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Global Design Team: A Global Service-Learning Experience*

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The rising globalization trends of international competition and the changing societal, professional, and global landscapes for engineering graduates, call for action towards integrated learning strategies to prepare engineers for the future. This paper describes a global service–learning experience, the Global Design Team (GDT), which provides students with high-impact, multidisciplinary, collaborative experience. The global design experience is an intense international cultural exchange woven into service–learning development projects that address engineering grand challenges. This experience strives for positive, sustainable interaction with stakeholder communities through the application of technical skills and competencies of students to specific challenges within the partner communities. The research question addresses whether GDT is an experience effective at positively impacting the global competence of engineering students. The paper presents the GDT model and assessment results of two experiences in Kenya and Palestine. Students participating in GDTs are asked to participate in a pre/post course assessment that monitors the efficacy of the program in meeting a set of global competency outcomes, and community partners are asked to provide feedback on their relationship with the team. Results indicate that the GDT offers engineering students an experience effective at positively impacting global competence, with the potential to be expanded to institutions both nationally and globally. Furthermore, the international partners survey indicates that the GDT is an important service of value to the local community. The paper presents detailed survey and assessment results of what global attributes are impacted by this experience and ways to improve it. The paper shows that the GDT is a unique curricular experience towards changing the mindset of engineers from designing for an industrial-type client, to designing with a community.

Keywords: service-learning; global competency; multi-disciplinary teams; undergraduate design

1. Introduction

With significant changes in the demographics of the working population and an increasingly globally-linked economy, engineers will be expected to work across multiple time zones, cultures, and languages to address the grand global challenges of our time, such as the impacts of global climate change, sustainable energy, access to clean water, and the development of better medicines [1]. Development of solutions for these challenges will require multi-disciplinary and often, multi-culturally-minded expertise and approaches. To address this changing global environment, engineering institutions must position themselves to address the primary global challenges of today and the near future. International competition and changing societal, professional, and global landscapes for engineering graduates, call for action toward integrated strategies of learning, discovery, and engagement to prepare engineers for the for the future.

Curriculum-integrated, project-based, service-learning is well-suited to preparing engineers to effectively apply their technical knowledge to real-world problems while considering the complexities added by non-technical issues such as social, cultural, economic, and political factors. The model proposed by Purdue University's Global Engineering Program to address this curricular gap is the Global Design Team.

The concept of Global Design Teams was first introduced by Silliman, *et al.* [2] as an international service learning experience. The goal of this paper is to present the Global Design Team as a global service learning experience and to assess its impact on student learning and host communities. Specifically, the objectives of the paper are:

1. Review selected service and global learning models across selected engineering institutions.
2. Present the Global Design Team as an international service-learning model with selected example projects.
3. Show preliminary assessment results of student learning and impact on host community (i.e. value to partner).

2. Selected service-learning models

This section investigates what qualifies a program as "service learning" and currently employed models of both domestically-based and international service learning at Purdue University and other institutions.

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2.1 Service learning

Purdue University's Center for Instructional Excellence [3] defines service learning as an experience that incorporates the following components:

1. Connecting service with learning by instilling curriculum-based competencies through service with a positive community impact.
2. Reflection on participation that allows for assessment of personal development and impact on the community, as well as evaluation of project progress.
3. Reciprocity in that both the student and partner organizations give and receive equally.
4. Critical thinking through participation in situations which inspire creative problem solving.
5. Social responsibility by raising civic awareness, expanding participants' empathy, and increasing interest in community engagement.
6. Experiential learning that allows students to exercise skills through hands-on learning that will be valuable in their future.
7. Needs-based projects that are identified by the community.

Purdue's most notable domestic service-learning experience is the Engineering Projects in Community Service (EPICS) Program. Project teams are classically an interdisciplinary group of students from the College of Engineering (non-engineering majors do participate as well) who range from freshmen to seniors. Typical project partners include domestic not-for-profit organizations, schools, and departments within Purdue University. Project ideas are submitted by the partner, and objectives are developed with the partner and project team over a period of time. Projects may last several semesters over which team members will change as students graduate or decide to no longer participate in the program. The EPICS program boasts a vertically-integrated project team model of freshmen through seniors which allows for continuity between semesters [4].

