.

Introduction

To be effective engineers and global citizens, today's engineering students must understand the global nature of society and the complexities of a world economy. The National Academy of Engineering projects that, because of growing political and economic ties among nations, engineers will discover that their designs have much broader and more significant impacts than they once did. As a result, engineering practice will be driven by attention not only to the familiar topics of intellectual property, project management and cost-benefit constraints, as well as multilingual influences, cultural diversity, moral/religious repercussions, global/international impacts, and national security.[1]

In 2000, Smerdon noted that, "Perhaps there is no single factor of greater importance in its effect on engineering education than the internationalization of engineering practice."[2] A recurring theme Smerdon recognized is that engineers will continually be adapting and learning as they encounter rapidly changing technologies throughout the world and become cognizant of societal, economic and ethical issues. International design requirements will challenge engineering students to understand other cultures and the ways their designs will affect multiple societies. If these designs are developed with cross-cultural teams, there will be the added challenge of managing various cultural dynamics.

In 1994, the American Society for Engineering Education (ASEE) analyzed the changes needed for engineering education.[3] Their report stated that engineering education programs must be relevant, attractive and connected. Action items were identified to provide a better education in the professional skills without detriment to the technical skills. This activity culminated in the ABET initiative that became known as Engineering Criteria 2000.[4] An important element of these criteria is the emphasis on assessing the professional skills. These skills directly relate to those skills need for international competencies.

The political arena has recognized the need to face issues of global competitiveness. In his 2006 State of the Union Address, President Bush addressed the rise of new technology competitors around the world, especially in China and India. He noted that technical advancements provide economic strength. As a competitive and innovative nation, the U.S. must continue to lead the world in human talent and creativity. Key elements of his initiative were to develop new technologies and improve students' science, math and technical skills. In addition, engineers must have the competencies to function globally in leadership positions.

Other recent publications note the need for U.S. technological workforce changes to remain competitive in a global world. Freidman (2005) points out that technology has significantly changed the work environment as traditional barriers to competition have been removed and new dynamics are developing.[5] This change should not be envisioned as a threat, but an opportunity. To meet the challenges of this new opportunity, many changes will be necessary for the engineering community. The Council on Competitiveness notes that a key national strength is innovation. To capitalize on the innovative spirit, the council has recommended that key initiatives focus on developing talent, investments and infrastructure. An important element of talent development is equipping workers to perform in a global economy.[6] The National Academy of Engineering reinforces this need for talent development by outlining the challenges of a global world.[7]

Ultimately globalization is impacting all engineering graduates. Their designs will often be targeted to a global marketplace, but the technical expertise of international users and the appropriateness of certain technologies will vary significantly. Many companies are already global with many more going global every day. Engineers participate on global teams as individuals are spread around the globe to implement complex projects. Globalization is expanding our science and engineering labor force both by becoming more internationally diverse and more internationally mobile.[8] However, few universities have been intentional about integrating global, cross-cultural education into the engineering curriculum.

John Brown University has recognized the need to make global issues an integral part of the students' education. In 2003, JBU embarked on Project Campus Globalization, a campus-wide endeavor designed to integrate global and cross-cultural elements into all department curricula and into the campus culture. Campus Globalization received funding from the U.S. Department of Education. The university core curriculum now requires every student to take at least one three-hour global studies course in fulfilling degree requirements. The Department of Engineering has embraced this activity and is working to incorporate global issues into courses that span the typical four-year course plan. This initiative is seen as an opportunity to significantly strengthen the engineering program, improve ABET outcomes, and further strengthen ties with our liberal arts colleagues. For course purposes, globalization is defined as exposure to other cultures, understanding how problems are defined differently in different cultures, and developing skills to work in culturally diverse environments. The beginning element of this educational endeavor is the freshman engineering concepts course.

Our original course structure follows the basic philosophy of providing the student a broad knowledge of what engineering is and the various disciplines that can be chosen to meet career desires. One of the key objectives is to provide sufficient information about various engineering disciplines so that a student can make an informed choice of a major. At JBU students are able to pursue studies majoring in electrical/computer and mechanical disciplines. Students are informed about ABET Engineering Criterion 2000 and how it will affect their educational experience. A key element of modifying the course to include global issues was to maintain current objectives, introduce them from a global perspective, and not overload this introductory course for either the student or the professor. This paper will describe the original course content, changes that were made to incorporate global/cultural issues, course assessments and lessons learned.

