AC 2010-197: ADDRESSING THIRD WORLD POVERTY IN FIRST-YEAR ENGINEERING CAPSTONE PROJECTS: INITIAL FINDINGS

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Addressing Third World Poverty in First-Year Engineering Capstone Projects: Initial Findings

Abstract

The ABET Criteria for engineering programs require that students attain specific learning outcomes, including understanding engineering in both a global and social context, and designing within multiple realistic constraints. To address this goal, the College of Engineering at Ohio Northern University has implemented a First-Year Engineering Capstone course featuring a requirement that all projects must involve the design of a poverty alleviation device. Such a device must be geared toward improving lives in a country where at least 40% of the population meet the World Bank's definition of living in either extreme or moderate poverty, earning less than $2 a day. The projects require the student team to follow and document an engineering design process, including regular written reports, oral presentations, and the development of a functional prototype providing proof of concept. Teams were also required to design and present a poster as part of an entrepreneurial "idea pitch" competition. This paper will present the initial evaluation as to the effectiveness of the use of poverty alleviation as a design theme plus recommendations for the improvement of the process.

Introduction

Engineers can make a difference in the lives of others – not just one person at a time, but in the hundreds, thousands, or even millions through the thoughtful development of just a single well-designed project. As engineering educators, one of our roles is to raise awareness of both issues and opportunities. All too often, students arrive at college with visions of designing that which is at the forefront of technology: a faster car, a longer bridge, or a next generation iPod. But what about the over two billion people in the world's population who live on less than $2 a day? Visionaries such as Dr. Paul Polak, author of *Out of Poverty* [1] and a Distinguished Lecturer at the 2008 ASEE Annual Conference, do not see this group as "poor people" but as potential entrepreneurs and customers. Through his work in various Third World countries, Polak has successfully demonstrated that products designed to applicable constraints and combined with local empowerment can have an impact in markedly improving the lives of the less fortunate. Consequently, Polak's ASEE presentation inspired instructors of the first-year engineering courses at Ohio Northern University to undertake, what was to some, a radical redesign of their curriculum: the incorporation of a capstone project focusing on poverty alleviating designs for a Third World country.

First-Year Engineering Curriculum

The first-year engineering curriculum at Ohio Northern University is a year-long (three quarter) sequence. The intent of the sequence is to both introduce students to interdisciplinary topics of importance in engineering and to integrate the students into communities of their peers. The focus of the first course is on teamwork, technical communication, the consideration of engineering criteria and constraints, and an introduction to a formal engineering design process. Technical communication topics include preparation of common engineering documents, such as memoranda and cover letters, and an oral presentation entitled the "One Minute Engineer" [2],

which is similar in format to an elevator speech. Characteristics of entrepreneurship are introduced; these include innovation, creativity, and novel approaches to solving problems. Engineering in a global context is also presented by covering the National Academy of Engineering's Grand Challenges [3] at the beginning of the course. This is built upon at the end of the course through an examination of engineering solutions to problems dealing with water issues; projects discussed were related to both infrastructure needs and methods for sourcing, delivery, and storage of clean water. The design projects for the first course are generally small in scope, focusing more on the design process rather than the design themselves. Among the projects were creating a robot arm out of cardboard, designing a tower of straws [4], and calculating the timing characteristics for an oscillator circuit based on the 555 timer IC. The second course in the sequence builds on the first with more extensive projects and an expanded use of engineering software. Professional skills involve more structured team methods, expansion of technical communication topics (including the preparation of engineering reports), and the documentation of steps taken through the engineering design process. Interdisciplinary team-based projects grow in complexity in this course: projects include the design and testing of a parachute. The final course in the sequence is the First-Year Engineering Capstone design course, which is described in detail in the next section.

First-Year Engineering Capstone Course

Ever since the engineering programs at Ohio Northern University adopted a common first-year engineering sequence, the last course in the sequence has been offered as a capstone course featuring a project where student teams go through all steps of the engineering design process over a ten week period. The course description is as follows:

> A team-based conceptual design project based on the engineering design method: preparation of proposal, generation of design alternatives, consideration of constraints and criteria, selection of design alternative by decision matrix, testing and verification of design by prototyping, and preparation and presentation of design report.

Teams of either three or four students are assigned at the beginning of the quarter and remain together throughout the design, development, construction, and demonstration of the project. Student teams are given the overall theme for their design, along with constraints and grading criteria, via the distribution of a Request for Proposals (RFP) document. An example RFP, used for soliciting the designs presented in this paper, is shown in Figure 1.

Teams are required to follow a real engineering process through their design. Teams develop and present a formal written proposal with a proposed timeline and budget. Once their proposal is accepted, teams document each meeting, building a project notebook. Teams also meet regularly with their supervisor (i.e., their instructor) for formal design reviews. The teams are expected to present themselves professionally, follow a meeting agenda, summarize their progress, present their design notebook, and ask any pertinent questions. It should be noted that questions from the teams are not limited to these meetings: assistance is available during regular class meetings and office hours as with any course. Meeting effectiveness is assessed using a rubric, allowing teams to receive meaningful feedback.