In 2010, EPICS had been adopted by twenty universities in the United States, Columbia, Puerto Rico, and New Zealand, including Butler University in Indianapolis, Indiana [5]. At Butler, participation in EPICS is required in order to receive a B.S. in Software Engineering and enable students to be eligible for a four-year NSF scholarship [6].

Service-learning experiences are offered at numerous engineering institutions across the nation. Massachusetts Institute of Technology, University of San Diego, Illinois Institute of Technology, University of Massachusetts-Lowell, University of Michigan, University of Colorado at Boulder, Colorado School of Mines University of South Florida, Florida A&M, Florida State University, and Pennsylvania State University all host a variety of successful and impactful international and domestic service-learning opportunities [6–17].

Engineers Without Borders (EWB) and Engineers for a Sustainable World (ESW) are other examples of engineering service-learning models that are present at many institutions across the United States and world. EWB has 150 chapters in the United States and 250 chapters worldwide [18]. EWB pairs student groups with host communities and non-governmental organizations to address infrastructure and resource issues in developing countries. EWB's model promotes community ownership of the project and integrates social, economic, and environmental factors in order to promote sustainability. Student groups may visit their host community for one week up to several months depending on the circumstances. EWB has set forth three criteria for attributes they expect designs to exhibit, including: ability to be replicated in neighboring communities, easy to maintain, and low-tech [18].

Engineers for a Sustainable World (ESW), with 22 chapters in the United States and one sister chapter in Rwanda, has a slightly different model in that they address issues of sustainability in the developed and developing world by bringing together multi-disciplinary teams of students from inside and outside engineering. Student groups partner with local organizations to empower them to maintain and improve upon the design and technology provided by ESW [19]. Both EWB and ESW are non-curricular activities, in that they are typically promoted as student organizations with a faculty advisor and a local project contact. Progress and deliverables have limited accountability as the students are not driven to produce based on an end-of-semester deadline or grade.

3. Global Design Team (GDT)

Global Design Teams are unique because they bring together undergraduate and graduate students from different disciplines, inside and outside of engineering, to solve real-world problems in partnership with an international partner over the course of one academic semester. Depending on the size and scope of the project, teams may range from two to twenty students under the advisement of a faculty member. GDTs partner student teams with end users of the project outcomes, such as non-governmental organizations (NGOs), community groups, businesses, or other research institutions to accomplish three primary goals:

1. Provide students with real-world, full-cycle design experiences.
2. Raise the global awareness of students through global experiences.
3. Increase global humanitarian impact.

GDTs provide students with the opportunity to put their technical engineering skills to work in an unfamiliar, real-world setting. Some engineering fundamentals transcend location; but, many attributes of a competent global engineer require experience to be achieved. These attributes include understanding issues of sustainability in different cultures and regions of the world and the ability to communicate and partner effectively across cultures. GDT provides students with an experience that increases their global competence through addressing a problem that while technically familiar, is contextually unique. Students are required to communicate directly with their international partners via conference calls, Skype, emails, and during personal travel. This interaction increases student competence and confidence for communicating across cultures. Furthermore, designing for communities divergent from one's own provides students with the opportunity to consider problems and related influencing factors holistically. In future situations encountered by the engineer, the problem and factors may not be the same, but the mindset for thinking about problems will be familiar.

Elements of a successful GDT include:

1. Local logistical assistance in the form of a partner organization working on the ground at the project location.
2. Local engineering support such as a project engineer or other technician working for the partner organization. This individual will be knowledgeable about the region and the project and can provide data and other technical information and feedback to the team.
3. Global engineering program support which includes financial assistance, travel and logistical arrangements, and contacts with the partner organization and other technical expertise.
4. Technical advisor/academic unit to support and advise the team through the design process. When the partner organization is an academic institution, it is advisable that a faculty advisor be involved at both ends to coordinate student efforts.
5. Academic accountability in the form of participation for academic credit in order to ensure that the final deliverable meets the caliber expected from the students involved.

The GDT model fills current gaps in international service learning by providing students with projects that are relevant to their degree program and complementary to their curriculum. Students are able to contribute their individual skills and interests to the team and exercise them in a way that a traditional engineering curriculum would not allow. Furthermore, GDT allows for the building of a knowledge base, control over project quality, and an opportunity for long-term partnership. These projects provide learning experiences to the students as well as a sense of service and value added to the international partner. This added value is the main criterion for impact assessment discussed later. Projects are intended to be part of a long-term partnership between domestic institutions and the local host. The private sector can and has played a significant role by: providing resources to offset travel expenses and pilot designs, facilitating local in-country logistics, and serving as long-term partners to help with identification and implementation of long-term community needs.

