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Insights Gained from the First Teaching of a Multidisciplinary Appropriate Technology Course

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Insights Gained from the First Teaching of a Multidisciplinary, *Appropriate Technology* Course

Abstract
Our students are becoming more interested in developing skills that allow them to be global engineers. In addition, some faculty have personal desires to make a difference in developing countries and see such opportunities as beneficial to the growth of their students. Presently, organizations such as Engineers Without Borders (EWB) provide opportunities to students. However, many students are unaware of these or are busy with classwork or are building their resumes in other ways. The addition of an elective course focused on such work can open these opportunities to all students.

To address this need, an Appropriate Technology course was designed to explore both the technical and humanitarian prowess necessary to positively increase quality of life and promote innovation in the developing world. Our goal was to prepare students to effectively participate in humanitarian work in developing countries.

The course was designed to encompass the topics of most urgency in developing countries including water treatment and infrastructure, sanitation and energy. The course was taught by three faculty members and a consulting engineer. The expertise of the faculty spanned civil and environmental engineering, mechanical engineering, and electrical engineering. In addition, each faculty member had some limited amount of experience overseas. The consulting engineer had extensive experience with EWB teams and in developing engineering solutions worldwide.

The concept of “Do No Harm” was woven throughout the course by exposing students to international case studies. One class per week was dedicated to considering success of humanitarian engineering projects and the unfortunate frequency of failed – though well-intended – projects. Assignments forced the students to reflect upon positives and negatives and incorporate the best in their plans. Additionally, the students were challenged to develop a design and prototype to transport water from a creek on campus considering appropriateness and sustainability in their designs.

We measured our effectiveness in teaching the “Do No Harm” concept and engineering in the context of the developing world. We evaluated our success using evaluations and course surveys. We were particularly interested in gauging changes in students’ perceptions about the impact engineers can have in working with developing communities. The outcomes from our experience and assessment can serve as a reference to other instructors considering incorporating appropriate technology into new or existing courses to suit student, instructor and institute interests.

Introduction
Many students are motivated to learn when faced with real and difficult problems such as those rooted in the developing world. Some faculty have personal desires to make a difference in developing countries and see such opportunities as beneficial to the growth of their students. While there are some occasions for students to work with developing communities through

organizations such as Engineers Without Borders (EWB), for various reasons many students are unable to participate.

To capture the motivations and learning opportunities that engineering design in the context of developing communities presents, an "Appropriate Technology for Developing Communities" course at Rose-Hulman Institute of Technology (RHIT) was developed in the summer of 2015 and implemented in the fall of 2015. Appropriate technology is defined as a "technology that is suitable to the social and economic conditions of the geographic area in which it is to be applied, is environmentally sound, and promotes self-sufficiency on the part of those using it."[1] The creation and execution of a course focused on sustainable (or appropriate) technology for the developing world with a multidisciplinary scope provided a unique opportunity for students to consider the practice of successful engineering in the developing world from an engineers' perspective. Other courses exist at RHIT that consider sustainability, but there are not many that are designated as engineering technical electives, and none that focus on application for developing communities.

Background

While this course might be the first of its kind at RHIT, courses with a bent towards or an outright focus on humanitarian development, service learning, or appropriate technology have been developed and implemented in a multitude of ways at many institutions. The University of Colorado-Boulder has been a model for integrating humanitarian engineering into engineering education by notably founding EWB and creating courses and research programs around the technical service organization[7]. Several institutions including Rice University, University of Colorado-Boulder, and the University of Wisconsin-Madison have created courses and programs to address the topic of sustainability due to EWB undertakings at their universities. EWB projects have also inspired and lead to senior design projects at many universities including the University of Colorado-Boulder, the University of Arizona, and Lafayette College[2-4]. Additionally there are many certificates and programs that integrate appropriate technology for developing communities into entire programs. Michigan Technological University is a prime example with their Master's Degree in Engineering for Developing Communities and Peace Corps program.[5] The Ohio State University has not only developed specific certificate programs, but has also been a leader in integrating humanitarian engineering throughout curricula in courses, labs, capstone experiences, a minor and an M.S. program.[6]