Original content

This course is a two-hour lecture/discussion class that teaches basic engineering concepts and the design process. The original course contained elements that have been common to many engineering programs across the nation. Course objectives are to understand: 1) what is engineering? 2) what is the role of ABET and how does this impact educational requirements? 3) understanding the engineering design process, 4) beginning to learn basic engineering computer tools, 5) developing writing skills, and 6) establishing ethical engineering practices.

The course begins with understanding what engineering is. There is the classical definition that engineers use science to solve problems. Most programs have come to recognize that this is an oversimplification of the engineering discipline. The students are taught that engineers have to consider many elements that go beyond the physical sciences and mathematics. There are the additional, broader issues of economics, politics, environment, health, safety, quality, ethics, culture and other contemporary issues.

Along with an understanding of general engineering, students are introduced to various disciplines: civil, mechanical, electrical, chemical, aeronautical, bio-medical and others. The course provides a broad understanding of multiple engineering disciplines but concentrates on the electrical/computer and mechanical majors provided by JBU. This content allows the student to make an informed choice about their chosen major. This choice may include a transfer to another university if they want a degree area not provided by our institution.

As can be seen from the discussion of above, it is quite easy to inform the students about ABET outcome criteria. The classical definition of engineers using science to solve problems provides a venue to explore what is commonly called the technical skills. The expansion of engineering activities into more social, economic and political arenas provides the opportunity to introduce the professional skills that are also a part of an accredited program. Students are instructed to look for these program outcomes in their four-year educational experience beginning with the freshman concepts course.

The engineering design process is introduced as: needs identification, problem definition, search, constraints, criteria, alternatives, analysis, decision, specification and communications. Application of this process is demonstrated using a simple, fun exercise. A bag of miscellaneous parts; paper plate, tongue depressor, rubber bands, mouse trap, tape, pins and similar items; are given to the students with some form of fun problem to solve. Time is given to develop and demonstrate their solution and class time is set aside for evaluation and reflection on the process. The project for the past two years was to launch a marshmallow a distance of ten feet and have a teammate catch it in their mouth.

Throughout the semester various assignments are developed to integrate the SolidWorks and Multisim computer tools, technical writing assignments and ethical discussions into the other course activities. Students are aware that this is only a beginning. 1) They will see many different computer tools throughout their time at the university. 2) Writing is not just an exercise for the English students. It is an important communication skill for engineers. And 3) the Christian heritage of JBU provides a baseline where ethics will be continually developed from a Christian worldview. From this basic framework, the course redesign proceeded to incorporate global issues without diluting current content and overloading either the student or the professor.

Global/cultural changes

A key to redesigning this course was to make changes that would augment existing instruction but not add so much content that existing information would have to be sacrificed due to time constraints. With this perspective it was easy to build on the ABET professional requirements and the engineering design process.

ABET criteria 3(h) establishes a requirement for engineering practice within the context of global, economic, environmental, and societal contexts. Some individuals have encouraged that the global and cultural aspects be separated into a criterion (l).[9] This course redesign took the position that this incorporation directly fits multiple professional criteria (c, f, g, h, i, and j) without having to create a separate area for additional ABET tracking and auditing.

Within the engineering design process, the course redesign particularly utilized the areas of problem definition and communications for incorporating global issues. Due to the research efforts of Downey and Lucena,[10] there is a wealth of information available on how other cultures define problems. Their work gives many examples from Britain, France and Germany. The American engineering thought processes have their heritage in colonial times. However, there has been significant adaptation that today causes conflict and teamwork issues when multi-cultural teams work to solve today's problems. In this course, students are introduced to how different societies think and a requirement to be sensitive to those differences in order to effectively work in a diverse, cross-cultural world.

As problems are defined and alternatives analyzed, a system of units and measures has to be established. Within the United States, the common measurements are derived from the Anglo-Saxon weights and measures and became known as the British units. Internationally, most of the world uses the metric or Systeme International d'Unites (SI) for their engineering standard.

