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Comparison of Education Models for Increasing Student Exposure to Engineering in Developing Countries

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Abstract

The challenge of increasing the exposure of undergraduate engineers to the opportunities for, and constraints on, working in developing countries has resulted, at the University of Notre Dame, in the examination of three models for providing appropriate learning experiences. Experience with a multidisciplinary experiential seminar on water supply in Haiti (involving students from multiple colleges at the University of Notre Dame) is compared both with a cross-disciplinary elective course on water supply development (again, involving students from multiple colleges at the University of Notre Dame) and with an REU (Research Experience for Undergraduates) site focused on water resources in developing countries (involving students from a number of universities and focused on research in Benin, Haiti, Honduras, and Chile). The Haiti seminar and the REU program both involve travel to, and interaction with, locals in the developing country. Impact of these three models on student learning is examined through application of surveys to students participating in each of these models, the pool of students applying to the research projects, a control group of senior engineering students, and representatives from industry. Both entrance and exit surveys were administered to the students in the elective course and students participating in the REU program. Among the similarities observed among students in all three groups was an increased perception (in particular, compared to the industry representatives) of need for education on international issues and the liberal arts. Differences among the groups were correlated to the primary learning objectives of the three models. Additionally, the Haiti and REU models attracted a disproportionately large percentage of women.

Introduction

The Department of Civil Engineering and Geological Sciences at the University of Notre Dame has dedicated effort to increasing awareness among undergraduates of the role of the engineer as a significant contributor within a multidisciplinary team for addressing water resources in developing countries. This effort is related closely to the recognition at Notre Dame, as well as at other institutions of higher education[1], that there is an increasing need to expose undergraduate engineering students to the social, political and cultural components of engineering practice. Three models of learning experience (summarized in Table 1) have been utilized in at Notre Dame with various levels of commitment of financial resources, faculty time, and risk:

- Model 1: A classroom experience taught entirely at Notre Dame on development of international water resources (enrollment included a combination of engineering and non-engineering students),

- Model 2: An experiential seminar involving an interdisciplinary team of Notre Dame students who train at Notre Dame and then travel to Haiti to work on hand-pump repair, and

- Model 3: An REU site on water resources in developing countries (supported by the NSF Research Experience for Undergraduates program) involving students from multiple universities who train at Notre Dame and then join faculty from Notre Dame, the University of New Mexico (Dr. Michael Campana), or the University of Nevada, Reno (Dr. Scott Tyler) for research experiences outside the United States.

The classroom experience involves students from a variety of disciplines who study the technological, economic, political and social aspects of developing water resource projects (of various magnitudes) in developing countries. The course involves student projects completed in cooperation with contacts in developing countries. This course requires commitment of one faculty member for the semester in which the course is offered. There are no significant financial issues (either to the student or the university) related with this learning experience. The classroom experience is limited to no more than 20 students per semester.

The experiential seminar involves 5-10 undergraduates from Notre Dame (including both engineers and non-engineers) who train two-hours per week over 8-12 weeks on hand-pump repair and then travel with a faculty member to Haiti. In Haiti, this group works with the local population in training on hand-pump repair and sustainable maintenance of water wells. The majority of the costs associated with this seminar are borne by Notre Dame (through internal funds and private donations). The course requires a commitment of one faculty member, as well as travel time to Haiti for that same faculty member (usually 10 days to 2 weeks). In addition to the financial commitment required for this seminar, there are a number of risks to the students and faculty in this seminar. These include travel within the U.S., air travel to Haiti, ground transportation in Haiti, the risks commonly associated with fieldwork on wells, and the lack of availability of medical care in Haiti. Risks associated with housing, food, and vehicle care are minimized, in this seminar, through long-term association of this seminar with a missionary compound in northern Haiti.

The REU (research experience for undergraduates) site involves 8 students (supplemented with additional funding to include additional students) who participate in general training at Notre Dame, followed by project-specific preparation at one of the three participating schools (Notre Dame, University of New Mexico, and University of Nevada Reno). Each student then joins a faculty member on a short-term research project in a developing country. Following return from the developing country, the students present results of their effort at a student research symposium. This experience represents the highest cost of the three learning experiences in terms of faculty commitment, financial requirements, and risk. The training portion of this REU requires full time effort of one faculty member for approximately 4 weeks. The international

Table 1: Models examined for a learning experience related to engineering in a developing country. Model 1 is the classroom experience. Model 2 is the Haiti seminar. Model 3 is the REU program.