Most of these programs describe the lessons learned as mostly positive for both students and instructors. Some of the benefits described in the references include helping to improve diversity, retention and critical thinking[2-6], as well as helping to develop an ethical obligation to equip current student-engineers with the necessary tools for addressing engineering challenges at the global level[7]. Codes of Ethics for major engineering organizations point towards such obligations. Specifically, the National Society of Professional Engineers (NSPE) states as one of the Fundamental Canons that "Engineers…shall: Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession".[8] In an ever-global world, engineers must be – and our students are interested in being – prepared to practice engineering in a variety of contexts. Finally, in terms of teaching humanitarian engineering by teaching both technological approaches and social considerations, the "precautionary principle", a guideline for environmental policy making, can lend credence to the attitude required for successful projects. Similar to the physician's commitment to "Do No Harm"[9], the precautionary principle should protect human and environmental health even if uncertainty exists.[10] Encouraged by the benefits of the integration of humanitarian engineering in other programs, the ability and success of such undertakings, and the obligation we have as engineers to be responsible, ethical and "Do No Harm", we developed and implemented a course designed to allow students to participate effectively as engineers in solving problems in developing communities.

Course goals

The course was designed to explore both the technical and humanitarian problem solving skills necessary to positively increase quality of life and promote innovation in developing countries. As a result of this course, we wanted students to be able to consider the appropriateness of technologies for the developing world, as well as be able to reason out solutions for a variety of different types of engineering problems. Our overall goal was to prepare students to effectively participate in humanitarian work in developing countries.

Course demographics and specifics

Eighteen students in their sophomore (4/18), junior (3/18), senior (11/18) years majoring in electrical (7/18), computer (4/18) mechanical (3/18), biomedical (3/18) and civil (1/18) engineering were enrolled in the course. The course was housed within the Electrical and Computer Engineering (ECE) Department (course number: ECE398). Thirty-three percent of the students were female, which is 11% greater than the 22% at the institute level; and three percent were international, which is 9% less than the 12% at the institute level. There were no major restrictions, though at RHIT there are only engineering majors. With calculus III and physics II as prerequisites, the course was developed for sophomores from any major. These prerequisites for a fall term offering excluded freshmen unless they were very advanced. However, the majority of the students enrolled in the course were upperclassmen (61% seniors, 78% juniors and seniors). Students could take the course as a technical elective which would fulfill the two to three technical electives required within the various engineering curricula.

Course structure and approach

The course was designed to encompass the topics of most urgency in developing countries including water treatment, sanitation, agriculture, energy, communication and transportation. Table 1 specifies the general and weekly topics covered in the 10 week term. The course was taught by three faculty members and a consulting engineer. The topics were divided among the faculty although the course was very much team taught: all instructors attended all classes and added to class discussions as appropriate. The expertise of the faculty spanned civil and environmental engineering, mechanical engineering, and electrical engineering. In addition, each faculty member had some limited amount of experience overseas in developing communities. The consulting engineer presented material and added to course discussion mostly for the water, sanitation and agriculture topics. However, with his extensive experience with EWB and international consulting, he added to discussions throughout the course. Lucena, Schneider, and Leydens' book, *Engineering and Sustainable Community Development* was selected as the course textbook.

Table 1. Topics covered in the Appropriate Technology course.

Week	General Topic	Weekly Topics
0	Do No Harm	Introduction, Do No Harm, Appropriateness
1	Water	Sources, Contamination, Household-scale treatment
2		Community-scale treatment, Distribution, Pumping
3	Sanitation	Wastewater treatment, Solid waste
4	Agriculture	Irrigation, Pumping, Food preservation
5		Stoves and ovens, Building materials
6	Energy	Photovoltaic cells, Batteries
7		Solar thermal, Hydroelectric power
8		Wind power, Lighting
9	Communication	Radio, Cell repeaters
10	Transportation	Basic utility vehicles, Bicycles

To integrate humanitarian considerations into the design of engineering solutions, the concept of "Do No Harm" was woven throughout the course by exposing students to international case studies with reflective exercises. One class per week was dedicated to considering the success of humanitarian engineering projects and the unfortunate frequency of failed – though well-intended – projects. These case studies highlighted possible cultural, lingual, experiential and educational differences between the community members and outside engineers. Many of the case studies described how political situations, minority status, physical location, and resource availability further complicate implementation of technological solutions. Care was taken to weave the "Do No Harm" concept through all topics and activities throughout the course. Intentional repetition and reflection allowed students to fully explore both the positive and negative human impacts of engineering. We wanted to emphasize that while the non-technical aspects of development are not as easily defined, nor comfortable, for student engineers[11], their consideration is crucial. We wanted our students to not only identify as problem solvers with technical expertise, but as engineers who can develop – in collaboration with community members – sustainable, nuanced, holistic solutions to real problems.