Students are introduced to these systems and participate in discussions on their relative merits and usage of each.

Along with basic units, it is important for our students to understand different number and dating systems. Contemporary news daily reminds students of the importance of the Middle East to world stability. Many students can be expected, shortly after graduation, to work on a project that directly or indirectly has usage in this area of the world. Many of them are not aware of the basic differences in Farsi numbering systems. Pakistan and India have become a common engineering team member that requires regular interface and dialogue for design completion. Again, few students have considered that the Urdu numbers are quite different from their own. There is a common expectation that other cultures will learn an English numbering system and we should not have to be aware of theirs. This type of arrogance can cause friction for team dynamics.

Calendar dating has been known to cause some interesting misunderstandings in the business world. It is quite common for dates to be designated by numbers separated by slashes or dashes; i.e. 9/11/06. However, the meaning of this numerical arrangement has no worldwide standard. When a team member, agrees to provide information on the above date, are they agreeing to September 11, 2006 or November 9, 2006. Just looking at the numbers, one cannot decide. Knowing the country of origin does not often provide the solution. Australians writing for Australians would see this as the November date. However, if they are writing for an American it could be either date depending on their own reference point at the time of creating the numbers. This course redesign opened discussions on this issue so that the students would be able to understand the differences and begin to show sensitivity to others and wisdom in clarifying the true meaning of the originator.

The final element in the engineering design process is communications. An important element of this stage is the creation of engineering drawings that accurately portray a design and allow for reproduction. As a teaching exercise, the author creates a classroom situation to demonstrate the difference in verbal communications and the written accuracy of a completed drawing package. A student chooses a small, simple item for a bag of parts. The student must verbally describe the item to the class without showing it to anyone. It is the job of the rest of the class to create a mechanical drawing of the item. It is common for at least someone in the class to figure out what the item is and is able to create a drawing that at least represents some level of similarity. No one creates a drawing of a quality that would allow for mass production. This demonstration can be completed a couple of times in a fifty minute class period.

For variation and demonstration of cultural issues, the author chooses an international student to describe the second item in the bag. However, the ground rules are modified ever so slightly. The purposeful selection of an international student has also resulted in a student that is very fluent in a foreign language. The verbal description must proceed in the native language of that student. As would be expected, the initial reaction of the rest of the class is astonishment, confusion, and some level of frustration. With a little encouragement, the class realizes this could be a real-life scenario and they have to learn to adapt. To date, they have always been able to find a fellow student who understands the language of the speaker. The process proceeds at a slower pace, but it proceeds nonetheless. Again, the result has always been in someone being able to create a similar drawing. But the learning process has allowed the class to understand that not all engineering situations will be familiar. They have just experienced first-hand proof that some of their own classmates have a different cultural perspective.

There are multiple short writing assignments in the class to help develop understanding and skills in documentation and communication. One of those assignments was modified to incorporate a global perspective. The students are instructed that they are developing a global understanding. They are to explore the background behind a historical engineering accomplishment or person. First, they choose a historical figure or an important engineering development from another country that took place prior to 1900. An engineering discovery is not limited to a single person or law. Great feats include structures such as the Roman aqueducts, Mayan temples, and Egyptian pyramids. Engineering may progress by events or procedures, such as Australia's "Lost Generation" or Mendel's genetic experiments. Great engineering also advances through intelligent and visionary people such as da Vinci, Newton, Henry, Paschal, Marconi, Ohm, or Kirchoff. The student is encouraged to understand the cultural climate that would have influenced each event or person. They then must consider how that impacts engineers today and how their personal career may be impacted.

The above course adaptations are changes that could be made within the original course structure without adding work or changing the classroom time. Original discussions are now simply reframed to consider global and cultural issues.

One change that did add content is a discussion on appropriate technology. The new course syllabus takes a week to discuss the issues of appropriate technology and how engineers need to adapt designs for integration into needy societies. Over the two years that this new course has been in place, guest lecturers have proven to be very effective in stimulating discussion and critical thinking in this class segment.

