Incorporation of Poverty Alleviation in Third-World Countries in a First-Year Engineering Capstone Course

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The first-year engineering curriculum at Ohio Northern University includes a one year course sequence culminating in a one quarter capstone design course. A requirement for projects to involve the design of a poverty alleviation device was recently introduced. The initial implementation required student teams to identify an impoverished country (using the World Bank's definition) and address a specific need of the population. The project requirements include following and documenting the engineering design process, preparation of a proposal, regular verbal and written status reports and development and presentation of a prototype. The poverty alleviation requirement has allowed students to directly experience multiple learning outcomes as specified in ABET assessment criteria including understanding engineering in a global and societal context, along with criteria typically found in a capstone course such as the ability to function in teams and to communicate effectively. Quantitative and qualitative assessment of the project showed that students felt the experience related to societal and realistic constraints. Future iterations of the class will require devices be designed toward poverty alleviation for a persona rather than a country; the goal is to emphasize the human aspect of the students' design. Personas have been developed based on an actual senior capstone experience in Kenya.

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Background

Engineers can make a difference in the lives of individuals, groups, or whole populations. Typical perceptions of engineering are often that engineers design the next great innovation rather than helping society. Dr. Paul Polak, author of *Out of Poverty*[1] recognizes impoverished populations as potential customers and entrepreneurs. He has shown that designing products to applicable constraints and with local empowerment can have a tremendous positive effect on the lives within these populations. With this ideal in mind, the culminating capstone course in the first-year curriculum at Ohio Northern University was modified, requiring all designs to address some area of poverty alleviation.

The First-Year Engineering Curriculum

The first-year engineering curriculum is a year-long (three quarter) sequence. The overall intent of the sequence is to introduce engineering concepts and to integrate the students into their peer community. The first course in the sequence focuses on professional skills such as teamwork, technical communication, entrepreneurial characteristics of engineering and global aspects of engineering. The consideration of engineering criteria and constraints and a formal engineering design process is also introduced. Design projects are generally small in scope and focus more on the design process rather than the final product. The second course in the sequence builds on the first with more extensive projects, more emphasis on technical communication and an expanded use of engineering software. The final course in the sequence is the first-year capstone course. Student teams are formed and tasked to prepare a proposal, design a device following an engineering design process, document and report on the design regularly throughout the quarter through formal design reviews, and finally develop and present a prototype device.

Incorporating Poverty Alleviation into the Capstone

Dr. Polak's work was meant to apply generally to professionals and, academically, to senior and graduate level design; however, incorporating his concepts into a first-year capstone provided an ideal avenue to emphasize the real-world aspects of engineering. One of the goals of the first-year sequence is to show engineering in a global context (through the National Academy of Engineering Grand Challenges[2], for example). The use of poverty alleviation as a design theme and requiring research into an impoverished society provides students exposure to real-world problems - not "problems" that are contrived as an end unto themselves. This requirement allowed multiple

ABET specified criteria to be considered. Specific objectives include:

- an understanding that an engineer can effect positive change for thousands, even millions, by designing for those who are impoverished;
- an experience with real-world examples of the realistic constraints (economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability) listed in ABET EAC Criterion 3c; and
- appreciation of the need for the "broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context," as called for in ABET EAC Criterion 3h.

Specific project requirements included:

- Teams were to identify a country where 40% or more of the population earn less than the World Bank's relative poverty threshold of $2/day.
- Teams were to identify a specific need relevant to their country to address.
- Teams were to prepare and present a proposal for approval.
- Teams were to prepare status reports through the quarter, and present these in a formal project review with the instructor.
- A prototype must be designed, built, tested and presented to the instructor and the class.

Assessment

Quantitative assessment results were obtained through an end-of-quarter survey administered to all 109 students enrolled in the course, consisting of 10 Likert-scale items (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree) and items asking for the student perception of the influence of each specific ABET-defined realistic constraint on their project using a 4-point scale (Strongly, Moderately, Minimally, None). Qualitative assessment results were taken from open ended questions on the survey plus a reflective essay assigned in one section. Similar quantitative items are grouped together for presentation.