Request for Proposals:
Design of Poverty-Alleviating Devices

Summary

The Other 90 Design, Inc. (TO9D), is a not-for-profit multinational corporation that has as its mission to develop products that will benefit the 90% percent of people on Earth who are poor by helping them out of "absolute poverty", which was defined by the World Bank in 1990 as the earning of an equivalent income of $2 a day or less. TO9D attempts to accomplish this goal through focusing development efforts on products that either allows people to earn their way out of poverty or allow people to spend less time, money and/or effort on the necessities for life. Among the products developed to date are:

- Solar-powered flashlight for nighttime illumination (replacing kerosene lamps)
- Low-cost drip irrigation and water storage systems (for locations with both rainy and dry seasons)
- Donkey carts (for material deliveries in roadless areas)

TO9D is now accepting proposals for new products designed for alleviating poverty in one or more impoverished countries.

Specifications

The proposal must identify a real world poverty situation in a specific nation where at least 40% of the population earns less than $2 a day…

Figure 1. Summary of Request for Proposals.

Teams have to formally demonstrate the functionality of their designs at the end of the quarter. These demonstrations usually involve the presentation of a prototype in action (such as a scale model of a drip irrigation system) or a video presentation if the device is not suitable for use in a classroom (such as a solar cooker). Final demonstration presentations are assessed using multiple rubrics; the effectiveness of the presentation and the technical aspects of the design are assessed both by the instructor and by other students.

The remainder of this paper will focus on two particular modifications made to the First-Year Engineering Capstone course: the specification of a poverty-alleviating device as a design concept, and the effects of the use of an "idea pitch" competition upon the design process.

Incorporation of Third World Poverty Requirement

Over the years there have been a wide variety of project themes used in the First-Year Engineering Capstone course, but few ever really had any purpose other than to serve as a project theme – they were an end unto themselves. Consequently, most of the projects did not provide adequate insights into the purpose of engineering in that the goals of the projects had little, if anything, to do with the improvement of the human condition. The inspiration for moving away from the previous approach occurred as a result of the 2008 ASEE Distinguish

Lecture presentation by Dr. Paul Polak. In his presentation, Polak described how engineering faculties are starting to focus on design-affordable products for the poor. While his emphasis was on promoting this as an avenue for senior- and graduate-level design projects, it was apparent to the author in attendance that there would also be educational opportunities in taking this message to first-year engineering students, by:

- showing how an engineer can effect positive change for thousands, even millions, by designing for those who are impoverished;
- presenting real world examples of the realistic constraints (economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability) listed in ABET EAC Criterion 3c; and
- developing an 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.

Accordingly, a requirement was made for projects in the First-Year Engineering Capstone course to focus on the design of a poverty alleviation device. The use of poverty alleviation as a design theme provides students exposure to real world problems, instead of "problems" that are contrived as an end unto itself. The very nature of poverty – the lack of earning potential and dealing with limited resources – forces consideration of several realistic constraints. Solutions have to be affordable (economic), addressing basic human needs relevant to a particular socio-economic group (social, health & safety). An ideal design would use locally obtainable materials (sustainability) in an environmentally-conscious manner (environmental) that can be assembled from a small number of components by those possessing limited skills and/or tools (manufacturability). Furthermore, these constraints serve to narrow the scope of the project such that it is approachable for a first-year engineering student, as the mass application of modern technology is not a requirement for poverty alleviation. In many cases, a simple, low-tech, well-designed solution will make a considerable positive impact in ways that large-scale, bureaucratically-intensive projects cannot hope to do. So that students would examine these issues, as part of the response to the Request for Proposals teams were asked to not only indentify their proposed design, but to also indicate how their design would be used in the context of addressing the poverty issues of a particular society.

Another benefit of the poverty alleviation requirement is that it provides an interesting introduction to the principles of entrepreneurship. In *Out of Poverty*, Polak details how a grassroots, entrepreneurial approach can help people out of poverty by focusing efforts on unexploited market opportunities through the development of innovative, low-cost tools. Several "win-win" examples are given where locally produced and distributed devices (which provide the builders and distributers an income) allow the purchasers to earn more money through their own efforts. These examples illustrate to students the impact of engineering solutions in global, societal, environmental, and economic contexts, as called for in ABET EAC Criterion 3h. Finally, there is an intangible asset when working on problems that affect those in need, which is perhaps best expressed through a quotation from *Out of Poverty*:

> "Working to alleviate poverty is a lively, exciting field capable of generating new hope and inspiration, not feelings of gloom and doom. Learning the truth about poverty generates disruptive innovations capable of enriching the lives of rich people even more than those of poor people."

So why not energize our first-year engineering students, and let them experience through the design process how each one of them can make a difference in the lives of others who are less fortunate? Granted, the results of a term project conducted by a handful of first-year students will probably not result in an actual product; however, it will expose students to occupational possibilities not yet considered and raise their social consciousness as to the potential services they can render to others through the profession of engineering, thereby reinforcing their decision to become an engineer.