3.1 Building a knowledge base

The Global Design Team model provides an opportunity for project continuity from one semester to another. By involving students from multiple grade levels and committed faculty, projects may be completed in phases and the knowledge base increased every year. Students from the previous year will contribute their knowledge gained and build a greater understanding of the project community and technical issues involved. This continuity can be achieved through academic route via faculty members or administrative route via departmental administrative staff. This structure requires additional resources which can be justified since the GDT model does leverage ABET requirements that many of the US and international institutions seek accreditation for their programs.

3.2 Quality control

Delivering a quality product to the project partner is one of the most important aspects of a GDT. This is ensured by having close faculty involvement and regular feedback from the project partner. Faculty leaders are responsible for ensuring technical soundness, while the project partner helps to ensure that students are considering projects holistically and including considerations for economic, social, cultural, and political-related factors specific to the project location. Multiple levels of feedback by the faculty and the project partner during the design process help to ensure that the final project deliverable is appropriate and meets the needs of the community. On occasion it has been necessary for representatives from the Global Engineering Program to intervene in the design process to ensure that community partners are being fully involved, or course objectives are being met.

3.3 Partnership

Long-term relationships with project partners are established by providing the organization with quality deliverables and a commitment to a future partnership that is strengthened through visits to the partner, including during the project delivery. Project sustainability, continuity, and maximum impact is ensured by integrating the GDT within institutional and research partnerships that help generate ideas whose pursuit directly builds on a long-term desired partnership. This partnership increases the chance to solicit outside funding to sustain these projects over time. Financial sustainability of the GDT is essential for the longevity and continuity of the projects.

3.4 Project conception and development

Projects are proposed by a partner organization in a bottom-up approach. Organizations, institutes, or other entities approach Purdue as a potential partner to help address the specific design needs of their organization or the community their organization serves. Also, academic institutions which have a current partnership with Purdue University may identify projects in their own community for teams to address in cooperation with students from their institution. The proposers of these projects typically turn into the on-the-ground consultants through the design and implementation process.

3.5 Faculty recruitment

Faculty recruitment is crucial to the success of GDT. It is necessary to match willing and committed faculty with regionally and technically appropriate projects. Committed faculty, experienced in working in the target region, are critical to successful projects. Success, in this case, is determined by: student learning, on-the-ground impact (value to partner), quality of project deliverables, timely transfer of deliverables, and sustainability of the project (financially and in terms of the partnership).

The financial aspects are addressed through grants and sponsorship from private, non-governmental, or public sector partnerships. Financial and partnership sustainability are critical to long-term success.

3.6 Student recruitment

For projects typically occurring in the Spring semester, a callout is held in September to solicit interest from students. Information about upcoming projects is also distributed through academic advisors, faculty, and the web. Applications are used to achieve the desired team size and demographic (with regard to seniority, area of study, and experience). Once a team is established, meetings begin in late fall to establish team objectives, discuss background information, and initiate team dialogue contact with the partner. Students from approving academic units may participate in a GDT as their senior capstone experience.

3.7 Timeline

Throughout the semester, students work on the project, attend regular group meetings, and maintain regular contact with the assigned person at their partner organization via conferencing software and e-mail. Students ask questions, request data, and provide information about the team's progress, while at the same time, the partner organization provides feedback and assistance toward an appropriate solution. Progress presentations are provided regularly during the semester to peers, faculty, and project partners, enabling on-going feedback and guidance on future steps. At the end of the semester, students will have a deliverable ready to present to their project partner at the project location. Many students (62 percent of participating GDT students in Spring 2009) choose to travel to their project location to present their work in person to the project partner, visit the project site, and implement the design. Funding for travel and other project travel expenses is provided through grants and sponsors, however, the students do bear a portion (typically one-third) of the expenses.

