AC 2010-2028: SPECIAL SESSION: DEVELOPING INTERCULTURAL ENGINEERS THROUGH SERVICE

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Developing Intercultural Engineers Through Service

Abstract
This paper reports on recent efforts to understand the cultural awareness among engineering students. A standard assessment program has been instituted across the various programs at Michigan Technological University with pre-, during-, and post-project phases. The mixed-methods assessment plan consists of surveys, reflection statements, journaling, a wellness indicator, the Intercultural Development Inventory, and project reports. Details of the assessment plan in addition to preliminary analyses will be presented with special attention on lessons for service learning program development.

1. Motivation
Now more than ever, it is important for American engineering students to be exposed to and understand the engineering challenges facing the developing world. Not only are significant problems confronting a vast number of people under-served by engineers, future technology investments will be mainly outside the States\textsuperscript{1}. Only with a keen understanding of global diversity can engineers develop effective solutions through innovation within the constraints of available resources, cultural demands, and technological appropriateness. Additionally, considerable insight or potential breakthrough discoveries may be learned from indigenous design and construction techniques. Not surprisingly, expanded learning criteria in emerging Body of Knowledge (BOK) efforts, and various blue-ribbon reports regarding next generation engineering needs, all call for culturally savvy engineers\textsuperscript{2,3,4,5}.

As global megatrends influence the training of engineering students, domestic trends are confounding efforts to meet the demand for engineering professionals; few of the various experiments in engineering education have resulted in notable enrollment increases despite considerable resource expenditures. In the United States engineering continues to struggle to attract students, especially women and minorities. Yet, at most campuses, it is evident that engineering programs which emphasize humanitarian efforts and service to society attract women\textsuperscript{6,7}. An interesting development has been the largely student-led growth of Engineers Without Borders-USA. Nearly 190 university chapters have been started within seven years of the organization’s inception (more than half of the nation’s engineering colleges have a chapter); this phenomena is unprecedented in that it occurred outside the intention of academia or government, and has fueled the creation of similarly-focused curricular programs at many universities\textsuperscript{8}. Most EWB chapters report similar observations: highly motivated students finding a professional passion, of which virtually half are women. One issue in this explosive, grass-roots growth in international service involvement by engineering students is that activity got ahead of understanding; little is known about the impacts of such programs. While some university-specific studies have been conducted\textsuperscript{9,10}, coordinated, multi-institution, long-term assessment efforts are just beginning to examine outcomes for all stakeholders (e.g. students, faculty, university, community partners).
2. Response

Over the past fourteen years, twenty international development programs have emerged at Michigan Tech, recently under the coordination of the D80 Center (www.d80.mtu.edu). All share a few characteristics: each focuses on development for the poorest 80% of humanity (mostly activity is abroad, although some domestic work exists), each augments (rather than revising) existing curricula, and each exists on voluntary participation by students and faculty. In this same period student involvement has dramatically grown from 5 to 300 students per year, resulting in more than 500 development projects have been completed with communities in more than 40 countries around the world. Opportunities exist for students in all majors and all years of study.

After years of grass-root, faculty-led, program development, new programs are being strategically added to create professional development paths for any student at the university. These paths allowed a scaffolded approach to building international experience with “starter”, “intermediate”, and “advanced” levels of in-country work lasting two weeks, two months, and two years, respectively. Additionally, to enhance the learning process, these programs are designed to offer differing mixes of learning environments; this Learning Domain is qualitatively depicted in Figure 1. Traditional curricula are classroom-dominated, and in engineering at least, often have some project work, and perhaps are some discovery-based (research) learning. Considerable research exists to show that this classroom (typically lecture) driven approach to learning yields underwhelming results. The Center, cognizant that its work involves real people in need, bases its multi-dimensioned Learning Domain in the belief that its community partners depend on students who are more effectively educated. Service-based learning can provide a powerful motivation (the “why?”), classroom-based learning can be a good way to learn basic material (the “what?”), project-based learning is an excellent way to apply learning (the “how?”), and discovery-based learning a key way to explore the unknown (the “what if?”). Because students opt into the various Center programs, there is no way to guarantee an ideal professional development path, but by providing multiple divergent opportunities the probabilities improve.

![Figure 1. Learning Domains depicting the mix and relative magnitudes of learning environments for a typical engineering curriculum (left), and an Engineers Without Borders program (right)](image-url)
Interestingly, these programs average 50.2% women, more than twice that for Michigan Tech’s student body overall (~24% female). Among all these efforts, it has become clear that successful projects and beneficial learning outcomes are rooted in the ability of students (and faculty) to effectively work with people in extremely different cultures. With the formal inception of the D80 Center in 2007, a standardized assessment program was developed to better understand outcomes to all stakeholders. The student assessment protocol is introduced in this paper.