Awareness of the Engineering Profession

Three of the survey questions related to the student's awareness of the engineering profession and its applicability to society. Specific items were:

1. "This project provided me with insight as to what it is like to be an engineer",
2. "This project reinforced my decision to become an engineer", and
3. "The project I worked on allowed me to apply the engineering design method to a real-world problem."

As shown in Table 1, approximately 96% of students agreed that project allowed them to apply an engineering design method to a real problem.

Table 1. Relating to the Engineering Profession.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	33 (37%)	47 (53%)	9 (10%)	0 (0%)	0 (0%)
2	26 (29%)	48 (54%)	13 (15%)	2 (2%)	0 (0%)
3	39 (44%)	47 (53%)	3 (4%)	0 (0%)	0 (0%)

Impact of Engineering on Society

Questions meant to assess student perception on the impact of engineering on society included:

1. I learned about the impact of engineering solutions in an economic context.
2. Please indicate the degree to which your project was influenced or affected by the following realistic constraint: economic.
3. I learned about the impact of engineering solutions in an environmental context.
4. Please indicate the degree to which your project was influenced or affected by the following realistic constraint: environmental.
5. I learned about the impact of engineering solutions in a societal context.
6. Please indicate the degree to which your project was influenced or affected by the following realistic constraint: social.

The results (Table 2) show a strong positive response, which is significant given that these are some of the more difficult constructs to integrate into first year courses as well as capstone courses.

Students recognized the economics involved with the project, with strong agreement that their project was either moderately or strongly influenced by economic constraints. Given that students were involved with a poverty alleviation project, nearly 100% agreement with these two statements should be expected. Students also showed strong agreement in the environmental and societal categories. Results for other realistic constraints are also of interest. Manufacturability (97% strong to moderate influence) and sustainability (92% strong to moderate influence) were the two more influential

constraints according to the results of the survey, with economic coming in third. The influence from the political constraint varied by the country chosen, as only 27% of the students indicated their project was strongly to moderately influenced by political constraints, while an additional 45% (for a total of 72%) felt it was just minimally influenced by their selection.

Table 2. Relating to selected societal and related realistic constraints

	Strongly Agree	Agree	Neutral	Disagree
economic context*	27 (30%)	45 (51%)	14 (15%)	3 (3%)
environmental context*	16 (18%)	43 (48%)	25 (28%)	5 (6%)
societal context*	12 (13%)	47 (53%)	24 (27%)	6 (7%)
Realistic constraint:	Strong	Moderate	Minimal	None
economic	58 (65%)	24 (27%)	6 (7%)	1 (1%)
environmental	38 (43%)	38 (43%)	12 (13%)	1 (1%)
social	16 (18%)	44 (49%)	44 (25%)	7 (8%)

(**note: no "strongly disagree" responses*)

Cultural Awareness

Two survey questions that were posed related to cultural awareness:

1. "This project increased my awareness regarding how people are affected by poverty" and
2. "This project increased my knowledge of the culture(s) of another country."

These results (Table 3) may not appear overwhelmingly positive at first glance, as 68% of students agreed that they were made more aware of poverty, and 43% reported an increased cultural awareness. However, it should be noted that typical first-year engineering projects (not necessarily related to poverty alleviation) would not be expected to generate an increased cultural awareness.

Table 3. Relating to the Engineering Profession.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	19 (21%)	42 (47%)	22 (25%)	5 (6%)	1 (1%)
2	6 (7%)	32 (36%)	33 (37%)	15 (17%)	3 (3%)

Further, as one student stated, "I know Third World countries need the most help…,"which indicates that some students may not have experienced an *increased* or *improved* perception due to their project; instead, the project could have supported and reinforced their existing perceptions on poverty and culture.