During the first year, JBU had the opportunity to have artisans from the mountains of Guatemala visit the campus. The artisan's life would be considered backward and underdeveloped by the standards of the world. A key element of their life was creating beautiful, hand-woven fabric pieces that could be sold to tourists. The proceeds would finance the next set of thread for a new fabric or garment. A small amount of profit was set aside to pay for educational opportunities for their children. The artisans attended the class, discussed the dying and spinning of the thread, and demonstrated the weaving of the fabric. They do not have a mechanized loom. The fabric warp was held in place by sticks with one end attached to a tree or similar immovable object and the other connected to the waist of the weaver. Much of the process could have been mechanized. But it was also very important to recognize that much of the color combinations and weaving process had cultural significance. Not only did we discuss how to make the process easier, we also had to discuss what was technically appropriate and morally ethical. Would it be ethical to introduce a new technology if we knew we would also be participating in the elimination of something with strong cultural meaning?

For the second year, speakers were brought into the class from a local third world community development institution. The institution has been very active in multiple underdeveloped areas in both water purification and renewal energy processes. Unfortunately, there are several areas of the world in which potable water is not easily available. Throughout the twentieth century, air and water pollution have increased[11], further decreasing the availability of safe water. By the year 2015, it has been projected that nearly half of the world's population will live in "water stressed" areas.[12] There is a problem with both the quality and quantity of water. The presentation increased student awareness of this potential career element.

Assessment

As the Engineering Department at JBU incorporates global issues into multiple areas of the curricula, it is important to concurrently have an assessment system to measure progress. It was decided to use two different instruments for this task. The Intercultural Development Inventory is a proven, psychometric instrument that evaluates cultural sensitivity along a continuum from ethnocentric to ethnorelative.

The Intercultural Development Inventory (IDI) is based on Bennett's Developmental Model of Intercultural Sensitivity (DMIS).[13] This instrument has undergone extensive research and has a proven content validity, construct validity, and high reliability.[14] The DMIS is a cultural development model that begins with denial as the most ethnocentric element. The continuum moves through stages of defense/reversal, minimization, acceptance, and adaptation to the most ethnorelative positions of integrated. This continuum is shown in Figure 1.

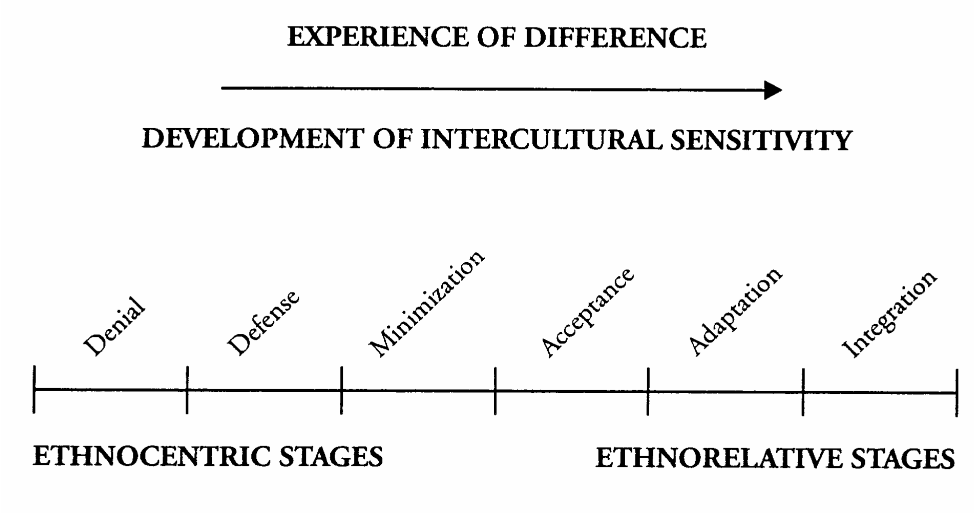

Figure 1. DMIS model.

This survey provides a cultural sensitivity snapshot of the participants. The response of the engineering freshman can be seen in Figure 2. The red represents the participants' perception (PER) of where they think they are on the scale. The blue is normative data that represent where the participants actually are developmentally (DEV). This information provides a baseline of where the students are as they begin their academic career. From this analysis, it is obvious that there is plenty of opportunities for continued cultural development as the measured levels are predominantly below the population mean which lies between Min1 and Min2.