4. GDT curriculum

4.1 Course learning objectives

Specific course learning objectives (CLOs), overarching to all GDT projects, have been developed. It is expected that students participating in GDT will fulfill these objectives through their research, design, interaction with partners, and delivery/implementation of the design to the project location. Objectives are split into three categories and include:

Technical:

1. Apply basic engineering principles to global settings/problems.
2. Apply relevant design standards for different countries.
3. Utilize design tools used in various countries or institutes.
4. Research appropriate technologies for particular geographic regions of the world (pre-

Table 1. Purdue University's Global Engineering Program "Global Learning Outcomes" [22]

Global Technical	Global Professional	Global Social—Cultural
I.1 An awareness of varying regulations, codes of practice, standards, technical specifications, testing/inspection procedures, environmental regulations, and systems of measurement between countries and regions. I.2 Familiarity with the concept of a "global product platform." I.3 The ability to apply familiar concepts to unfamiliar, real-world problems I.4 The ability to use design tools to solve engineering problems	II.1 The ability to adapt to cultural norms in a professional arena and act appropriately II.2 The ability to make ethical and socially responsible decisions in the context of a culture divergent from my own. II.3 The ability to analyze problems from a different cultural frame of reference. II.4 The ability to communicate professionally in a culturally-appropriate manner.	III.1 The ability to practice social and cultural responsibility, e.g. resource sustainability. III.2 Proficiency in a second language. III.3 The ability to be cross-culturally adaptable/flexible III.4 The ability to contribute to a culturally-diverse team
Sample Assessment Items		
Item I. 3 My engineering knowledge could be adapted to apply to local conditions.	Item II. 2 I can make ethical and socially responsible decisions in the context of a culture divergent from my own.	Item III. 3 I am cross-culturally adaptable and flexible.

viously implemented technologies in region and in world).

5. Research and consider available materials and labor skills of the community to ensure applicability, sustainability, and maintainability of designed artifact.
6. Learn about specific challenges (political, economical, environmental, etc.) of the region of the world and how they may impact design.

Professional:

7. Exhibit effective team work skills.
8. Communicate and conduct oneself professionally and appropriately with global partners.
9. Make ethical, context sensitive decisions.
10. Exhibit effective presentation skills.
11. Manage time effectively.
12. Exhibit sense of responsibility to partners and target community.

Inter-personal:

13. Accept cultural norms and practices/
14. Exhibit awareness of cultural diversity.
15. Exhibit awareness of political/religious/cultural similarities and differences of target community.
16. Exhibit a personal interest in the people and the culture of the target community.

5. Global competencies

The Global Engineering Program proposed a set of global engineering outcomes, mapped from Purdue's Engineer of 2020 Target Attributes, as inspired by the National Academy of Engineers', *The Engineer of 2020* [20–21]. In developing these outcomes, the Global Engineering Program considered each of Purdue's Engineer of 2020 target attributes and identified those that could be enhanced through global learning experiences. As an example: work in multi-cultural teams can contribute to the development of more effective leadership abilities, while science and math skills can be improved by curricular changes at home and do not require an international learning experience to increase scope. Leadership abilities and knowledge of science and math are two of the twenty Purdue's Engineer of 2020 Target Attributes [21]. A new set of outcomes were derived and are, for the purpose of this study, considered to represent global competence for engineers. Table 1 includes these outcomes and sample items from the assessment instrument. Details of the assessment protocol using this instrument are described in Section 7.

6. Assessment limitations and next steps

The ability of these Global Learning Outcomes to measure the impact of the Global Design Team experience, and other international opportunities, on students is limited. Results from design teams in 2010 highlighted many shortcomings of the measure. This combined with the relatively low sample size of students completing both pre- and post-assessments has forced the researcher to rely primarily upon qualitative data for determining whether GDTs have had an impact on student learning. In an effort to build the next generation of assessment, a course profile, following the methodology used to develop course profiles for the ABET, Inc. accreditation for GDTs was developed. The global learning outcomes listed in Table 1 consist of a varying number of performance criteria

(PC) which further define the meaning behind each of the outcomes. Figure 1 contains these learning outcomes and related performance criteria. Following each PC, is a number in parentheses which refers to the level, adapted from Bloom's Taxonomy of Learning [23], at which each of these criteria should be exhibited by students on a scale from 1 to 8, where 1=Knowledge, 2=Comprehension, 3=Application,

Outcome I.1: An awareness of varying regulations, codes of practice, standards, technical specifications testing/inspection procedures, environmental regulations, and systems of measurement between countries and regions.
Students will have:

1. an awareness that standards very between countries and regions (2)
2. a knowledge of how to find standards for different countries (1)
3. an ability to apply such standards to design (3)
4. an understanding of the factors that influence the difference in standards between regions (4)