Model	Limited to Notre Dame Students?	Limited to Engineering Students?	Travel to Developing Country?	Approximate Group Size	When Offered	Minimum Number of Faculty Required	Estimated Cost	Estimate Of Risk
1	Y	N	N	10-20	Semester	1	Low	Low
2	Y	N	Y	10	Semester	1	High	High
3	N	N	Y	10	Summer	3	High	High

travel requires commitment of approximately two weeks time from a minimum of three faculty members. The administrative responsibilities amount to a part time commitment of one faculty member during the spring semester. The financial commitment (currently supported by funding from the NSF) includes stipends for the students and international travel costs for the students and faculty. The risk is increased over the Haiti seminar due to the fact that students are going to multiple international locations. Food, transportation, medical care, and political awareness all become potential issues, as does a wider variety of field activities associated with research on water resources in remote regions of developing countries.

Important questions in designing and offering these three learning experiences include whether they are effective in achieving their learning objectives (outlined below) and whether the increased faculty time, financial burden and risk associated with the latter two models are warranted based on the experience obtained by the student. These two questions are addressed in this manuscript through analysis of student and industry surveys, as well as student response to these learning experiences.

Learning Objectives

The three learning models share a number of learning objectives. In addition unique learning objectives are associated with each model. The common objectives include:

- Engineering students must demonstrate understanding of the challenges involved in pursuing engineering projects in developing countries (including technical, social, economic and political considerations).

- Students must work in a multidisciplinary team to identify solutions to one or more complex problems involving water resources in a developing country.

One learning objective unique to the classroom experience is:

- Students must comprehend and incorporate non-technical considerations in their development of a project plan for a water resource project in a developing country.

Learning objectives unique to the Haiti seminar include:

- The students must work in-country with a project team that includes engineering students, students from outside of engineering, and locals.

- The students must consider the spiritual and social, as well as technical and economic, aspects of working with the local population on water supply.

Learning objectives unique to the REU experience include:

- Students must gain significant appreciation for graduate-level research.

- Students must work with engineering students and faculty from peer institutions in a developing country.

Assessment Tools

We have applied a number of assessment tools to the comparison of these learning experiences. These tools include:

- A common survey on expectations of an undergraduate curriculum in engineering given to six study groups:
    - Students in the classroom experience
    - Students in the Haiti seminar
    - Applicants to the REU program
    - Participants in the REU program
    - A control group of Notre Dame seniors
    - Industry representatives visiting campus for student interviews
- Student surveys comparing expectation for the undergraduate curriculum against student experience of the undergraduate curriculum (given as single surveys to the control group, the students in the Haiti seminar and the REU applicants and as entrance/exit paired surveys for the REU participants and the students enrolled in the course).
- Student essays for both the Haiti seminar and the REU program.
- Statistics on the student mix of participants in all three experiences (primarily in terms of gender).
- Monitoring of post-graduation activities for a number of the students involved in these programs.

The use of surveys follows on the common practice of the use of surveys as assessment instruments[2,3,7]. Due to relatively small numbers of survey responses (<60 for the industry survey, <40 for the control group, and <15 for each of the other groups), data collected from these tools are analyzed through exploratory (qualitative) comparison among groups and change in response between entrance and exit surveys. Further, qualitative aspects of the closing essays are compared to determine differences in the learning experiences.

Common Survey

A survey was applied to all groups indicated above. A portion of this survey involved asking the respondent to evaluate: "On a scale from 0 (not important) to 10 (critical to the curriculum), evaluate how important each of the following *should be* within a curriculum in science / engineering". Responses to the following nine components are presented herein for each of the study groups:

1. Skills in mathematics
2. Skills in the area of specialization
3. The ability to work in a team
4. Ability to communicate results (reports / presentations)
5. A strong liberal arts component
6. Exposure to recent science/engineering projects (guest lectures, field trips, etc.)
7. Opportunities to pursue classes / projects outside of the United States
8. Opportunities to pursue projects in developing countries
9. Undergraduate research

Figure 1 shows the mean response for each of the study groups relative to these nine questions (for the REU participants and students involved in the classroom experience, results reported in Figure 1 are based on surveys administered at the end of the learning experience). Two observations are made in comparing the mean response of the various student groups to industry. First, there is remarkable agreement among the various study groups in terms of response for components 1-4. In particular, both industry and the students appear to recognize the importance of teamwork and communication skills to the engineer. Second, there is a strong