Qualitative Assessment

Students overall expressed satisfaction for the design aspects of the capstone course. Specific comments on the opportunity to work with a socially-oriented engineering project were also very positive. For example:

- "It was a good experience to see what other people have to deal with on a daily basis. It opened my eyes to how valuable the simple things we take for granted are to them, such as water."
- "In less than ten weeks time, our group met, designed, assembled, and is in the process of testing a functioning prototype. Using the engineering design process, our group successfully engineered a solution to a problem half a world away. Even though our design may never actually be used in Niger, our group has discovered it is a very plausible, less time-consuming method of cooking."
- "I have learned that engineering is more than just sitting in an office crunching numbers and thinking up designs. It is an application of knowledge into worthwhile solutions to better groups of people; possibly the entire world."
- "I believe this was a good topic for the project in that it allowed for us as developing engineering students to see the way in which engineers actually try to help alleviate some of the major problems in the world, such as poverty."

Some students expressed that they initially found the scope of the project overwhelming; however, most of these comments did (correctly) say that the projects were eventually successful:

- "At first, we had no idea what it was we were doing. The most frustrating part of the course was trying to determine the problem that our team was trying to solve. With such a broad topic of 'poverty' it was difficult for us to get a grasp on a single idea. It was only after careful and patient research and re-research that we were able to decide on a viable problem to find a solution for."
- "When the problem was first introduced to us it seemed like we were given 10 weeks to solve the world's problems for $25 as college freshmen. Even though we got through it, the project seemed very daunting at first."

- "My first day in class, I was in shock that we were thrust into such a big responsibility of designing a poverty alleviating device."

Lessons Learned

Although the project was very successful, opportunities for improvement were discussed among the instructors and taken from the qualitative assessment and end-of-quarter course evaluation comments. These included:

- Earlier introduction of contextual concepts: While poverty, societal and global issues were raised, resources could be introduced more systematically earlier in the course sequence; this could be useful as students form their initial design concepts. Dr. Polak's Web site[3], the IEEE Global Water Challenge[4] and similar sites offer excellent online resources for courses prior to the capstone.
- Improved team selection: Teams were intended to be interdisciplinary, but some teams were self-selected, or formed by the students themselves. Future team selection is intended to be driven by software specifically developed to form functional teams, which considers schedule, discipline and other factors.
- More management, fewer lecture periods: The capstone course as implemented had two formal review sessions. One additional formal review session is planned. The formal reviews were an excellent opportunity for formative assessment, and were of great benefit to the students.

The Incorporation of Personas

Personas are detailed descriptions of individual, fictionalized customers often used in software engineering or computer science courses. The customer is pictured, and details about the specific business and the related tasks that characterize a typical person of that persona class are given to encourage the designer to focus on the needs of the customer as an individual. Specific personas include a name and picture of the individual and pictures and descriptions of their housing and lifestyle. Details on their typical day, education and or job are also included. Some needs may be mentioned within the descriptions, but the complete persona illustrates that there are clearly multiple needs for the individual. Personas will be incorporated into the first-year capstone to encourage student teams to focus on the needs of an impoverished individual, both to help make the problem more realistic and to better develop empathy for those for whom the students are designing. By having a persona character to refer to, it is expected that students will be further engaged with the "human side" of engineering due to the literal personification of relevant societal criteria. Further, it is expected that the design will appear to be more open-ended as multiple needs may interact with one another.

The first set of personas are being created with data collected by a civil engineering senior capstone group that has recently traveled to the site of their project in Kenya. They were able to capture sets of pictures of people and their living conditions, along with detailed descriptions of their surroundings, needs, attitudes and societal expectations. Additional personas are being created based on data from other impoverished countries. Although the personas from countries other than Kenya will be based on "second-hand" information, they are intended to be realistic and representative of the society.

Conclusions

The implementation of a first-year engineering capstone project focusing on poverty alleviation as a design construct has been proven to be very successful. Quantitative and qualitative assessment showed that the integration of poverty alleviation was effective in providing an early, "real-world" exposure to many of the realistic constraints outlined in ABET Criterion 3c. Ample evidence was found indicating that students appreciated the opportunity to work through each phase of the engineering design process from proposal to prototype development. The first-year capstone course and the incorporation of the poverty alleviation requirement allowed students to develop or solidify their awareness of how engineers as professionals and engineering as a profession can benefit society. While the project itself was very successful, areas for improvement as documented are planned with the intent of further emphasizing realistic constraints in and societal components of engineering. The experience should help integrate students into their engineering community and inspire them to design for the betterment of mankind.

References

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