To provide practice towards achieving these goals, in-class discussions, homework assignments, exams, and a final project required students to reflect upon positives and negatives of technological solutions to developing community problems. For example, when introducing the topic of water treatment, students were asked, "What are potential benefits of improving drinking water sources?" and subsequently, "What are the potential negatives of improving drinking water sources?". Lively class discussions seriously considered these questions. As follow up, students were asked on a homework assignment to "explain three benefits that you deem most important and why, and potential consequences that could undermine them" in the context of improving drinking water sources.

In their capstone experience, five multidisciplinary teams of three (4/5) or four (1/5) students, self-selected, were challenged to design and prototype a means to transport water from a creek on campus. Teams were constrained by a requirement to pump water three feet above the creek bank elevation on a $150 budget. The teams were encouraged to minimize cost and time to fill a five gallon bucket while maximizing ease of use and robustness of materials. The teams were evaluated on these items as described in Table 2. To add a competitive flair to the challenge, teams were contesting for the lowest cost per flow in final demonstrations.

Table 2. Grading rubric for final presentations / demonstrations / final memo submittal for course project. Percentage breakdowns for each project component were out of 100%.

Final Project Components	Items being Evaluated	%
Presentation	Progress	40
	Communication	30
	Technical Understanding / Question Handling	30
Demonstration	Quality / Durability	40
	Performance (Flow rate at 3 ft above bank elevation)	30
	Practicality / Appropriateness	30
Final Memo	Reflection on demonstration: suggested improvements	30
	Overall lessons learned	40
	Budget comparison (real to expected)	10
	Writing quality	20

The breakdown of all of the course components is shown in Table 3. We designed the point distribution to allow for individual work to make up the majority of points (65%), while the remaining points were allocated for the design team work (35%). This distribution was used for several reasons. First, we wanted to encourage students to be responsible for their learning (i.e. discourage team freeloading). Second, the exams were take-home and largely essay-based, especially the first exam, and questions were in-depth. Feedback from students indicated that they spent much time considering and completing their exams. We expected analysis and evaluation of course topics. For example, in the instructions for the exams, students are told that "Explanations are required to receive full credit for any answer. Justify, justify, justify your reasoning clearly." A sample question illustrates:

> *A rural community has access to a river, an open spring, and a deep rock well as options for sourcing their drinking water. Briefly describe the possible advantages and problems (think about technical, environmental, social, and economic issues) that could exist for each one. Finally, provide a **justified** recommendation for which source the community should use, a contingency plan, and what they should be on the look-out for to ensure as safe of water as possible. Be sure to **state your assumptions**.*

Students had access to course textbooks, notes, other reference materials, and had ample time (including class time) to complete their exams. Based on students' questions and informal feedback for both the homework assignments and exams, we considered that students were learning and that these items represented individual students' learning well.

Table 3. Coursework point distribution.

Coursework Item	%
Homework	15
Two Exams	50
Initial Design Memos	10
Design Presentation	10
Design Demonstration	5
Final Memo	10

Three initial design memos focused student teams on solving the design challenge multilaterally, and provided opportunities for input from the course instructors. The discussion items for the various memos are detailed in Table 4. We found that these memos, due throughout the course, helped break down the overall project into manageable submissions. This was particularly important for sophomores and juniors who may not have had much prior design experience. The iterative nature of the memo submissions also encouraged reflection.

Table 4. Discussion topics for incremental project memos.

Memo	Minimum required content
1	Selection of energy source, pumping method, performance expectations, appropriateness of prototype.
2	Design drawings, parts list, detailed budget, estimated flow rate (supporting calculations), reflection on feedback to Memo 1.
3	Plans for training community members to operate, maintain, and repair design.
Final	Suggested improvements to design, lessons learned, budget comparison, cost per flow calculation.

The study described herein was performed to evaluate the effectiveness of the Appropriate Technology course in achieving our goal of preparing engineering students to effectively participate in humanitarian work in developing communities. We were particularly interested in evaluating our ability to teach the concept of appropriateness as it relates to all aspects of engineering design, since it is key to successful projects in developing communities.