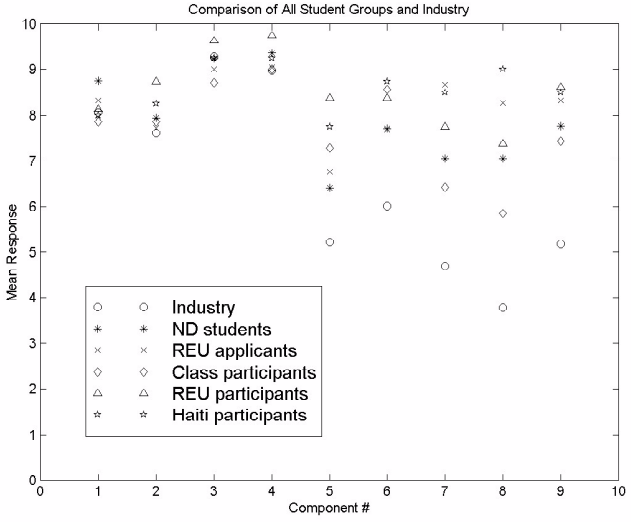

Figure 1: Comparison of mean response among all study groups to the survey question on the nine components of the undergraduate engineering education. A response of 10 means that the component was considered extremely important to the curriculum whereas a response of 0 means that the component was considered to have no value in the curriculum.

degree of separation between the industry response and the student responses in terms of the importance, to undergraduate engineering education, of exposure to the liberal arts, case studies, international engineering and undergraduate research. The students rate these latter components as more important to the engineering curriculum than indicated in the average industry response.

In comparing responses among the individual student groups, there is relative strong separation among the responses for the final five components. Perhaps most significant, the applicants to the REU program and the students participating in the Haiti seminar rank the importance of study outside of the U.S., including in developing countries (components 7 and 8), quite high. In contrast, the control population from Notre Dame, the students who have completed the REU experience, and the students who have completed the classroom experience rank this component lower. We anticipate that this separation may be related to a significant difference in the learning experience (or expectation of learning experience) among these student groups. The REU applicants and the students who have participated in the Haiti experiential seminar have, by their expressed desire to participate in these programs, a significant interest in international water resource development and interaction with the local population. Further, the REU applicants differ from the REU participants because they have not yet been exposed to the learning experience (this observation is supported by the entrance/exit survey comparison for REU participants, below). Finally, the Haiti students have been exposed, to a greater degree than the REU participants or the students in the classroom experience, to the social and personal constraints on projects in developing countries. Hence, these two groups either perceive (the applicants) or have experienced (the Haiti participants) the limitation of their technical knowledge in solving problems in the developing world.

In contrast, students who participate in the REU program or the course are exposed to the technical details of pursuing an engineering project in developing countries. As such, they have an opportunity to observe that many of the technical skills required of the engineer for working in a developing country are identical to those required of engineers working in developed countries. Hence, these students may view engineering in developing countries to have only minimal differences from the engineering to which they are exposed in their current engineering curriculum (and, thus, there is less need for specialized courses on international engineering).

Interestingly, the REU applicants, REU participants, and Haiti seminar participants all rank research as being more important to the undergraduate curriculum than do the control group or the students completing the classroom experience. While this result was anticipated for both REU groups (given the focus on research experience), the result for the Haiti seminar participants cannot be fully explained based on this limited data set.

A final observation on these results relates to the ranked importance of the liberal arts component of the undergraduate education. It is interesting to note that the three student groups participating in a learning experience ranked exposure to the liberal arts as significantly more important than did the other student groups (including the REU applicants) or the industry representatives. It would appear that, with all three learning models, the students have utilized the opportunity to consider the importance of the non-technical aspects of engineering projects.

Comparison of Expectation versus Experience

A second portion of the survey applied to all student groups asked them to respond to: "On a continuous scale from 0 (not stressed) to 10 (heavily stressed), evaluate the degree to which each of the following *has been stressed* during your undergraduate education". The same components as listed above were provided as possible components. For the remainder of this manuscript, we refer to this as *question* 2 and the student response as experience. We refer to the original question as *question* 1 with the responses referred to as *expected* or expectation. The results from this portion of the survey were evaluated both in terms of the actual response to the question and in terms of the difference in response between question 1 and question 2 (i.e., the difference between expectation and experience). Use of the difference as an assessment tool follows on the experience of others[4] demonstrating the potential utility of paired rankings in the assessment process.