Outcome I.2.: Familiarity with the concept of a "global product platform."
Students will have:

1. a knowledge of the concept of a global product platform (1)
2. an understanding of the interconnectedness of the globe with respect to economies and the environment (2)
3. an understanding of global issues and trends (4)
4. an understanding of the need to be innovative and add value to the field of engineering in order to be competitive (2)

Outcome I.3: The ability to apply familiar concepts to unfamiliar, real-world problems.
Students will have the ability to:

1. identify basic engineering principles that transcend location (5)
2. identify problem constraints (6)
3. consider and incorporate various design factors and constraints (such as economics, safety, manufacturability, sustainability, environmental) (4)
4. evaluate relevance and quality of engineering solutions (6)

Outcome I.4: The ability to use design tools to solve engineering problems.
Students will have the ability to:

1. use basic software tools (word processing, spreadsheets, graphics, and Internet) (3)
2. use engineering analysis software tools (3)
3. use data analysis software (3)

Outcome II.1: The ability to adapt to cultural norms in a professional arena and act appropriately.
Students will have:

1. the ability to analyze a situation and react appropriately (3)
2. an understanding of relevant cultural norms (4)
3. an awareness of the language and demeanor appropriate for a given situation (6)
4. respect for the opinions and interaction styles of others (6)
5. the ability to promote oneself in a cultural-appropriate professional manner (3)

Outcome II.2: The ability to make ethical and socially responsible decisions in the context of a culture divergent from my own.
Students will have:

1. an awareness of what is generally considered culturally appropriate in regions of practice (3)
2. an awareness of the existence of varying cultural norms (3)
3. the ability to analyze an engineering solution to determine its relevance and acceptability in a given culture (4)
4. an awareness of their ethical responsibility to the community (7)

Outcome II.3: The ability to analyze problems from a different cultural frame of reference.
Students will have the ability to:

1. analyze the relevance of engineering solutions from the perspective of their client (4)
2. understand the contextual complexities of engineering problems (4)
3. add or remove design constraints depending on their cultural relevance (6)

Outcome II.4: The ability to communicate professionally in a culturally-appropriate manner.
Students will have:

1. knowledge of differences in communication across cultures (3)
2. the ability to present and discuss technical and non-technical information (7)
3. the ability to utilize appropriate interpersonal skills (3)

Outcome III.1: The ability to practice social and cultural responsibility, e.g. resource sustainability.
Students will have:

1. an awareness of their ethical responsibility to the community (7)
2. the ability to incorporate resource-conserving (with respect to cost, the environment, natural resources, labor, etc.) practices into engineering design (6)
3. an awareness of the impact their work will have on the community (6)

Outcome III.2: Proficiency in a second language.
Students will have the ability to:

1. communicate effectively in a second language in social settings (8)
2. communicate effectively in a second language in professional settings (8)
3. feel comfortable in situations where a foreign language is being spoken (7)
4. learn terms in a second language which will enhance their experience in a foreign country(7)

Outcome III.3: The ability to be cross-culturally adaptable/flexible.
Students will have:

1. an understanding of relevant cultural norms (4)
2. the ability to adapt to unfamiliar cultural settings (3)

Outcome III.4: The ability to contribute to a culturally-diverse team.
Students will have the ability to:

1. work effectively with individuals from different cultural backgrounds (3)
2. articulate multiple and divergent perspectives when debating and proposing a solution to a problem (4)
3. understand the norms of team dynamics in different cultures (5)

Fig. 1. Performance criteria for each global learning outcome (Numbers in parentheses refer to the degree to which students are expected to reach through participation in a Global Design Team).

4=Analysis, 5=Synthesis, 6=Evaluation, 7=Valuation, and 8=Not Applicable. This course profile continues to evolve as discussions continue regarding the potential impact of GDTs and the definition of global competence for engineers are debated by researchers.

7. Assessment protocol

As a starting place for measuring the global competence of engineering students, an instrument was developed, based on the outcomes in Table 1. These instruments are intended to evaluate which outcomes are currently being addressed by target programs/courses within the College of Engineering and to explore the relationships between outcomes exhibiting statistically significant change, the student's year in school, gender, and the project location or travel destination.

7.1 Instrument

Students participating in Global Design Teams are asked to participate in a pre-/post- course assessment that monitors the efficacy of the program in meeting the global competency outcomes, as reflected in Table 1. A pre- and post-assessment with matched items, using a Likert Scale [24] was developed to evaluate which global competency outcomes are addressed by different global learning opportunities.