Idea Pitch Competition

In the first-year engineering course sequence, students receive instruction on technical communication topics such as the preparation of engineering memoranda, letters, and proposals. Additionally, they receive instruction on effective oral presentation skills. A requirement added to the capstone course was that, during the developmental phase of the design process, each team had to develop and present a poster detailing the basic ideas and concepts of their design. Research posters and poster presentations are not common technical communication vehicles within first-year engineering programs; possible reasons include the lack of a suitable printer, the expensive cost of media, and not having an appropriate venue for presentation. However, during the spring quarter the first-year engineering students at Ohio Northern University were invited to participate in an interdisciplinary, university-wide "idea pitch" poster competition, offering an ideal opportunity to discuss poster presentations as a communication mechanism. Students were given one lecture period of instruction on poster layout, including design, text sizes, and the inclusion of graphics. Some of the instructions given for poster design are presented in Figure 2.

Designing the Poster

You will design a 36" by 48" poster which will be printed for you by the college.

1) Create a document in PowerPoint. ("PDFpen" can be used on Macs. Microsoft Publisher was not able to scale the poster appropriately. If you are using Adobe Illustrator, avoid the "autotrace" tool.)
2) In PowerPoint, select Design-Page Setup-Slides Sized For-Custom. Then enter 36" by 48". This is also where you can select Portrait or Landscape.
   a. The printer cannot print within 0.5" of the edge of the paper.
   b. Note: it is important to set the paper size before beginning to design the poster
3) Your poster should use pictures with at least 150 dpi and up to 300 dpi resolution for sharp photos.
4) Proof your document on a regular printer first. You can print a reduced version of the poster by selecting the printer option "Scale to Fit". Check for spelling errors!

Figure 2. Poster design specifications.

For student edification, poor design practices were also discussed and in some cases illustrated, including ineffective layouts, excessive text, pixilation of graphical images, inadequate font size, and avoiding the use of graphics, color schemes and/or backgrounds that detract from the message. To prevent costly mistakes from occurring, draft posters were printed on regular-sized paper and presented to the instructor for prior review and approval before final printing on one of the poster printers in the College of Engineering.

Through use of the "One-Minute Engineer," students in the first-year engineering sequence already have had prior experience with the preparation and presentation of an elevator speech [5]; this experience was very helpful in discussing the concept of presentation in a poster session. Discussions on delivering the main point of a presentation with an appropriate amount of enthusiasm and professionalism, the handing of questions, and the expectations from the judges were covered in class. The venue for the "idea pitch" presentations was the Student Poster Competition, part of the Extreme Entrepreneurship Tour (EET) which visited campus in 2009 during the fourth week of the spring term. The EET was a campus-wide event sponsored by the Kern Family Foundation through the Kern Entrepreneurship Education Network, meant to promote key concepts of entrepreneurship into the curriculum at all levels. The poster competition was open to all students from any major. Posters could be entered in one of the following judging categories:

- Ideas that improve society [for anywhere in the world].
- Ideas that improve healthcare [for any group of humans on the planet].
- Ideas that use technology to create new processes or products that improve our lives.
- Ideas that create new businesses in West Central Ohio and therefore jobs in this region.

Each team specified what they considered to be the appropriate track for their project. The requirement for first-year engineering capstone designs to address Third World poverty alleviation eliminated the "new businesses" track, so the first-year engineering students were essentially restricted to the first three of the aforementioned categories.

Prior to the competition, students were given a copy of the judging rubric to be used and the use of the rubric was discussed. The main categories within the judging rubric were as follows, with appropriate criteria for judges to award a score in one of five performance criteria levels in each area:

1. How well does the pitch/poster articulate a specific problem or unmet need and identify the customer/potential customer?
2. How unique and viable is the proposed solution in addressing the identified need? How well researched is the idea for the profit or non-profit business activity?
3. How effectively and passionately does the presenter articulate the problem, solution and call to action?
4. How effective or accomplished are the speaker's skills? How well designed and presented is the poster? How well is the Q/A handled?

At the competition, posters were displayed for judging during a two hour period. Each team designated who would exhibit their poster during this period. Judges included both faculty from

across the University and external industry partners. Judges were instructed to spend approximately 10 minutes with each poster; during that time, they listened to the presentation and asked leading questions to encourage the presenters to justify and expand on their proposals. It is important to note that teams prepared their posters and presentation very early in the term; accordingly, the designs presented at the poster competition were very much in the preliminary stages. The competition therefore provided a very important service for the teams as a formative assessment tool with near instantaneous feedback. As a consequence of the "idea pitch" competition, many of the teams implemented significant modifications in their designs.

Example Poverty-Alleviating Design Posters

Two of the posters presented by first-year engineering capstone teams received first place awards within their respective divisions; both of these posters are featured in this section.

The first poster, entitled "Thirst for Life", received the first place award in the "Ideas that use technology to improve our lives" category. In their poster, shown in Figure 3, the team makes a strong case for the need for their proposed low-cost water filtration system.

Figure 3. Poster from "Thirst for Life" design group.

A second example, shown in Figure 4, was selected as the winner in the "Ideas that improve society" category. This team also built a strong argument for the need of a simple device; in this case, a solar-powered device useful for both cooking and the purification of water. At the competition, it was evident that this group had performed a significant amount of development compared to other groups: their device was well specified, and they had a significant amount of data to test with their upcoming prototype.