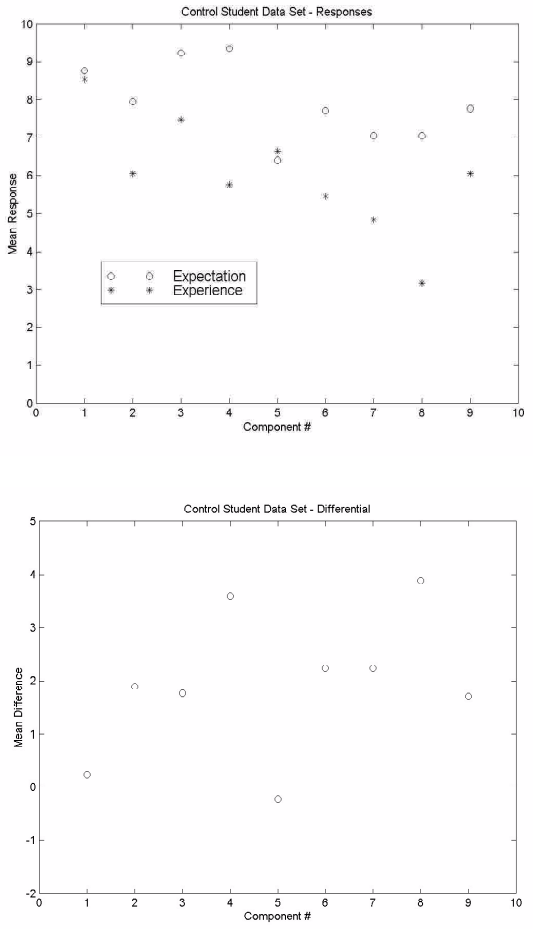

Figure 2: Survey results for control group in terms of the mean of the raw data for both questions 1 and 2 (top) and in terms of the mean of the differences between response to question 1 and response to question 2 (bottom).

Figure 2 (top image) shows the comparison of the responses to the two questions for the control group. Typical of many of the results we observed, the students consistently measured "has been stressed" below their rank of how important the component "should be". This is particularly apparent in terms of team efforts, communication, and experience in projects outside of the United States (including developing countries). The one exception to this trend is in the response to component 5, the importance of a liberal arts component to the undergraduate engineering curriculum. A second manner of viewing these data is illustrated in the lower figure (Figure 2). This involves recording the difference between the response to the first question and the response to the second question.

Figure 3 shows the comparison of mean difference between responses to question 1 and question 2 for all student groups. It must be noted at the beginning of this discussion that the Haiti group has a very small sample size (5) and is therefore subject to substantial uncertainty. It is also noted that the surveys used for the class, REU participants, and Haiti seminar were surveys conducted at the end of the learning experience (comparison with surveys conducted at the beginning of the experience are discussed below).

Figure 3 demonstrates that there is some common structure among the various student groups, but also substantial difference among the specifics of the responses. The most obvious commonality is the larger mean difference for components 6-8 as compared with components 1-3 and, for many of the student groups, components 4 and 9. It is noted that components 6-8 relate to student experience outside of the classroom (engineering case studies, work outside the US and work in developing countries). It is therefore not surprising that the students who have ranked these issues as being important to their education (see Figure 1) would also identify the relatively low level of coverage of these topics within their curricula. It is noted further that component 8, whether the students feel they should be exposed to experiences in developing countries, showed the largest difference between expectation and experience for nearly all groups (with the response to component 5 being slightly higher for the Haiti group).

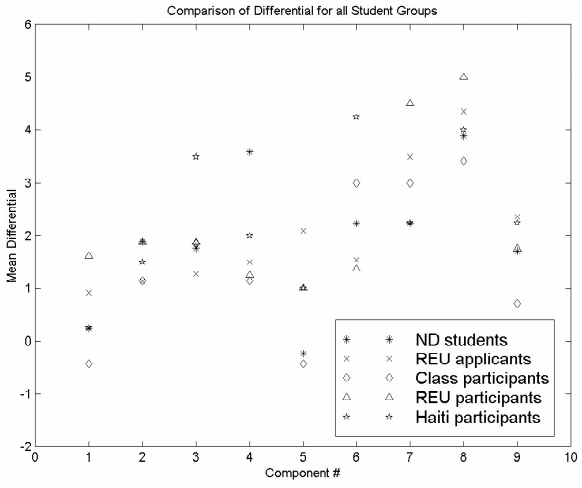

Figure 3: Comparison of the differential between response to question 1 and the response to question 2 for the various student study groups.

Perhaps more interesting in these results are the differences among the student groups. With respect to the question on inclusion of a strong component of liberal arts education, it is noted that the REU applicants (not the REU participants) show a greater differential response between expected and experience than the other student groups. We attribute this difference to a number of factors, including: (i) this group is self-selecting towards substantial interest in the non-engineering aspects of their engineering experience (but typically have not yet had the opportunity to seriously pursue this interest) and (ii) the remaining groups (with the exception of the REU participants) are biased by the educational experience at Notre Dame in which it is stressed through the advising structure and literature on its programs that Notre Dame provides a strong liberal-arts component to the undergraduate educational experience.