The pre-assessment is administered in person when students start involvement with the Global Design Team at the beginning of a given semester. Subsequently, the post-course assessment is administered, either at the end of the semester or following the students return from travel, whichever is relevant to the particular student. Post-assessments for programs ending outside of the academic semester are administered using a secure online platform.

The instrument is also available to be administered to the course instructor at the completion of the course. This application of the instrument will evaluate whether the instructor intended or believed they were addressing the global learning outcome during the course. Finally, project partners or hosts are asked to answer some of the items from the instrument via telephone interview. The host is asked to comment upon the quality of the design, with regard to appropriateness (sustainability and user-centeredness) and acculturation of the students while visiting the project location.

7.2 Journals

Since Spring 2010 students have been asked to reflect upon their participation in the Global Design Team through required journal entries, done weekly during the semester and daily while traveling. Journal entries may be written and submitted as a group, but personal journals are also encouraged. In-semester journal entries include information about progress on the project, distribution of work load, interaction with the partner organization's contact person, interaction with technical advisors, challenges, surprises, non-technical learning experiences (cultural, social, etc.) and anything else that seems relevant to the student. Journal entries during travel include information about daily activities, contacts made in the host country, interactions with hosts, notes on culture, challenges, and surprises. Students are encouraged to provide photos to supplement the journal entries. Some guiding questions are provided to the students to aid them in writing a beneficial reflective journal entry. As these journals were not required by the faculty leaders for academic credit, journals were submitted inconsistently and in low numbers. Excerpts from the journals were used to support claims of student learning, but could not be analyzed in the intended fashion.

Ideally, the journals would be coded for instances of commentary related to the global competency attributes of Table 1. Examples of the proposed analytical codes are presented in Table 2. Through analysis of the journals, the researcher would be able to determine which of the attributes are being addressed, and which may need to be explicitly addressed through changes in course structure. Analysis would also provide insight into the triggers

Table 2. Sample analytic codes for analysis of qualitative data

Learning Outcome	Description	Example(s)
Communicate across cultures effectively through technology	Comments regarding communication with international partner	"We Skyped with Busia and asked him questions about common irrigation practices in Ghana." "The email Amjad sent this week helped us move forward with the database."
Applying familiar concepts to unfamiliar real-world problems	Comments regarding using previously learned skills and knowledge and applying it to the design at hand	"When I was interning for the USDA, we designed spring developments for livestock which might work for this location." "We considered applying the same kind of steering found on a riding lawnmower to the design."

that prompt students to develop certain learning outcomes.

8. Results and discussion

Descriptions of past GDT projects are provided in Table 3. For 2011, seven diverse projects are planned for five countries and will provide an opportunity to impact more students from different disciplines.

8.1 Case Study 1: Water filtration, Eldoret, Kenya

In partnership with Moi University and the Aqua Clara Foundation, a Michigan-based not-for-profit organization, a team of Purdue University students developed a method for the provision of potable water at St. Catherine's Girls' School in Eldoret, Kenya. Under the advisement of their faculty leader, the team developed and tested reactors for reducing concentrations of microbial pathogens and fluoride in the water supply, attempting to meet World Health Organization standards for potable water. The students traveled to Eldoret for several days to build and install a full scale reactor in situ. Travel was funded by a Purdue University-sponsored grant to encourage collaboration with Moi University.

Twelve students participated in this experience, and ten completed both the pre- and post-assessments. Of the ten students, eight were seniors in an engineering discipline, one was a graduate student in engineering, and one was a sophomore in Applied Mathematics. All but one of the respondents tra-