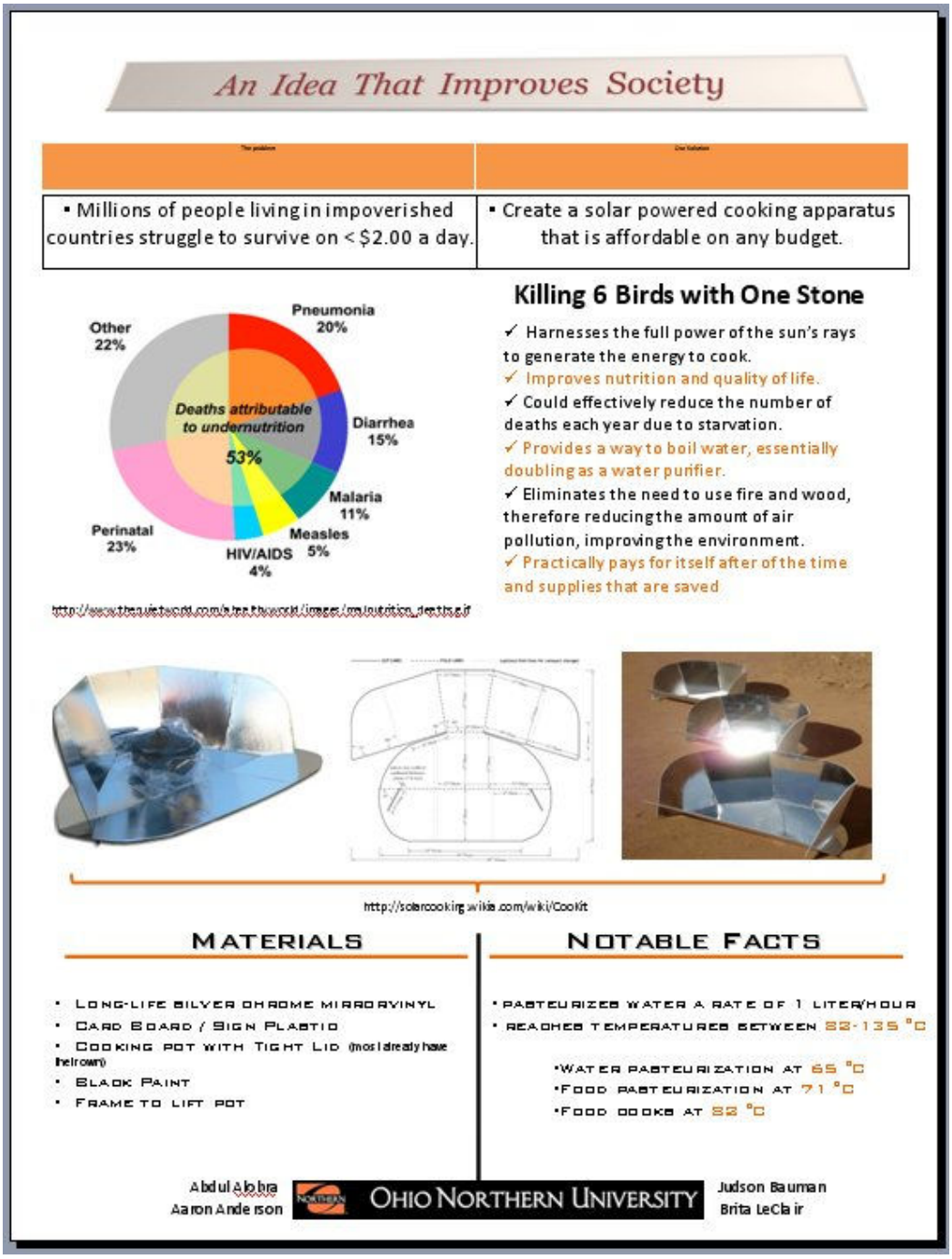

Figure 4. Poster for a proposed solar cooker.
(Portions of the text have been enlarged for the purposes of illustration in this paper.)

Formative Assessment: Results from the Idea Pitch Competition

Each team's poster and presentation was evaluated by at least three judges, and the resultant scores were averaged to determine the winners within each of the categories; in the event of a tie, multiple prizes were awarded. The results for the categories involving teams of first-year engineering capstone students are shown in Table 1.

Table 1. Total numbers of entries and prizes awarded.
(FYE: First-Year Engineering)

Track 1: Ideas that improve society			
Total entries	FYE entries	Total awarded prizes	Total FYE awarded prizes
11	5	5	4
Track 2: Ideas that improve healthcare			
Total entries	FYE entries	Total awarded prizes	Total FYE awarded prizes
8	4	4	2
Track 3: Ideas that use technology to create new processes or products that improve our lives			
Total entries	FYE entries	Total awarded prizes	Total FYE awarded prizes
21	9	4	2

As seen in Table 1, teams from the first-year engineering capstone course comprised 18 of the 40 overall entries within the three applicable areas, won eight of the 13 awards, and as previously mentioned, received two out of the three first place awards available to them. This is especially noteworthy since the first-year engineering students completed predominantly against teams comprised of upper-class business and pharmacy majors.