The largest difference in response is observed with respect to component 6, the component regarding the exposure to engineering examples within the curriculum. The participants in the REU program show lower differential between expectation and experience than do the students participating in the Haiti seminar or the classroom experience. This difference can be interpreted multiple ways. For example, one could make an argument that the REU program stresses technical engineering (research) whereas the Haiti and classroom experiences stress the non-technical aspects of these projects. Given that the REU participants come from programs with excellent coverage of the technical aspects of the engineering discipline, it is not unreasonable for these students to judge that their education has been adequate to support their summer learning experience. In contrast, the Notre Dame engineering program does not currently highlight the social or spiritual aspects of engineering as a regular component of the curriculum. As a result, it is not unreasonable for the students participating in the Haiti seminar or classroom experience to judge that this learning experience is different than the bulk of their prior education and, therefore, that their prior educational experience has included only limited exposure to these aspects of engineering. One could also argue that the difference among the differential responses among the student groups reflects the fact that the majority of the REU participants come from outside of Notre Dame and all participants in the Haiti seminar and classroom experience come from within Notre Dame. This latter explanation is supported, to a degree, by the fact that the REU applicants (who have not yet experienced the research effort) provide a similar difference between expectation and experience as the REU participants.

A second point of variation in these differential responses is in the component on undergraduate research. The participants in the Haiti seminar and REU programs, as well as the applicants to the REU program, all note a relatively high difference between expectation and experience (as compared to the control group). In contrast, the students who completed the classroom experience rated the difference between expectation and experience in undergraduate research substantially below the control group. The reason for this difference is not currently fully understood. It is worthy to note, however, that several of the students participating in this classroom experience were from the College of Science at Notre Dame where undergraduate research is a regular component of the curriculum.

Entrance Versus Exit Surveys

Entrance and exit surveys are available for both the REU participants and the students participating in the classroom experience. Figures 4a,b show the mean responses to question 1

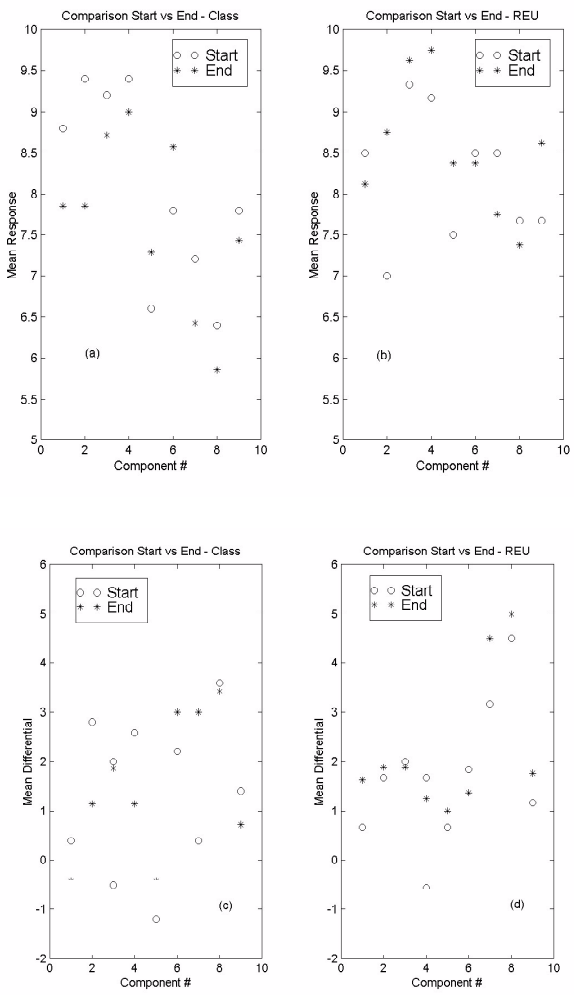

Figure 4: Comparison of student response at the beginning and end of the learning experience as expressed both in terms of rank of importance to an engineering curriculum ("a" for the classroom experience and "b" for the REU experience) and in terms of differential between questions 1 and 2 ("c" for the classroom experience and "d" for the REU experience).

for these two groups (including responses to both the entrance and exit surveys). Figures 4c,d show the mean difference (termed differential on the plot) between responses to question 1 and question 2 for both groups on entrance and exit surveys. With these figures, "start" refers to the survey response on the entrance surveys and "end" refers to the response on the exit survey.

The entrance and exit responses to question 1 show a number of differences between these two student groups. The mean responses of the students participating in the classroom experience were lower for components 2-4 (skills in technical area, team work, and communication) at the end of the learning experience than at the start. In contrast, the mean responses of the REU students for these components were higher on the exit survey than on the entrance survey. In addition, the students involved in the classroom experience indicated a zero to slightly negative change in expectation (from entrance to exit) relative to undergraduate research whereas the REU participants indicate a substantial increase in their response relative to

this component. It is anticipated that this latter difference is due to a number of issues, including the focus of the REU program on research opportunities, the focus of the classroom experience on team projects based on new applications of established technologies (versus development of new technologies), and the mixed (science and engineering) student population in the classroom experience.