Methods

In this study we evaluated the effectiveness of the Appropriate Technology course primarily using a survey and course evaluations. We administered a post-then-pre (retrospective pre) survey to understand students' acuities and skills resulting from the course, especially regarding changes in students' perceptions about the impact engineers can have in working with developing communities. We were particularly interested in measuring our effectiveness in teaching the "Do No Harm" concept and how to design sustainable engineering solutions in the context of the developing world.

A post-then-pre survey is a tool to assess present perceptions and through reflection, retrospectively assess previous perceptions to document behavior or perspective changes. A post-then-pre evaluation survey has the advantages that both the pre and post portions are administered in the same frame of reference which eliminates the response shift bias so that students' knowledge and attitudes were consistent when taking the survey. In other words, students were able to reflect on their experiences more specifically and precisely[12-16]. Like any survey tool, there are limitations to a post-then-pre survey: most prominent is recall bias, or the ability of students to correctly recall knowledge and attitudes that they held previously. Additional limitations include effort justification bias and cognitive dissonance such that students may describe improvement in order to justify the time, energy and money they invested; and to meet their own expectations of what they should have learned[13-15]. Because we were primarily interested in measuring students' changes in perceptions about the ability of humanitarian engineering to be entirely beneficial, or at least not harmful, we chose the post-then-pre survey tool in order to reduce the response shift bias.

A post-then-pre survey was administered during the last week of classes at RHIT through the Institutional Research, Planning and Assessment office at RHIT to ensure that students' identities would not be revealed to the instructor investigators and that results would only be known and reported in aggregate. Following internal review board requirements, informed consent was obtained from each participant prior to participation in the survey.

We also weighed course evaluation feedback and student performance on assignments and exams.

Results

Post-then-pre survey

Fourteen of the 18 students (78%) participated in the survey; course demographics were as described previously. Most of the student responses in the post-then-pre evaluation survey were significant. Tables 5 and 6 show the questions, responses and significance levels as determined by the Wilcoxon signed-rank test, denoted by the asterisks. The Wilcoxon signed-rank test is a tool used in place of a Student's t-test when data cannot be assumed to be normally distributed.

Table 5. Summary of Likert scale (1; strongly disagree – 5; strongly agree) post-then-pre evaluation survey questions with average response values (*M*), standard deviations (*SD*), and numbers of participants (*N*) for each question (out of 14 total respondents), currently and prior to the course. The final two columns specify the degree of significance of the differences in responses between the post-test and respective pre-test means at a 95% confidence interval (Significance level (*p*) indicates evidence against the null hypothesis ($p \leq 0.05$ indicates strong evidence); effect size (*D*) is the mean difference divided by the pooled standard deviation). Responses with $D > 0.7$ are considered to have a large effect size.

Evaluation Questions: *As a Result of this Course,*	**Currently**			**Prior to the Course**				
	M	*SD*	*N*	*M*	*SD*	*N*	*p*	*D*
I am likely to participate in humanitarian work.	4.43	0.76	14	3.86	0.86	14	0.011	0.7
I am able to recognize the limitations inherent in humanitarian work.	4.21	0.58	14	2.86	0.66	14	0.003	2.2
I am able to participate technically in humanitarian work.	4.14	0.77	14	3.79	0.80	14	0.132	0.5
I am able to recognize and consider community characteristics that would influence the appropriateness of a project.	4.50	0.52	14	2.79	0.98	14	0.002	2.2
I can give several examples of ways well-intentioned humanitarian work can do more harm than good.	4.64	0.50	14	2.29	1.07	14	0.002	2.8
I am able to give several examples of the day-to-day value and trade-offs of a project to the people using it.	4.36	0.63	14	2.50	0.86	14	0.002	2.5
If I find a project to be inappropriate after evaluating it against a community's needs and resources, I am able to determine what alternatives might be more appropriate.	4.36	0.50	14	2.79	0.70	14	0.002	2.6

Table 6. Final question of post-then-pre evaluation survey with average percent response values (*%*) and number of participants (*N*) for each response option (out of 14 total respondents), currently and prior to the course.