Table 3. Example GDT projects

Partner	Project Title: Description	Location
Spring 2008		
Palestinian Hydrology Group	Water Collection, Treatment, and Distribution: Five students from Agricultural and Biological Engineering developed a domestic and agricultural water distribution system and made recommendations for treatment and collection of spring water for a village in the West Bank.	Al'Nwaimah, Palestinian West Bank
Spring 2009		
International Water Management Institute	Irrigation Design Tool and Water Quality Risk Assessment: Four students from Agricultural and Biological Engineering developed an irrigation design program and water quality risk analysis for application in West Africa.	Ghana
African Centre for Renewable Energy and Sustainable Technologies	Basic Utility Vehicle: 12 students from Agricultural and Biological Engineering and Agricultural Systems Management designed and built a low-cost, low-technology vehicle for application in Cameroon.	Bangang, Cameroon
Spring 2010		
African Centre for Renewable Energy and Sustainable Technologies	Basic Utility Vehicle: 20 students from Agricultural and Biological Engineering, Mechanical Engineering, Agricultural Systems Management, and Mechanical Engineering Technology designed and built a low-cost, low-technology vehicle for application in Cameroon.	Bangang, Cameroon
African Centre for Renewable Energy and Sustainable Technologies	Hydroelectric Energy Design: 9 students from Agricultural and Biological Engineering, Chemical Engineering, Materials Science Engineering, and Mechanical Engineering analyzed hydroelectric technologies currently employed by ACREST and made recommendations for improvement to their systems.	Bangang, Cameroon
African Centre for Renewable Energy and Sustainable Technologies	Wind Energy Design: 2 students from Agricultural and Biological Engineering designed a wind turbine for application in Cameroon.	Bangang, Cameroon
Aqua Clara Foundation and Moi University*	Water Purification: 12 students from Agricultural and Biological Engineering, Chemical Engineering, Civil Engineering, Engineering Education and Applied Mathematics designed and constructed on-site a slow sand filtration system for a girls' school in Eldoret, Kenya.	Eldoret, Kenya
Palestinian Hydrology Group*	Water Resources Assessment: 8 students from Agricultural and Biological Engineering, Civil Engineering, Construction Engineering and Management, and Industrial Engineering analyzed and made recommendation for domestic and agricultural water distribution infrastructure, water pricing, and irrigation management strategies for Jericho.	Jericho, Palestinian West Bank

* Expanded descriptions below

Table 4. Kenya GDT student demographics

Respondent	Gender	Major	Year	International Student?
1	Female	Ag. & Bio. Engineering	Senior	No
2	Male	Applied Mathematics	Sophomore	Yes
3	Male	Chemical Engineering	Senior	No
4	Male	Ag. & Bio. Engineering	Senior	No
5	Male	Ag. & Bio. Engineering	Senior	No
6	Male	Ag. & Bio. Engineering	Senior	No
7*	Female	Ag. & Bio. Engineering	Senior	No
8	Female	Civil Engineering	Senior	Yes
9	Male	Engineering Education	Graduate Student	No
10	Male	Ag. & Bio. Engineering	Senior	No

* Did not travel to Kenya.

veled to Kenya. The results of these assessments are illustrated in Figures 2 through 4. The student scores are on a Likert scale of 1 to 5, with 1 being Strongly Disagree, and 5 Strongly Agree. The items (I.1 through III.4) can be found in Table 1, and the respondent demographics are available in Table 4.

Figures 2 and 3 provide individual student responses to the pre- and post-assessment of global learning outcomes, respectively. The advantage of the visualization provided by these figures is that we can see the variation in student responses. Outcomes I.1, I.2, and III.2 appear to experience the most variation between students. I.1 may have been a subjective question in that it asked whether students were "aware of varying standards and codes for design between countries and regions." The question was intended to gauge whether students were aware that different countries may have different standards than they are likely familiar with in the United States. It may, however, have been

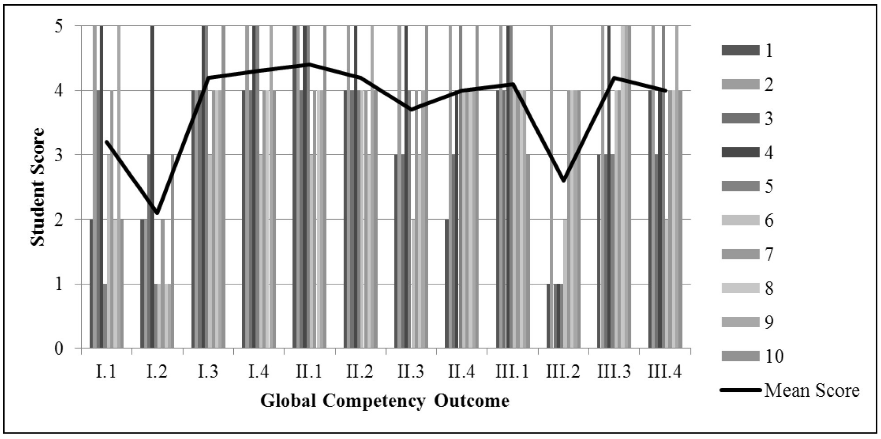

Fig. 2. Pre-assessment results of Kenya GDT by student and assessment item (n=10).