Both groups also show a number of common changes in expectation during the period of the learning experience. Both groups showed significant increases in response with respect to the liberal arts component. This is viewed as a positive affirmation of the common learning objective among all three learning models for exposure of the participants to the non-technical aspects of engineering projects. Both groups also show a decrease in response relative to the need for exposure to engineering outside the U.S. This result is interesting and somewhat surprising on first analysis in that both learning experiences were designed to increase exposure specifically to these types of experiences.

One interpretation of the result relative to components 7 and 8 involves considering the material to which these students were exposed during the learning experience. In both cases, the students were exposed to technologies that were easily understandable given the technical background of the students. Further, while the social, economic and political issues involved in the projects were of importance in the experiences of both of these groups, neither group was in a position in which they had to overcome these non-technical issues or fail in their efforts (this is NOT the case with the Haiti seminar where dealing with the non-technical aspects of the projects was critical to the success of the project). Hence, it is anticipated that the students may have concluded from this experience that, while it was a positive experience for all involved, the experience did not translate into one that should be required of all engineering undergraduates (hence, the lowering of the expectation). Additional study of this response (including deeper examination of student thoughts on these topics) will be pursued in future offerings of the classroom and REU experiences.

Figures 4c,d illustrate that a number of trends are also observed in the difference between the student expectation and experience. With respect to components 2-4, for example, the students completing the classroom experience had lowered expectations (Figure 4a) and generally found that their expectations at the end of the experience were more in line with their experience (i.e., a decrease in the differential for these components in Figure 4c). There was less consistency in comparing the expectations and the differentials for the REU participants with respect to these three components (compare Figures 4b and 4d). Component 9 provided a distinctive difference between the two student groups. The students completing the classroom experience showed both a lowered expectation and lowered differential relative to component 9; the REU participants indicated an increase in both expectation and differential. This result shows that there is a clear difference in outcome of these two learning models.

It is interesting to note that not all trends in the differentials reflect trends in the mean expectations shown in Figures 4 a,b. Of significance to the present discussion, both groups of students showed an increased discrepancy between expectation and experience for component 7 (international experience) and a neutral or increased discrepancy for component 8 (experience in developing countries) as observed in Figures 4 c,d. These results seem to conflict with the

observed decline in expectation with respect to both of these components in both student groups (Figures 4 a,b). One possible implication of this result is that there may be a complex interplay here between expectations of the students with respect to perceived importance of international experience to an overall undergraduate experience, and the value that the students place on their individual, international experiences. Further study is required to help clarify the results illustrated in Figures 4 a-d with respect to components 7 and 8.

Student Essays

Written evaluations / essays were required from both the REU participants and the participants in the Haiti seminar. These written evaluations demonstrate significant differences in the impact of these two learning experiences on the students. The student essays submitted for the Haiti seminar reflect social and religious insights, as well as discussion of the difficult social and economic conditions that impact projects in developing countries. In contrast, the student evaluations submitted for the REU program reflect insight into research and logistical challenges associated with research collaboration in developing countries. Reviewing the learning objectives for these two learning experiences, these outcomes appear consistent with the intended objectives of these courses. The following examples of student responses (representative of the range of responses received) illustrate the degree of difference in student response to these two learning experiences:

REU Participants:

- *I felt as though our trip was the perfect balance of research, data analysis, learning and play. I am very interested in the arsenic contamination, and possibly a future study.*

- *In-country experience was great. Positives were that we were very involved in the data collection and could follow the process from the beginning – theory – to the end – data analysis and conclusions.*

- *In terms of expectations: I expected to have an eye-opening experience, and that the field work would heavily impact my perspective on environmental engineering (and other work – research), as well as on my thoughts about my future.*

- *I expected to join up with a heavily research-oriented program, involving field work in Benin. From the beginning, I was introduced to very sophisticated techniques of analysis, and the program retained a very clear start-to-finish vision of how these techniques would be used with relation to our groundwater sampling in Benin.*

Haiti Seminar:

- *This society, with its uncanny balances, is deemed necessary to be changed by the outside world. The question is how should it be changed. What is the proper approach? From just a brief visit one can see how many attempts have failed. In retrospect, it is easy to see the past's faults, but to incorporate these faults and design the perfect future seems barely in the realm of possible. . . I found my purpose was not to encompass the*

communities with Americanized standards, but embrace the culture and educate those I come in contact with about tools of a healthy community.