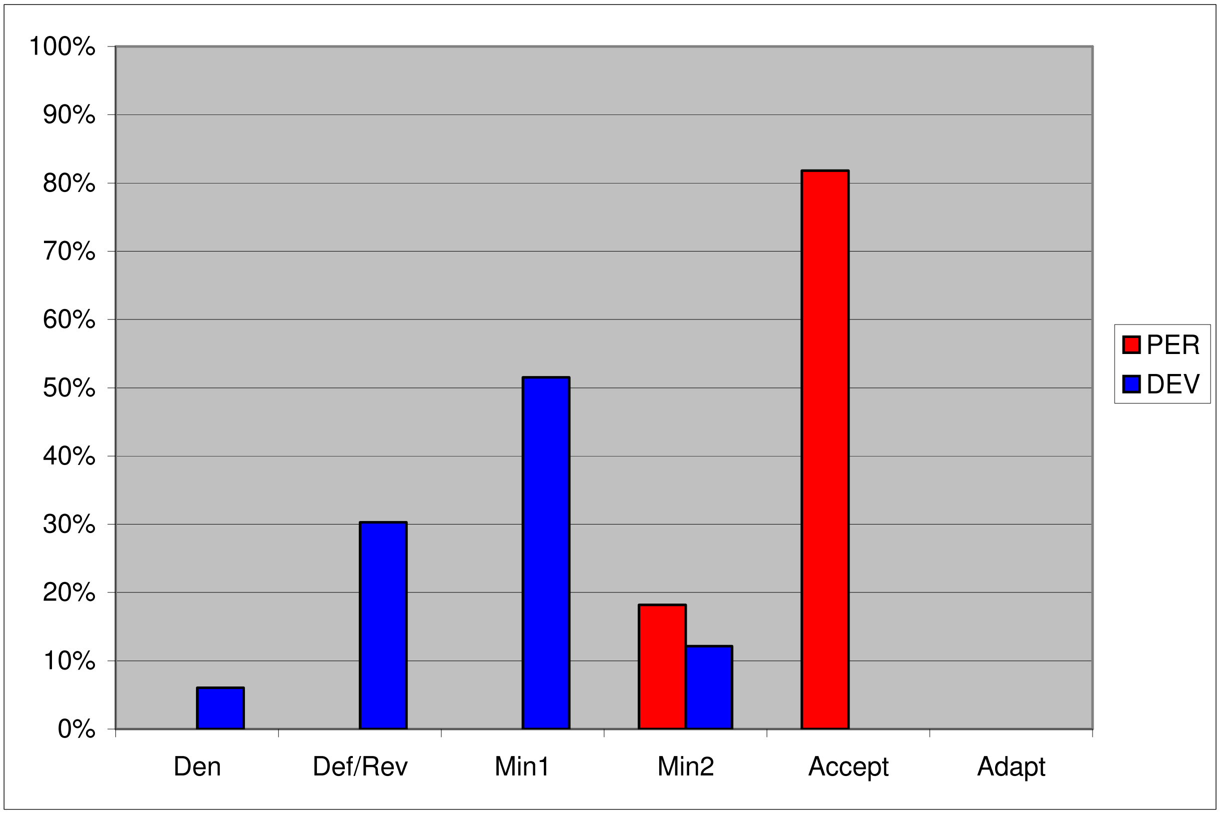

Figure 2. Baseline Freshman Concepts Responses.

Along with administering the survey, various demographic data was obtained from the students. 67% reported having lived in another culture and 30% reporting from three months to ten years. 21% are foreign students now living in the United States. 91% reported some level of foreign language ability. To really understand the impact of JBU global educational interventions, it will be necessary to perform post-testing of these students prior to graduation.

A course evaluation survey was administered as a second assessment to determine how well objectives were met. The survey was a series of attitudinal questions where each student was asked to indicate their extent of agreement or disagreement with the statements on a five-point Likert-type scale (5 = Agree). The bank of questions was developed with a specific group of questions targeting the original core to see that no value was lost and another group to evaluate the response to the added global activities.