3. Assessment Protocol
After nearly a decade of experience with these programs it was clear that program development had reached a tenuous point: student demand was increasing so dramatically that resource demands (time, money, energy) exceeded supplies. Forming the D80 Center was a calculated decision to alleviate this problem. A key mission for D80 was to better understand stakeholder impacts in order to better design (or re-design) programs, as well as better advocate for resources based on return-on-investment principles. All twenty programs have been phased into the following student assessment strategy over the past three years.

Basic demographic data is collected for program participants including major field of study, gender, age, ethnicity, nationality, travel experience, language experience and reasons for participation. The assessment strategy focuses on three key outcomes: technical proficiency in international sustainable development solutions, individual and team well-being, and understanding of the societal context of engineering projects. Together, these are some of the challenging aspects of meeting the ambitious goals for modern engineering and technology education set out by NAE, ABET and others\textsuperscript{4,11}.

The D80 student assessment is divided into three phases: preparation, in-country, and reporting (Figure 2). This structure allows for an examination of “before and after” as well as transient effects. The specific assessment methods are briefly addressed below.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{assessment_timeline.png}
\caption{Typical assessment timeline depicting program phases with assessment methods, their timing and frequency}
\end{figure}
3.1 Intercultural Development Inventory
The Intercultural Development Inventory (IDI) is a cross-culturally valid and reliable method to assess intercultural competence development\textsuperscript{12}. The IDI yields quantitative results, placing the student along a spectrum of intercultural sensitivity from ethnocentrism to ethnorelativism in stages of denial, defense, reversal, minimization, acceptance, and adaptation\textsuperscript{13}. The IDI is conveniently available as an online 50-question tool, but requires a $10 fee for each test and a qualified administrator for use. It typically takes up to an hour to complete, and is generally taken one month prior and following the in-county experience.

3.2 Needs Assessment
An internally developed online survey was created to gather the demographic data mentioned above, as well as information on program participation to date, whether these programs attracted the student to Michigan Tech, reasons for participation, perceived skills needs, and opinions on next professional steps. The survey consists of thirteen questions and can be finished in ten minutes.

3.3 Content Analysis
Emergent content analysis is conducted on required program documentation, including journals and final project reports. Sensitivity towards the stresses inherent in these programs, as well as overburdening of requirements, has led to a model for journal reporting frequency of approximately eight times over the course of the in-country phase (see Table 1). In practice, each entry is read immediately after submission to better understand what the student is experiencing in order to provide rapid feedback, assistance, and mentoring, if necessary. The content analysis is performed upon conclusion of the program. All journal entries are submitted as computer files (either in the field, or transcribed by the student later). Typical journal entries take thirty minutes each. Content analysis for journal entries and reports is facilitated through the use of software tools, from simple (Text Tag Cloud Generator, Wordle) to sophisticated (Metafy).

Table 1. Frequency of in-country journaling by student participants in international service programs within Michigan Tech’s D80 Center

<table>
<thead>
<tr>
<th>In-country duration</th>
<th>Reporting frequency</th>
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<tbody>
<tr>
<td>2 weeks</td>
<td>daily</td>
</tr>
<tr>
<td>2 months</td>
<td>weekly</td>
</tr>
<tr>
<td>2 years</td>
<td>quarterly</td>
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</table>

While the journals can provide insight into transformative processes (and if nothing else, assist reflection and retention) and the final reports are a summative indicator of professional pursuits and knowledge, a Challenge Question was added to assess intercultural insight pre and post in-country experience. The Challenge Question response is scored on a simple rubric based on the
student’s ability to explain national differences among a team of professionals; both question and rubric are inspired by the work of Downey et al. The Challenge Question is typically administered one month prior and after the in-country experience, and students have thirty minutes to respond. An example Challenge Question is:

"As an American engineer/scientist, you have been invited by an NGO to help design an 'appropriate, sustainable, and socially responsible' water system for a village in northern Tanzania. The design team includes engineers and scientists from the U.S., the Netherlands, Kenya, and Tanzania because the NGO is based and operates in those countries. How prepared are you to enter this work situation? What knowledge and capabilities do you have and what do you lack?"

Student responses are scored on a scale of 0 to 3 (0=inaadequate, 1=needs improvement, 2=adequate, 3=excellent).

3.4 Rapid Self-Evaluation

As alluded to above, experience has shown that international sustainable development programs can be especially demanding on student participants. The Rapid Self-Evaluation (RSE) was developed as a quasi-realtime measure of how a student is doing physically and overall (typically encompassing emotionally, project work, etc.). This is administered by the program mentor through a simple interview and approximately the same time each day. The interview consists of two questions that the student evaluates themselves on a scale of 1 (awful) to 10 (awesome):

1. On a scale of 1 to 10 how are you doing physically today?
2. On a scale of 1 to 10 how are things going overall today?