Survey Question	Percentage Options	Currently		Prior to the Course	
		N	*%*	*N*	*%*
Approximately what percent of your effort in humanitarian work would go to evaluating the value of the project (i.e., background research, community assessment, and follow up) versus the technological aspect of the project?	100%	0	0%	0	0%
	80%	5	36%	0	0%
	60%	7	50%	1	7%
	40%	1	7%	4	29%
	20%	1	7%	9	64%
	0%	0	0%	0	0%

What is striking about this data is the consistency of students' understanding of the concept of "Do No Harm" to our emphasis of the topic. For example, even when technical solutions seemed necessary and beneficial, such as building latrines in villages where open defecation is practiced, students were asked to evaluate the pros and cons of building latrines versus the do nothing approach. Students were asked to consider economic, environmental, social and health perspectives in their evaluation. Together we discussed the loss in social interactions, etc. that may come with development that without taking a real pause, we wouldn't even conceive of from our US perspective. The same approach was applied to all technologies discussed in class from basic (e.g. latrines, passive solar) to more advanced (e.g. bioreactor, photovoltaic cell) technologies.

Students noted that as a result of the course they feel prepared to give examples of well-intentioned projects that have gone wrong. Students also indicate that as a result of the course they feel comfortable enough with the complexity of humanitarian projects and confident enough in their ability to navigate them to offer alternative solutions to better address needs. These findings shed light on several aspects of the course design. First, the use of the case studies were effective in imbedding concrete examples of key course concepts. Second, analysis of the case studies allowed students practice and the ability to develop their engineering skills in a low-risk environment. Over the course of the term, the case studies with reflective exercises and perhaps the course project enabled students to practice critical thinking, creativity, and systems engineering analysis skills that are crucial to not only successful humanitarian engineering projects, but to developing innovative solutions in any context.

This survey revealed that students did not feel that the course was particularly helpful in preparing them technically to participate in humanitarian work beyond their previous training. This was interesting insight because this course, with prerequisites of calculus III and physics II, was developed for sophomores from any major. However, the majority of the students enrolled in the course were upperclassmen (61% seniors, 83% juniors and seniors). These students were accustomed to technically complex course content and it is understandable they thought the course was comparatively less technically challenging with its emphasis on the "Do No Harm" concept and multifaceted nature of development work. It is interesting that while the content and case studies were developed for our students to understand the complexity of humanitarian work, students felt the technical challenges were not complex enough. Perhaps as instructors we need to better explain that complexity in engineering challenges is not always strictly technical.

Some topics were covered in more technical detail than others. We agree with students that more assignments could be given prior to the final project to provide practice in making good engineering decisions with the unique constraints that come with working in developing countries with and for people that may not have a technical background. It is our hope that one of the take-away points of the course was that many humanitarian engineering decisions are informed by non-technical aspects of projects.

According to our survey results, the importance of this non-technical dimension of humanitarian projects was communicated, as post-course 36-50% of the class felt that 80-60% of effort in a humanitarian project should go to evaluating the value of the project, respectively. Evaluating the value of the project would mean background research, community assessment, and follow-up. Thirty-six percent felt that 80% of effort should go towards evaluating the value. Prior to the course, 29-64% of the students felt that 40-20% of effort should go towards evaluating a project's value.

Written student feedback similarly described these changes in perception over the course term, as sampled below:

- "Before this course I hadn't put a lot of thought into what it means to provide an appropriate technology as opposed to just a technology."

- "[The] do no harm concept was a new concept. I always thought that humanitarian projects are good, and didn't think they [could] do harm."

- "[This course] really made me think more about if the community would need the project or not, or whether they would actually use it. Thinking about the impact of a project is just as important as designing a project that will work."

- "I learned a significant amount of what it takes to properly tailor a project to a community…It is much more difficult to implement a humanitarian project than just designing or building it."

- "I learned a lot about the potential to do harm. Talking about the different trips and projects some of the professors have been on helped me to understand what it takes to do work in other areas. I also enjoyed reading about the case studies and seeing where others have made mistakes."

- "…one major topic of this class that was really driven home for me was the need to ask the community and listen to what their desires are. The people or organization coming to help is almost always of a different culture, ideology, society, etc. and don't know how daily interactions are in this community. Resources could be wasted making something the community doesn't need or want."

- "…I came to understand that there are many ways someone can help communit[ies] from water to energy to sanitation."

- "…I also learned that projects can be perceived as a way of saying that [a] community's way of doing something is wrong, but really it is just different than what we are used to. I learned this through the various homework assignments and reading material."