- *For me, it was in understanding these basic lifestyle differences that enabled me to fully appreciate the people of Haiti. My view of them changed from one of pity to one of awe and admiration.*

- *Making a difference in a Third World country; is it even possible? One thing that I learned from our trip there was that it isn't too hard to make an immediate difference. The difficult aspect of such an experience is making any kind of lasting difference . . . This trip had a profound impact on me. I told my friends when I got back that I felt like I had learned just as much in a week down there than I had all semester. It was just a different kind of knowledge. It's the kind of knowledge that can never be taught through a book or a classroom.*

- *The moral questions that volunteer engineers must ask themselves introduce yet another degree of difficulty. Whether or not modern engineering would truly help the people of Haiti is a very real concern with an indefinite answer.*

Gender Mix in the Learning Models

The literature on engineering education shows considerable interest in gender issues[5,6,7]. As a result, records of applications for the Haiti seminar, applications to a prior REU site at Notre Dame (an REU site focused on classical research projects and unrelated to the present REU), and the current REU program were assessed for indication of gender preferences in these programs. In the most recent application pool for the Haiti seminar, 50% of the applications were from women. By design, the participants of the Haiti seminar are chosen to maintain a final population of 50% women. Although the current REU program has only been in existence for one summer, a bias towards women has been noted with 55% of the applications for the summer of 2002 and 56% of the applications for the summer of 2003 coming from women. During the summer of 2002, the REU consisted of 9 women among its 10 participants (90% rate). These numbers compare with the prior REU program (previous 5 years) that maintained an application pool containing 43% women. These numbers can be compared with a 27% population of women in the Department of Civil Engineering and Geological Sciences at Notre Dame and the national average of ~20% women graduating from engineering programs in the United States[8]. Hence, there is evidence that both the Haiti and current REU programs represent viable models with respect to attracting a greater percentage of women into the application pool than are represented in the engineering undergraduate curriculum. It is anticipated that this bias is a direct result of the applied, altruistic nature of these learning experiences.

Exit Activities

Monitoring of the post-experience activities of the students provides a final indicator of the impact realized from these models. Although information for the Haiti seminar is informal and the REU program is in its first year (unfortunately, the students participating in the classroom activity have not been monitored), certain trends appear in the data.

Specific to the 10 students participating in the REU program, three are currently in their junior year of study and have therefore not had the opportunity to pursue post-graduate activities. Of the remaining 7 students, we are aware that four are definitely pursuing graduate school and one will be pursuing graduate school following a personal post-graduation experience. The remaining two students expressed strong interest in graduate school (in the exit survey), but have not communicated with us stating that they definitely have applied to graduate programs.

Specific to the 28 students who have participated in the Haiti seminar over the past 5 years, we are aware of at least 7 (25%) who have pursued service opportunities following graduation (or are planning to pursue these activities upon graduation). Further, at least 5 (17.8%) of these students have pursued, or are planning to pursue, graduate studies. Seven of the remaining students are still undergraduates who have not indicated their future plans. While we know that some of the remaining students have moved into the work force, we have lost track of the activities of 9 of these students.

From these sparse data, we make two observations. First, the REU program appears to be successfully supporting student decisions to pursue graduate studies. Second, the Haiti program appears to have a broader impact on the students, supporting the decision of some students to pursue graduate studies while supporting the decision of other students to pursue service oriented opportunities following graduation. It is noted, however, that the data remain too sparse, at this time, to make any conclusion regarding causal relationships between these learning experiences and student decisions to pursue graduate studies, service opportunities, or other opportunities following graduation.

Discussion

The Department of Civil Engineering and Geological Sciences at the University of Notre Dame has dedicated effort to increasing awareness among undergraduates of the role of the engineer as a significant contributor within a multidisciplinary team for addressing water resources in developing countries. Three forms of learning experience have been utilized in this effort with various levels of commitment of financial resources, faculty time, and risk. From the assessment of student response (as measured by surveys and indicated in exit essays), a number of observations can be made relative to these three models (summarized in Table 2):

- All three models fulfill the common learning objective of student exposure to technical and non-technical aspects of engineering projects in developing countries. Evidence in support of this conclusion includes the increased appreciation for the liberal arts in all groups and the content of the closing essays for both the REU and Haiti experiences (which reflect significant appreciation for the technical and/or social, political and economic factors that impact engineering projects in developing countries). Although not discussed specifically in this manuscript, it is also apparent from the products produced by these students that all three models fulfill the second common learning objective of students working in teams to address a significant water resource project.