This takes about thirty seconds per student. While the students are allowed to have this interview in private, most opt to do this in a group setting. The method, while extremely simple and carrying all the biases of self-assessment, is a powerful way to facilitate several things: (1) a chance for the student to reflect on how they feel, and express it in summary form (this is extremely effective for students with introverted and/or quantitative habits), (2) a follow-up conversation if scores seem unusually low, and (3) when done in a group setting, a chance to learn how others are doing.

The above mix of qualitative and quantitative methods has proven to strike a balance between adaptability, usability, value, and intrusiveness, an imperative compromise for sustainable use. Some results are shared next.

4. Findings

It is impossible to present all the findings to date. Instead one program’s results are used to illustrate rich detail, and then general findings common to many programs are offered.
4.1 Example Findings: Developing Global Scientists and Engineers in Tanzania

The Developing Global Scientists and Engineers (DGSE) program builds appropriate technology research teams composed of engineering and science graduate students from Michigan Tech and University of Dar es Salaam in Tanzania, public health students from University of Minnesota, and faculty from all institutions. Each team develops a research project that ultimately could create technologies or services designed to improve living conditions in Tanzania and elsewhere. The program is structured to be nearly one year in length with four months of culture, language, and research preparation, ten weeks of field research in Tanzania, and four months of reporting findings. Ten students are typically in each cohort.

4.1.1 Intercultural Development Inventory

Students took the Intercultural Development Inventory (IDI) approximately six weeks prior to departure for Africa and four weeks after return. Group pre- and post-fieldwork results are shown in Table 2. The IDI generates two summary scores, a perceived intercultural sensitivity (where the person thinks they are), and a developmental intercultural sensitivity (where the person actually is).

<table>
<thead>
<tr>
<th>IDI Metric</th>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td>Perceived</td>
<td>123.0</td>
<td>123.7</td>
</tr>
<tr>
<td>Developmental</td>
<td>96.6</td>
<td>98.2</td>
</tr>
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</table>

As a group, these students are planted firmly in Minimization, an intercultural perspective that focuses on the similarities among different people (i.e. minimizes the differences). This is often a reasonable view to work efficiently with others, yet may be limiting effectiveness by missing the richness contributed through an understanding of diverse ways of thinking. This group of students perceives that they are accepting of intercultural differences, but their developmental (actual) scores suggest they have work to do to reach that perspective in practice. Slight gains were made in intercultural sensitivity from the Africa experience (in all cases the lower the pre scores for an individual, the greater the gains; for the student with the lowest pre score, a 15.9% gain was made), nevertheless, the marginal improvements may suggest program preparation could benefit from an enhanced cultural focus.

4.1.2 Needs Assessment Survey

Results from four questions in the Needs Assessment are presented in Table 3 below.

While this group started the program with an interest to learn from others (e.g. top two reasons expressed were to understand global and societal issues, and gain culture experience), a
pragmatic reason (to get project experience) was the third most expressed reason. After time in Africa (a new experience for all of the participants) the reasons shifted to strictly humanitarian perspective. When reflecting on skills needed project management was replaced by language skills in the top three responses, pre versus post, respectively. In terms of length of stay, there is a slight shift towards wanting longer experiences abroad following the DGSE program. Lastly, changes in interests shift from more self-focused (major, travel) to socially-focused (career, international issues). What is not revealed in the summary provided for the last question in Table 3 is the substantial drop in interest in major, and the rise in interest in pursuing higher levels of education. This seems to be a product of a better understanding of the complexities associated with real international development issues and solutions.

Table 3. Cohort (2009) rankings of top three reasons for four sample questions from the Needs Assessment survey, before (pre) and after (post) ten weeks of field research in Tanzania (n=6)

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre</th>
<th>Post</th>
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| Why did you want to participate in this program?                         | 1. To understand global and societal issues  
2. For the cultural experience  
3. To get project experience | 1. To do something meaningful during my studies  
2. For the cultural experience  
3. Help others in need |
| What skills do you most need to improve to be effective in this program? | 1. Community assessment  
2. Project management  
3. Project resource acquisition | 1. Language skills  
2. Community assessment  
3. Project resource acquisition |
| If you were to design the next program you participate in, how long would you spend in-country? | 1. One semester  
2. One month  
3. One year | 1. One semester  
2. One year  
3. One month |
| How have your interests been influenced by participation in international programs? | 1. Interest in major  
2. Interest in sustainability  
3. Interest in travel | 1. Type of career  
2. Interest in international issues  
3. Interest in sustainability |

Results from this simple study can be used to shape the next offering of the program; in this case an introductory language and culture workshop series is planned for 2010. Additionally, community assessment experts will cover basics of such work. Lastly, reasons for participation are a strong reminder to align in-country opportunities with larger program goals whenever possible.