Overall, students left the course understanding the importance of the evaluation process in successfully designing engineering solutions for developing communities. Students demonstrated their ability to design a system to pump water from Lost Creek on RHIT's campus with technical, budgetary, and social constraints. Students showcased their ability to apply what they learned in this course in addition to drawing on previous technical courses.

Course evaluations

Fifty percent of students participated in the end of term course evaluations (RHIT's mean response rate varies from approximately 55-75%, with highest response rates of 75+% occurring in the fall term and decreasing in subsequent terms). The low response rates for a fall term course might be explained by the fact that these students completed the pre-then-post survey in the last week of classes when the students were also supposed to be completing the institute-supported course evaluations. Seeing that we achieved a 78% response rate on our survey, students may have felt that they had already expressed their opinions and thus did not bother to complete course evaluations.

Students rated the overall quality of their learning as 3.56 out of 5.00 ± 0.53 (RHIT's mean from 2015-16 fall term was 3.99 ± 0.95). Overall, students rated the course also as 3.56 ± 0.53 out of 5.00 (RHIT's mean from 2015-16 fall term was 3.95 ± 0.94). The evaluation scores were below the 2015-2016 RHIT fall term average, signifying that there are improvements that we should make to the course. Summarizing the written comments, students recognized that this was the first iteration of the course and that improvements can be made in organization, timing, and the connectivity when moving between the three professors and outside experts with varying teaching styles. However, students appreciated the experienced consultants' participation in the course and the students felt that they were able to get a real-world glimpse into the opportunities and challenges of practicing engineering in developing communities. Students expressed their interest and joy in learning the content and its focus on the humanitarian engineering context. The novelty of the "Do No Harm" concept was also reinforced.

We did observe that course discussions changed over the course of the term. In the beginning of the course, before reading and analyzing many case studies and before much practice in considering the social acceptability of providing engineering solutions, discussions were meager on the potential consequences of practicing engineering and delivering technology in the developing world. Out of necessity, in the early stage of the course, pointed discussion questions were asked and students called upon to respond. Later in the course, students readily discussed with each other and the larger class the full range of possible outcomes of technological solutions. Based on class discussions and student questions, by the end of the class, students were more confident in prioritizing constraints in order to select technologies and in identifying appropriate approaches for realizing them.

At this stage in our evaluation process, we acknowledge that our evaluation of students' perceptions is purely qualitative, and that only student impressions are provided as quantitative assessment. Based on the perceived positive impact of this course on student understanding of the complexity of humanitarian engineering challenges, we plan to offer the course again in the 2016-17 academic year and we will continue to monitor our ability to teach the "do no harm" concept. In the future we expect to gather and directly assess student artifacts (homework assignments, exams and design memos) in order to evaluate students' understanding and ability to apply the "Do No Harm" concept.

Conclusions and Discussion

We developed a course to introduce engineering students to the unique design constraints of providing engineering solutions in developing communities. The humanitarian context may motivate certain students and even help in institutional retention of these students. The buildup of demonstration facilities on RHIT's campus will draw attention to our efforts and those of our students. Based on student feedback, we were successful in teaching the "Do No Harm" concept in the context of humanitarian engineering, a main aspect differentiating this course from other design courses.

Practical Implications

The creation and execution of an "Appropriate Technology" course focused on sustainable (appropriate) technology for developing communities with a multidisciplinary scope provided a unique opportunity for students to consider the practice of successful humanitarian engineering from an engineer's perspective. Instructors who may consider offering similar courses may want to consider the ability of such a course to fit within their curricula, a team teaching component, and course goals in terms of how they relate to course level and technical expectations.

Luckily, designated as a technical elective, and with universal prerequisite requirements, students from various engineering majors were able to take this course. We found that the diversity in majors among the students led to interesting course discussions and we hypothesize that the learning and creativity of the students was increased as a result. In working on the capstone project, we observed students from different majors helped each other to understand topics emphasized in different ways or to different extents in different majors.

Team teaching the course provided many opportunities for the students and faculty members along with some challenges. The pros of the team teaching approach are primarily related to sharing the teaching load among three faculty members and a practitioner. The arrangement allowed the course to be taught within teaching load (time) constraints since only two faculty members were able to count this technical elective course as part of their normal teaching loads. The team approach also increased the scope and richness of the course. Each faculty member brought his/her discipline-specific expertise as well as developing world experiences to the course, thereby fleshing out both the course content and international experiences that could be discussed in the course. The faculty members also learned knowledge and approaches implicit in the other disciplines when not participating as the lead instructor, and enjoyed the opportunities to learn throughout the term.