The teaching of ABET outcomes, both fundamental technical skills and professional skills, received high ratings.

- “ABET fundamental technical engineering outcomes were presented understandably" (4.06)

- “ABET professional outcomes presented understandably” (4.18)

Teaching of the engineering process continues to be understood by the students.

- "The marshmallow design project was informative with respect to the engineering process" (4.65)
- "The course provided a good overview of the engineering process." (4.40)
- "The class exercise on drawing an object that was verbally described effectively demonstrated the need for good communications" (4.56)
- "The final project provided a good opportunity to understand how others have applied the engineering design process." (4.62)

To develop student's communications skills, there were both writing and presentation requirements for the class. The presentation area received high ratings.

- "The final project gave me the opportunity to improve my presentation skills." (4.43)

But the writing segment received the lowest rating of any item on the survey.

- "I developed/improved my writing skills in this course" (3.28)

It was also observed from a qualitative perspective that the writing assignments created the most negative reaction from the students. The writing skills for many freshmen are quite weak. They are being held to a much higher standard of performance at the college level and they are not happy with the general situation. Over the semester, the quality of their papers does improve considerably. But they continue to have a negative attitude to more stringent requirements and they do not appreciate feedback that is similar to a critical peer review.

The introduction of computer tools received mixed evaluations.

- "I received a basic understanding of SolidWorks" (4.43)
- "I received a basic understanding of Multisim" (3.56)

The lesson learned from the Multisim evaluation will be discussed in that section of the paper.

From the data, it was concluded that introduction of global issues into the course curriculum was not detrimental to the original, core course content. The assessment also demonstrated that the global issues provided new understanding to the students.

- "The class exercise on drawing an object that was verbally described in a foreign language demonstrated the issues of international communications." (4.75)
- "The Global Perspectives paper effectively required me to learn about an historical engineering development in another country." (4.25)

- “The lecture on units and numbers exposed me to differences that exist in international dates and numbering systems.” (4.06)

- “The Appropriate Technology segment provided good exposure to the needs of other societies.” (4.50)

- “The Appropriate Technology segment provided an understanding that many societies can not use or maintain modern technologies.” (4.53)

- “The Appropriate Technology segment causes me to consider “other” perspectives when I define design problems.” (4.50)

The results from the assessment show that global issues can be successfully integrated into the freshman engineering concepts course without degrading the original content.

Lessons learned

In evaluating the student assessments, the lowest responses were to the writing activities and learning Multisim. The author is not sure how to change the attitude that has been displayed toward writing. The students are being held to a higher standard and level of accountability. As students become aware of this new standard, they appear to experience a form of cultural shock. This academic requirement should encourage the college community to push back on the high schools to raise their standards and improve educational activities at an earlier stage in life.

A deeper look at the Multisim response also shows a student attitude problem, but this is correctable. Over the past two years, Multisim has been required in team related assignments. It is the student practice to divide team activities and perform only the task that is specifically assigned to each individual. Therefore, if an individual’s team task was to draw a circuit in Multisim, then that person learned the software. If not, the other team members tended not to learn the software. The assignments will be changed in future semesters to require everyone to perform some individual tasks with each software tool.

It was also observed that guest lecturers with real life experiences provide a point of high interest for the students. If funding were available, international guests would be flown in every year to provide lectures and discussion forums. Since that is not practical, efforts will be made to utilize immigrant populations in the area. JBU has an opportunity in this area since there is a strong Hispanic population and the local county has the largest Marshallese population outside of the Marshall Islands. Guests from these people groups would provide a diverse cultural perspective.

Conclusion

The course redesign has been a very successful endeavor. The students, as demonstrated by the IDI evaluation, enter their college experience with a cultural developmental position that is below the societal norm. The students have demonstrated an interest in what is happening in other cultures. Some of them see this educational intervention as an adventure and appear to be approaching this from the perspective of a tourist in anticipation of their next trip. Others recognize that the world dynamics are changing and that their own career will probably require interfacing with multiple cultures from Europe, Asia and the other continents. Regardless of the students' perspective, interest level is high and learning does take place. More interventions will be needed throughout the four-year experience to provide greater opportunity for cultural sensitivity development.

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