4.1.3 Content Analysis
An analysis of the Challenge Question is presented in Table 4. This tool is probably most fraught with uncertainty due to question interpretation variability, time limit for response, general dislike of essay writing among engineering students, and the necessary rubric scoring. No students scored a zero, not surprising as all student participants had considerable international experience.
There is an evident enhanced richness and relevance of content within the responses post- versus pre-Tanzania for all students; it is very clear that experience makes a difference in understanding the general nuances of another place. More of these questions could help shed light on specific learning outcomes, but there is little enthusiasm among students for this method to begin with.

Table 4. Results of Challenge Question scoring before (pre) and after (post) ten weeks of field research in Tanzania (n=6)

<table>
<thead>
<tr>
<th></th>
<th>0 (Inadequate)</th>
<th>1 (Needs work)</th>
<th>2 (Adequate)</th>
<th>3 (Excellent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Post</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

A preliminary content analysis translated the final research reports into tag clouds for quick comparison. Figure 4 below shows the results for two students’ research. By examining the frequently used words in documents like these a synopsis of highlights can be made, illustrating what the student viewed as key findings in this case within the constraints of a research document. More importantly, the content analysis constructs a way to compare the lessons learned between students. The pairing shown in Figure 4 reveals a difference in engineering complexity, where the first student presented their work in technical details relevant to the work, the second student added considerable language that connected the community partners, their needs, and constraints.

4.1.4 Rapid Self-Evaluations

Group results for the Rapid Self-Evaluation are presented in a graph covering the time spent in Tanzania (Figure 5). In general the students reported high marks (8.0 average for physical, 8.4 average for overall), a good sign for a demanding program. And yet a closer examination of the variability (long-term and intraday) merit comment. The trends over the length of the in-country phase show a slow decrease in physical well-being, whereas overall conditions improve. This is not unexpected; longer-term programs elevate the likelihood of becoming ill, and in this case, food and exercise habits change. The rising trend in overall state is indicative of progress culturally and on research projects. Intraday variability is an indicator of sudden impacts, often intestinal disease, but in more than one instance, a severe bout of homesickness. These interpretations of the quantitative RSE data would not be possible without asking follow-up questions when “unusual” scores are reported (one of the purposes of the RSE) and reviewing the student weekly journal entries. Especially challenging periods for the group and faculty mentors are during periods with large spreads in the RSE scores among students, for example during early July in Figure 5.
Figure 4. Emergent content analysis of final research reports from two students. Top student uses mainly technology-focused language, bottom student incorporates more language about society, people, and research complexities. Text size is proportional to word use frequencies, which are in parentheses.
Figure 5. Maximum, average, and minimum daily Rapid Self-Evaluation physical (top) and overall (bottom) scores presented for the 2009 DGSE student cohort (n=6) during ten weeks of research in Tanzania.

4.2 General Findings
Findings suggest program design is critical in two ways, cultural awareness training and length of in-country stay, improving both student experiences and project development. While exceptions exist, number and duration of experiences working with other cultures is important to creating a more nuanced understanding of intercultural differences. Among students participating in these programs, undergraduates generally have the most simplistic views of cultural differences with graduate students having a richer view; in the end, variety and length of experiences matters. The length of time for the field research program highlighted above is not ideal for the research mission but seems to the best compromise possible -- balancing student interest, available funding, and project demands -- yet community partners would clearly benefit
more from a multi-year presence by researchers. Creative solutions are needed to ensure that such programs meet all critical objectives, not simply the ones most convenient.

The nature of the cultural experience matters; being engaged with international colleagues, for example as demanded by research collaborations, is one thing, living in another culture, as international service requires, manifests much deeper learning. While shorter duration experiences can result in changed perceptions among students, progress in intercultural sensitivity is not guaranteed. Pre-departure training, mentoring during the in-country phase, and group sharing throughout can help all students make better advances in becoming intercultural engineers.

5. Conclusions
A mixed methods assessment program like that presented here is critical in understanding student outcomes, thereby influencing program design. Such protocols do demand considerable additional resources, often in an environment that does not require the effort in the first place. Yet, thoughtfully planned and executed, assessment evidence can powerfully affect many persistent institutional challenges including resource allocation, curricular design, value creation, institutional reputation, and student enrollment, among others.

6. Bibliography