The cons of the team approach are primarily related to inefficient communication and decision making about the course, though in general, the faculty members were not dismayed with these negatives. Specifically, decisions were made by consensus of the three instructors, which required meeting or discussion over conference calls or email. One of the faculty members was off-campus and previously-engaged during the summer development period which made communication more difficult than it otherwise would have been. A third of the way into the term the faculty members set a regular meeting time and met at least once a week. This commitment added to the time commitment of the course, but the meetings allowed for solidarity among the instructors and increased uniformity in communicating with students, as well as more efficient decision making about the course and student situations. In student feedback, one student noted that better consistency should be achieved among the teaching styles of the three faculty instructors and the practitioner. This, of course, may be a downside of team teaching, but is unlikely to ever be achieved beyond a certain level, and in fact, may not be entirely negative. With the experience of one iteration of the course, we can plan to be more consistent or at least help students transition between different instructors, but we can also play to each of our strengths.

As highlighted by the students' perceptions about their preparedness to participate technically in humanitarian work, we acknowledge that a consequence of the multidisciplinary approach and scope of our course may not leave students with the capability (or the feeling of being) technically effective humanitarian engineers. It is a balancing act between focusing on the "Do No Harm" and technical aspects of problems. While it is possible – and, we feel, necessary – to teach both, in the eagerness of our first iteration we may have focused too intently on the "do no harm" aspect. Additionally, engineering students tend to expect technical courses to focus in large part on solving (largely well-defined) problems, and open-ended (design project) problems may seem less technical than they actually are. We anticipate that in future iterations we can prepare more homework problems. Additionally, we may increase the technical rigor of the project by requiring students to provide more detailed analysis calculations to accompany their projects. We can also help students make connections between course topics in lecture to the course project by discussing the project more often and in various contexts. Any instructor interested in a course like ours will want to define learning objectives that clearly specify the social and technical goals of the course and how they will be achieved simultaneously. In the future we will be more specific in our expectations.

Future considerations

Through the development, first offering, and evaluation of an "Appropriate Technology" course at RHIT, we have had many insights. In future years we plan to be more intentional towards achieving both technical preparedness and social fluency for humanitarian engineering work. We will attempt to add quantitative elements to all qualitative aspects of the course. This may require us to teach economic analyses for decision making by drawing parallels to environmental economics. To augment, we will also continue to improve our collaborations with engineering practitioners, EWB, and aid groups to develop more case studies, particularly ones with quantitative analysis components.

Additionally, our dream is to have permanent installations of the project demonstrations on our campus in an outdoor laboratory (as an extension of our Ecological Systems Laboratory) along Lost Creek through RHIT's campus so that future course projects can build on them. For example, students in next year's course could build a sand filter or chlorinator for water pumped from Lost Creek.

Providing students with an experience to put what they learned into practice through an international trip is a logical next step to further our course goals and learning objectives. One of the faculty members involved in the project has possible locations and contacts set up, however student interest, financing, and availability must line up. A survey of the students at the end of the course did not show promise for a trip during the 2015-2016 academic year, mostly due to time constraints and lack of enthusiasm for spending winter break – and winter holidays – abroad. Perhaps advance planning and different scheduling options will allow for a trip in the future.

We plan to continue to measure our ability to teach students to consider the appropriateness of technologies for the developing world (the "Do No Harm" concept). To measure our successes and opportunities for improvement, we will continue to refine and administer our perceptions survey, but we will also directly measure students' work. We will refine our course goals and objectives, and revisit our course decisions (assessment tools, point distribution, teaming) to ensure that they map to our learning objectives. With respect to team teaching the course, we will continue to learn from each other and our mistakes. As the junior faculty member of the team reflected at one point during the course, "It is rare that I get the opportunity to both observe, and receive feedback from, multiple experienced, successful instructors – for an entire course!" The opportunities are many.

Overall conclusions

The course "Appropriate Technology" was developed in the summer of 2015 and implemented in the fall of the same year. The course goal was to prepare students to effectively participate in humanitarian work in developing countries. In the course students learned important technical and non-technical considerations related to water treatment, sanitation, agriculture, energy, communication and transportation. Throughout the course, strong focus was given to understanding how technical solutions from outside engineers can do great harm to developing communities when the needs and resources of communities are not evaluated well. Case studies and discussions with experienced professionals were regularly used to help students develop a sense of engineering intuition and the non-technical skills necessary for successful humanitarian engineering projects.