At the end of the course, a survey designed to collect both quantitative and qualitative data was administered to the 109 students enrolled in the course. Part of this survey involved the summative assessment of the "idea pitch" competition. Table 2 provides the results of the question, "Preparing a poster as a means to communicate our solution was a valuable experience."

Table 2. Responses to "Preparing a poster as a means to communicate our solution was a valuable experience."

Section	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	7	18	3	0	0
2	4	10	4	0	0
3	3	15	4	2	0
4	1	4	3	9	2
Total	**15**	**47**	**14**	**11**	**2**

The quantitative feedback shows that, overall, 62 of 89 (70% of respondents) selected “agree” to “strongly agree”, indicating that students found the poster session to be valuable. Notably, students in one section tended to disagree more than the students in the other three sections. If the results from section 4 are discounted, the student responses from the other three sections showed 57 of 70 (81%) selected “agree” to “strongly agree”.

For further assessment, qualitative, open-ended comments were sought as part of the survey. Two applicable comments are below:

- "In the idea pitch competition, our team took second place and earned $50. The group also had a few people offer to take further looks at the idea and even wanted to talk about helping out with funding."
- "The best part that the most was learned from was the poster contest. Here the group got to meet up with actual investors and take questions from people who knew what they were talking about and what they were looking for to better society. This is where the group's idea was finally finished and, once leaving that competition, we had many new ideas and ways to improve our final product."

The informal observations of the authors are that student teams generally found the preparation of the posters to be time consuming, and that teams sought confirmation more with this activity than with any other; for example, students more often asked “Is this right?” of their instructors through this process than at any other time in the course. The assumption is that this was due to students having little to no prior experience preparing research posters. After the competition, students generally reflected that they wished they had been more organized, but now that the expectations were known, it would be more straightforward if they had to repeat the process. Many teams described that they were surprised by both the quality and quantity of feedback and suggestions they received on account of their presentation. Specifically, the “Thirst for Life” team and a few others proposing similar approaches to filtration reported receiving valuable advice from judges who either had experience with such systems or knowledge of specific materials to use in the system. The received feedback was incorporated by many of the teams into their final designs. This activity was judged by the course instructors to be so successful that, in the event that the Idea Pitch competition through EET is not available in the future, a presentation venue utilizing a similar format will be created, with engineering instructors and college Industrial Advisory Board members serving as judges.

Summative Assessment

As previously mentioned, summative assessment was conducted through a survey administered to the 109 students enrolled in the course during the final week of the term. The quantitative portion of the post-activity survey consisted of 10 Likert-scale questions (Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree) and eight questions on the influence of each of the realistic constraints (as defined in ABET EAC Criterion 3c) on the project. The responses to the survey are grouped into appropriate conceptual areas as listed below.

1. Overall awareness regarding the engineering profession:

Two questions asked for each student's perception of the activity contributing to their awareness of the engineering profession as an overriding construct. Specifically, the survey queries were:

- "This project provided me with insight as to what it is like to be an engineer," and
- "This project reinforced my decision to become an engineer."

One additional question asked students to report on their awareness of the application of engineering to society as supported by their projects:

- "The project I worked on allowed me to apply the engineering design method to a real world problem."

The survey results for these questions are shown in Table 3.

Table 3. Overall awareness of the engineering profession.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Insight into being an engineer	33 (37%)	47 (53%)	9 (10%)	0 (0%)	0 (0%)
Reinforced decision to be an engineer	26 (29%)	48 (54%)	13 (15%)	2 (2%)	0 (0%)
Apply engineering to real world problems	39 (44%)	47 (59%)	3 (4%)	0 (0%)	0 (0%)

Students agreed that the poverty alleviation project provided them with insight regarding what it is like to be an engineer, with 90% in agreement, and none in disagreement with the statement. Furthermore, the project supported their decision to become engineers, with 83% of students responding with either "strongly agree" or "agree" to the statement, and only 2% in disagreement. Finally, 96% of the responses supported the statement that the project allowed them to apply an engineering design method to a real world problem, with none in disagreement. These response patterns are not necessarily surprising, as ample evidence exists that the integration of real world design problems into the curriculum is beneficial to an appreciation for engineering.

2. Applications and impact of engineering to society:

The survey also presented specific questions for obtaining the student's perception on their solutions based on both their contextual impacts and with respect to specific realistic constraints. For each set of questions, the 5-point Likert scale question is presented first, followed by the corresponding 4-point "degree of affectedness" scale question.

- "I learned about the impact of engineering solutions in an economic context."
    - "Please indicate the degree to which your project was influenced or affected by the following realistic constraints: economic"
- "I learned about the impact of engineering solutions in an environmental context."

    - "Please indicate the degree to which your project was influenced or affected by the following realistic constraints: environmental"
- "I learned about the impact of engineering solutions in a societal context."
    - "Please indicate the degree to which your project was influenced or affected by the following realistic constraints: social"

Student responses to these sets of questions are presented in Table 4.