Table 2: Summary of conclusions regarding learning outcomes for the three models: H=Learning outcome realized to large degree. M = Learning outcome partially realized. L = Learning outcome not realized or realized to minor degree. ND = No data.

Model	Gender Bias	Exposure to Eng. In Dev. Country	Work in Multi-Disciplinary Teams	Include Strong Non-Technical Component	Inter-National Travel	Work With Local Pop.	Work With Colleagues In Country	Active in Research	Spiritual Component	Service Outcome	Graduate School Outcome
1	ND	M	H	H	L	L	L	L	L	ND	ND
2	H	H	H	H	H	H	M	L	H	H	M
3	H	H	H	M	H	M	M	H	L	L	H

- While all three models satisfy the two general learning outcomes, the learning objectives unique to the individual models result in unique educational experiences for the students under each model. This is evident, for example, in the closing essays from the Haiti and REU participants. The essays from the Haiti program revolve very much around the personal experience of meeting the people and the frustration over trying to find solutions to problems for which the technical aspects were relatively mundane in comparison to the social and economic aspects. The essays from the REU program, in contrast, revolve very much around the research experience in a unique setting. The difference in student experience is also evident in the difference in post-graduation career choice of the students (with nearly all REU participants heading towards graduate education while the Haiti participants chose a number of paths including service and graduate school). Hence, it can be concluded that these three models produce three unique outcomes.

- These learning experiences appear to preferentially attract women engineering students. The percentage of applications to the Haiti and REU programs received from women has been significantly above the local and national percentages of women in engineering curricula as well as above the percentage of women applying to our prior REU program that was focused on more classical research themes.

- There appears to be a significant difference between the responses of the students versus those of the representatives of industry. Specifically, there is an elevated perception among students of the importance of experiential learning within the undergraduate curriculum (we refer here specifically to the perceived importance of strength in the liberal arts, exposure to engineering case studies, opportunities to pursue engineering outside of the United States, opportunities for exposure to challenges faced in developing countries, and undergraduate research).

Two questions were asked in the introduction to this manuscript. The first is relatively straightforward in terms of response. The data provided herein combined with review of the student project reports and presentations show that the overall learning objectives associated with each model are achieved within the individual models (Table 2).

The second question involved a judgment of the added risk, financial burden, and faculty time associated with the Haiti and REU models. The answer to this question is less well defined based on the available data. The data imply that all three models provide a worthwhile learning experience that is attractive to engineering students interested in engineering practice in developing countries. In terms of the individual models, we conclude:

- The classroom model (Model 1 in Table 2): This model provides students with exposure to the non-technical aspects of engineering projects in developing countries. The students also receive substantial opportunity to work in a team environment. Hence, from the standpoint of the learning objectives, this course can be justified. As noted in the data provided herein, however, this course does not provide substantial exposure to the native population. Its impact on the student interest in graduate studies or service opportunities is uncertain.

- The Haiti model (Model 2 in Table 2): This model provides the students with an experience substantially different from either the classroom or REU models due both to its focus on the spiritual and social aspects of the projects and to the close working relationship between the students and the local population. Review of the data, in particular the exit surveys, illustrates that this learning experience fulfills the learning objectives not only in the technical arena, but also those related to the spirituality and interaction with the local population. It is unclear whether these latter learning objectives (or the applied engineering experience obtained in the field) could be adequately addressed through modification of a classroom-based experience. Hence, it would appear that the added cost, faculty time, and risk associated with this experience can be justified, from an educational standpoint, for situations in which learning objectives such as spirituality or interaction with the local population are important course components. Outcomes from this model, as evidenced by our data, include both interest in post-graduation service opportunities and graduate school.

- The REU model (Model 3 in Table 2): This model provides the students with substantial exposure not only to engineering in developing countries, but also to graduate-level research. There is a strong propensity for the participants of this program to pursue graduate studies. Hence, this model fulfills all the general learning objectives as well as the first of the learning objectives unique to this model. Within our first year of experience with this model, we have had only limited success, however, in fulfilling the second unique learning objective (working with graduate students and colleagues in-country) due to logistical difficulties within the countries involved. In comparing this model with the other models, it is clear that this model provides a more rigorous technical (research) experience than does the Haiti model. It also provides a more dramatic learning experience than does the classroom model. Further, this model seems to be the most attractive to women enrolled in engineering curricula. The data are not conclusive, however, from the standpoint as to whether the additional costs, faculty time and risks associated with an international REU can be justified, from an educational standpoint, over the learning experience gained by the student in a standard REU experience. It is likely that this evaluation will depend strongly on the perceived importance of exposing these students to the conditions present in a developing country. Hence, it is anticipated that justification of this international experience, at least from an educational standpoint, must be evaluated on a case-by-case basis.

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