In this study we were particularly interested in gauging changes in students' perceptions as a result of this course, specifically regarding the impact engineers can have in working with developing communities. Student feedback demonstrated that we successfully taught the "Do No Harm" concept. Focus on this topic was well received by students as many were considering participating in humanitarian engineering projects. Students responded well to defining technology with respect to its appropriateness for various contexts. It is our belief that giving students the opportunity to consider new constraints and purpose for engineering design allowed them unique insights into the multidisciplinary, multidimensional and, most importantly, human aspects of engineering. It is our hope that our success in changing students' perspectives using case studies, professionals' first-hand experiences, and reflection in and outside of class can serve as a reference to other instructors wanting to include appropriate technology in their courses.

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References

1. Merrium-Webster Dictionary. http://www.merriam-webster.com/dictionary/appropriate%20technology Accessed March 20, 2016.

2. Bosscher, P.J., Russell, J.S., and Stouffer, W.B. 2005. *The Sustainable Classroom*: *Teaching Sustainability to Tomorrow's Engineers.* American Society for Engineering Education (ASEE) Annual Conference Proceedings. Portland, OR, June 12-15.

3. Gordon, R., Gordan, A., and Bedient, P. 2006. *Rice University Engineers Without Borders: An Exercise in International Service Learning*. American Society for Engineering Education (ASEE) Annual Conference.

4. Bielefeldt, A.R., Dewoolkar, M.M., Caves, K.M., Berdanier, B.W., and Paterson, K.G. 2011. *Diverse Models for Incorporating Service Projects into Engineering Capstone Design Courses*. International Journal of Engineering Education, 27(6): 1206-1220.

5. Colledge, T.H. *Convergence: Philosophies and Pedagogies for Developing the Next Generation of Humanitarian Engineers and Social Entrepreneurs*. International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE). The Pennsylvania State University, PA, 2012.

6. Bixler, G., Dzwonczyk, R., Merrill, J., Campbell, J., Greene, H.L., Passino, K.M. 2014. *Humanitarian Engineering at The Ohio State University: Lessons Learned in Enriching Education While Helping People*. International Journal for Service Learning in Engineering. Special Edition, 78-96.

7. Amadei, B. and Sandekian, R. 2010. *Model of Integrating Humanitarian Development into Engineering Education*. Journal of Professional issues in Engineering Education and Practice. 136(2): 84-92.

8. National Society of Professional Engineers (NSPE). *Code of Ethics*. http://www.nspe.org/resources/ethics/code-ethics Accessed March 20, 2016.

9. American Medical Association (AMA). 1995-2016. *Principles of Medical Ethics*. http://www.ama-assn.org/ama/pub/physician-resources/medical-ethics/code-medical-ethics.page Accessed March 20, 2016.

10. Kriebel, D., Tickner, J., Epstein, P., Lemons, J., Levins, R., Loechler, E.L., Quinn, M., Rudel, R., Schettler, T. and Stoto, Michael. 2001. *The Precautionary Principle in Environmental Science*. Environmental health Perspectives. 109(9): 871-876.

11. Lucena, J., Schneider, J., Leydens, J. 2010. *Engineering and Sustainable Community Development*. Morgan & Claypool Publishers.

12. Pratt, C.C. 2000. *Measuring Program Outcomes: Using Retrospective Pretest Methodology*. American Journal of Evaluation, 21: 341-349.

13. Rockwell, S. and Kohn, H. Summer 1989. *Post-Then-Pre Evaluation*. Journal of Extension, 27(2).

14. Davis, G. 2003. *Using Retrospective Pre-post Questionnaire to Determine Program Impact*. Journal of Extension, 41(4).

15. Howard, G.S. and Dailey, P.R. 1979. *Response-Shift Bias: A Source of Contamination of Self-Report Measures*. Journal of Applied Psychology, LXVI(2): 144-150.

16. Howard, George S., Ralph, K.M., Gulanick, N.A., Maxwell, S.E., Nance, S.W., and Gerber, S.K. 1979. *Internal Invalidity in Pre-Test-Post-Test Self Report Evaluations and a Re-evaluation of Retrospective Pre-Tests*. Applied Psychological Measurement, 3:1-23.