Table 4. Relation of project to specific contextual impacts and realistic constraints.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Engineering solutions in an economic context	27 (30%)	45 (51%)	14 (15%)	3 (3%)	0 (0%)
Engineering solutions in an environmental context	16 (18%)	43 (48%)	25 (28%)	5 (6%)	0 (0%)
Engineering solutions in an societal context	12 (13%)	47 (53%)	24 (27%)	6 (7%)	0 (0%)
	Strongly	Moderately	Minimally	None	
Affected by the realistic constraint: economic	58 (65%)	24 (27%)	6 (7%)	1 (1%)	
Affected by the realistic constraint: environmental	38 (43%)	38 (43%)	12 (13%)	1 (1%)	
Affected by the realistic constraint: social	16 (18%)	44 (49%)	44 (25%)	7 (8%)	

The results show a strongly positive response toward some of the traditionally more difficult concepts to incorporate into first-year programs. Most students correctly recognized the economic factors involved with the project, with 81% agreeing that the solution contained an economic context and 92% agreeing that their project was either moderately or strongly influenced by economic constraints. However, given that students were involved with a poverty alleviation project and were charged to design a device that would be affordable for an impoverish person, ideally there should be 100% agreement with these two statements.

Among those constraints for which the incorporation of poverty alleviation was hoped to influence besides economic were environmental and societal. Success in these areas was also shown by the strong student response evidenced in Table 4. In the environmental category, 66% agreed that there was an environmental context while 86% agreed that their project was influenced by environmental constraints. For societal concerns, 66% agreed that there was a societal context to their design while 67% agreed that their project was influenced by social constraints. The results for some of the 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.

As one of the goals of the use of poverty alleviation was to raise societal and cultural awareness, the following questions were posed, with the results presented in Table 5:

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

Table 5. Societal and cultural awareness.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Awareness of people in poverty	19 (21%)	42 (47%)	22 (25%)	5 (6%)	1 (1%)
Increased cultural knowledge	6 (7%)	32 (36%)	33 (37%)	15 (17%)	3 (3%)

These results may not appear overwhelmingly positive at first glance, as just 68% of students agreed that they were made more aware of poverty, and only 43% reported an increased cultural awareness. However, it should be noted that typical first-year engineering projects, which are not structured as these were, would not have generated any increased awareness. Furthermore, some students may not have experienced an increased or improved perception because the project supported and reinforced their existing perceptions on poverty and culture, as evidenced by one student's comment of "I know Third World countries need the most help…"

Two forms of qualitative summative assessment were conducted. First, in the aforementioned survey, several "open response"-type questions were posed to the students, including a request for comments regarding having projects based on the design of poverty-alleviating devices. The second qualitative assessment tool was a reflective essay assignment given in one of the sections. For the essay, students were instructed to reflect upon the following points:

- the individual contributions made to the team effort,
- the skills found to be most useful in completing the project,
- the most rewarding aspect of the course,
- the most frustrating aspect of the course, and
- suggestions for improving the overall experience in future offerings of the course.

Collectively, the students noted in their responses a considerable number of strengths. There was great appreciation shown for having the opportunity to work on a single project for an entire term, as it reinforced previous instruction regarding the engineering design process. Some of the student comments include:

- "It is one thing to sit in a class and learn about the design process, but it was a very rewarding experience to go out and be able to implement the things we learned in class. It was also a great learning experience to work with one group for a very big project throughout the entire quarter."
- "It really gave me a good perspective on what an engineer does and how they go about it."
- "It helped to familiarize myself with one group of people and it gave a greater amount of time for each of us to work together. By giving us this large amount of time on one project, we were able to use each individual's skills and techniques to enhance our group work."
- "The most beneficial aspect was the knowledge of what goes into doing a design project. I was under the impression it was easier, and there were not as many constraints, and that it was mostly design and inventing. It is quite evident now that it is a lot of extra work aside from those tasks."
- "For the past two quarters we have learned about, seen examples, and practiced only sections of the engineering design process. This quarter we actually went through every step individually and used each step in a real world application."
- "I felt a sense of pride upon the completion of our design. It was thrilling to start out with nothing but an idea and have it form into a complete working scale model."

Additionally, there were students who appreciated the opportunity to work on a socially-oriented project such as Third World poverty alleviation, not only for the relevancy of the work but for other, more insightful, reasons:

- "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."
- "It helps to maybe inspire people to continue developing products that make this world a better place for people who are not as fortunate to have as much money."
- "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."

Another observed benefit was that students felt that they learned about what it is like to be an engineer:

- "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."
- "It was important for us to see what all entails in a full design project. It really gave me a good perspective on what an engineer does and how they go about it."
- "This course was very rewarding in that I learned a great deal about how the engineering design process is implemented in everyday life and in the business world. This gave me

a window into the future so I can better know what to expect once I am a part of the engineering profession."
- "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."

Teamwork education is an integral part of the first-year engineering experience at Ohio Northern University; accordingly, many students appreciated having a full-fledged project to apply the principles covered through previous coursework:

- "I would consider teamwork to be the most rewarding aspect of the course. Working in a team can be very challenging at times. Learning to work well in teams that were assigned at random is something that is essential to learn for our careers in the future."
- "My most rewarding aspect throughout the quarter would have to be between the interactions with my fellow students, seeing our prototype actually prove its concept, and using knowledge from the year to accomplish our goals. After two quarters of limited student involvement, finally getting to work in a group setting for more than a week was extremely rewarding to me."
- "I have learned how surprisingly hard it is to work as a team to come to a solution."
- "Another way that the course has helped me grow is by forcing me to become a better leader by getting a group of four people to work together effectively on one goal."
- "This project also helped better my understanding of the dynamics of an engineering team."

A couple of students also made observations regarding the constraints involved with this project:

- "It was a brilliant way to make sure the students didn't spend too much money on designing their prototype."
- "This provided a good feel for what it is like working with a crucial constraint of not having much money."

While there were many positive comments, other students expressed various levels of dissatisfaction and frustration with designing a poverty-alleviating device as the focus of their first-year engineering capstone project. One of the major criticisms expressed was based on the premise that first-year engineering students are not capable of working on actual design projects, as they lacked a sufficient engineering background to develop an adequate design. Others felt that there was an insufficient amount of time to accomplish the task. These objections were anticipated by the faculty teaching this course, and an attempt was made to address these issues in that the process - not the product, which only had to be developed to the “proof-of-concept” stage - was what was being stressed. Although it was explained at the beginning of the course, and reinforced throughout the term, that there was no expectation that an actual marketable device would be designed, unfortunately some students took the assignment literally:

- "As freshmen with little to no actual engineering experience, it is not very practical for us to design something that will help alleviate poverty."

- "It is very difficult to design a device and have it working in less than 10 weeks. We were unprepared."
- "How are a bunch of freshmen in college going to create something that a senior engineer that has been in the business for more than twenty years not think of? How are we supposed to make a design better than someone who does this sort of thing for a living?"

Other students found themselves overwhelmed by the scope of the proposed project. This, in large measure, was the fault of the instructors, as steps could have been taken to place additional constraints on the design or to provide additional information and resources for the teams. However, it was decided, rightfully or wrongfully, at the beginning of this project to provide only the bare minimum to get projects started. While some students appreciated having the resultant flexibility of choosing their project, others were not as happy:

- "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."
- "It is such a broad and overwhelming topic that I feel that most of the students including myself missed your intended message. It was just so overwhelming to choose one project from the literally infinite number of projects that I believe most groups simply chose the 'easiest' idea just to get it done."

An additional cause for concern was that some students had difficulty relating to the problem of Third World poverty. The vast majority of engineering students attending Ohio Northern University come from in-state, middle-class households, and so have little, if any, personal experience either with experiencing poverty or with seeing the effects of poverty upon others:

- "I wish we had a little more time or assistance in seeing what real needs others had."
- "I know Third World countries need the most help, but for me it was hard to relate to these people and their needs, compared to designing a product for middle class Americans."

Some students had difficulty with the open-endedness of the project. At one extreme, a student suggested that the faculty should select the projects and randomly assign them to the teams. Others decried what they perceived as a lack of guidance in approaching the problem statement:

- "I wish that we had more guidance in the beginning in selecting a project other than being told to build something that will help someone in poverty that has to cost less than $5."
- "I felt as if this basis was too vague. It was extremely vast and made me feel as if I was not actually helping."

- "I thought it was a good idea that opened a lot of possibilities. However, having given options would have helped because it seemed that most people did something with water, and that is not the only problem that is affecting people living in developing countries."

Probably the largest problem encountered was with scheduling conflicts throughout the term amongst team members. Teams were constructed primarily at random, although there were attempts made to have at least one member from each of the engineering programs at Ohio Northern University represented on each team to insure an academically-diverse background; given the common first-year curriculum, this was not perceived as being a problem. However, the course faculty failed to consider such items as athletic practices, work study, and similar extracurricular activities as potential conflicts. Some of the comments received were the following:

- "It was exceptionally difficult and annoying trying to find time to meet with all of our group members. I feel that this could be improved through the use of a survey at the beginning of the course."
- "A major issue was trying to get everyone to the same meeting. Schedules seemed to clash and made it seemingly impossible to all be there at the same time."
- "I realized how important scheduling and time management could be."

Overall, while there were some areas where students expressed displeasure or raised concerns, most of the student feedback was positive. Probably the best student quote that captures the essence of what the authors were trying to accomplish is the following:

> "I think poverty-alleviating devices was an excellent choice as our designs. It is easy to get distracted by high tech devices and impressive designs in engineering. Most people forget that the application of an engineer's skills at a very low level can solve a problem plaguing millions or even billions of people. With the skills we had freshman year, we were able to design a working solution to provide clean drinking water; if more engineers were working on cheap solutions to basic problems, I believe extreme poverty could be eliminated, and that is an important thing to keep in mind in my career."

Proposed Revisions and Initiatives

The instructors of the First-Year Engineering Capstone course found the new approach to be satisfactory; however, no one ever gets things 100% right the first time. Based on the evaluation of student assessment materials, qualitative feedback from the distributed surveys, and personal observations, the following list of proposed revisions and new initiatives were developed for future offerings of the First-Year Engineering Capstone course.

1. *Earlier Introduction of Contextual Concepts.* In retrospect, the instructors felt that they should have "primed the pump" by introducing some of the ABET EAC Criterion 3h contextual concepts earlier in the first-year curriculum, along with appropriate exercises and the possible inclusion of a simple design project. Paul Polak's web site [6] includes a variety of resources, such as videos, suitable for classroom presentation and discussion.

2. *Project Selection*. Some students rightly pointed out in their survey responses that approximately half of the projects were water-related. Accordingly, there was a perceived lack of diversity present within the sections. Another lack of diversity was noted by one of the instructors: all but one of the countries selected were from sub-Saharan Africa, with some countries such as Kenya being selected multiple times. Poverty is everywhere and its alleviation involves more than just developing potable water supplies. One possible revision is to modify the selection of projects by requiring teams to select their country via a random draw. In this way there would be a greater diversification of countries being represented. To assist students teams with their research, each country represented in the random draw could also have a list of possible poverty alleviation areas to provide a suitable "jump start" to the project selection process.

3. *Team Selection.* The most frequently specified problem by the students had nothing to do with the project but with their teammates in that, for many groups, the variety of student schedules left for little common time available for collaboratively working on their projects. To address this problem, the instructors will select teams primarily on schedule compatibility. Fortunately, this can be easily accomplished through use of the Team-Maker application [7], which is distributed alongside its sister application, The Comprehensive Assessment of Team Member Effectiveness (CATME). These applications, which collectively was one of the recipients of the 2009 Premier Courseware Award, was developed to first form balanced teams based on instructor-supplied criteria, then use peer and self evaluations to assess how effectively each student individually contributes to the team. Collectively, CATME/Team-Maker provides tools appropriate to the task of organizing and managing a collection of student teams, which should at least alleviate the observed scheduling problems.

4. *Persona Development.* The design projects selected by the teams suffered from a lack of interaction with, and superficial knowledge of, those for whom the students were designing. There is the need to somehow make a connection between each design team and those for whom they are designing, but to do so in a fiscally prudent and viable manner. At some institutions, there is a chapter of "Engineers Without Borders" (EWB), whose members perform service work akin to that done through similar, more well-known organizations such as Habitat for Humanity. In their 2009 ASEE paper, Jaeger and LaRochelle [8] presented a wealth of data in support of the benefits of student EWB involvement, including a greater appreciation for other cultures, a stronger appreciation for teamwork, and an increased awareness of the role of ethics and personal responsibility in engineering. The development of EWB-derived in-class presentations and projects could provide a significant portion of the benefits mentioned in this paper to first-year engineering students. One potential methodology currently being developed is the creation and use of personas. Personas are fictitious characters created to represent the goals and behaviors of a particular demographic of interest. A persona is usually presented as a one- or two-page description that includes appropriate background information regarding a "typical" member of the targeted demographic along with a few fictional personal details to make the persona appear to be a realistic, believable character. Personas have been successfully used in fields such as marketing and user interface design, as they constitute effective "test platforms" for guiding decisions about a product, such as features, interactions, and visual design. The legwork involved with the creation of personas can be performed by students out in the field serving

on EWB – or similar – projects through interviews, observations, and photography. While Ohio Northern University does not have an EWB chapter, during the winter of 2009-2010, three ONU civil engineering students traveled to Kenya as part of a service mission and volunteered to gather relevant information, including photos and video, that would allow the creation of one or more persona prototypes. These prototypes will be evaluated and, if deemed successful, an attempt will be made to partner with other institutions for the development of persona sets for other countries.

5. *More Management, Fewer Lectures.* One suggestion made by students was a plea for additional team meetings with the instructor. Under previous offerings of this capstone course, teams would meet individually with the instructor at two specified times over the term; in comparison, senior design teams at the authors' institution conduct weekly meetings with their advisor. To accommodate this request, the course schedule was redesigned to allow for at least one additional group meeting. It is believed that an increase in the frequency of meetings will be of assistance by providing more frequent guidance for each team as they progress through their first meaningful complete design experience.

Conclusions

The implementation of a first-year engineering capstone course focusing on poverty alleviation as a design construct has been proven to be successful. Quantitative assessment indicated that the use of this particular design topic was effective in providing an early, "real world" exposure to many of the realistic constraints outlined in ABET EAC Criterion 3c and the contextual impacts of engineering solutions outlined in ABET EAC Criterion 3h. The assessment tools also furnished ample evidence that students were appreciative of the opportunity to progress through all of the phases of the engineering design process, thereby providing insight into the profession and reinforcing their decision to pursue a career in engineering. The development and presentation of a poster at the Idea Pitch competition provided additional benefits – beyond the practice of technical communication skills – by serving as a vehicle for formative assessment of their design with immediate feedback being offered. Through this course, students also developed an increased awareness of how engineers can positively impact society. Finally, areas for additional research, development, and modification were successfully identified through the evaluation of assessment data, providing opportunities for the further improvement of this pedagogical approach.

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