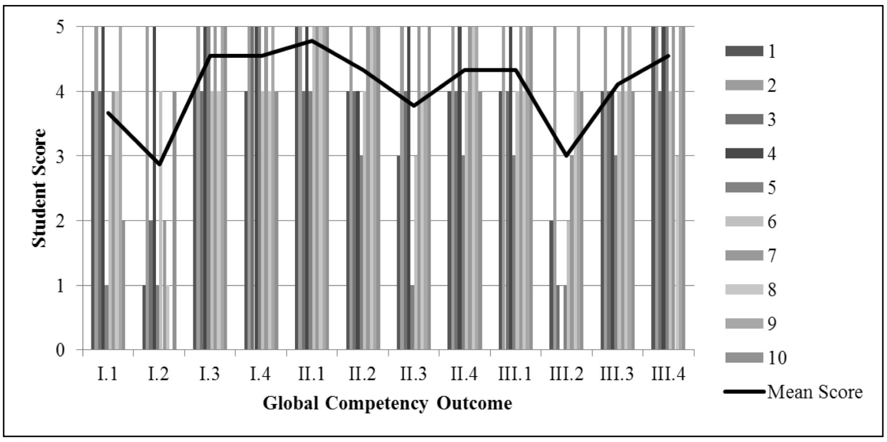

Fig. 3. Post-assessment results of Kenya GDT by student and assessment item (n=10).

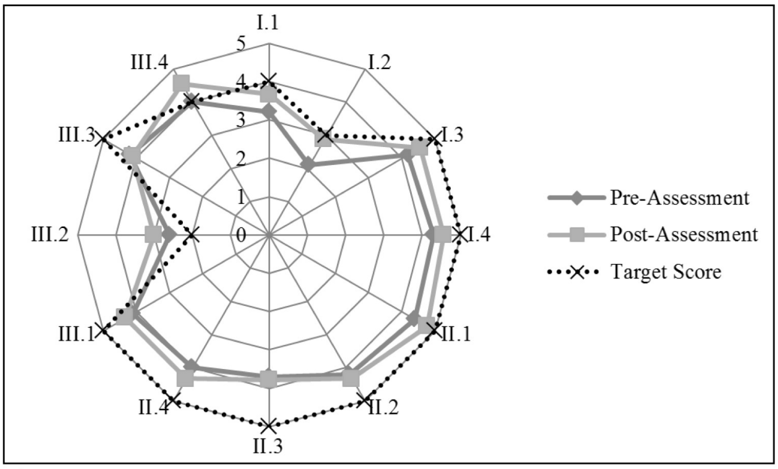

Fig. 4. Averaged pre- and post- scores for students who traveled from Kenya GDT (n=9, non-traveling respondents).

interpreted as asking whether or not students know these individual variations. The variations in I.2 and III.2 will be discussed in the Synthesis section (8.3) following Case Study 2.

Figure 4 provides a different visualization of the students' pre- and post-assessment results as well as the target score for the experience, that is, the faculty leader's opinion of how well they addressed the outcomes in their course. These results indicate that, on average, this experience added value to the students' global competence across nearly all measured outcomes. Increase is noted across 11 of the 12 attributes, with a slight decrease in III.3. The relatively low "added value" for this group may be explained by the fact that the students who participated had a very difficult time traveling to the location, delayed for days by the ash plume from the Icelandic volcano over Amsterdam, then had very little time to complete the task of building the water filter, let alone socialize with their project partners, once they finally arrived in Kenya. The students' self-assessment was overall slightly lower, but generally consistent with the experience the faculty leader thought he had provided. The sample size of the cohort of GDT students was too small to conduct statistical analyses on the data.

As mentioned in the assessment protocol, journal entries from students were submitted inconsistently and in low numbers, thus, the data was not analyzed in the intended fashion. Excerpts from the journals and qualitative responses from the assessments follow:

- "This experience should be a fundamental part of engineering curriculum. Not the international travel part per se but creating a real product that benefits others less fortunate than you is an essential part to understanding what engineering can do."—Respondent 9
- "The global aspect of the course was really awesome. It was great to see how a university in a very different culture operated. It was also a good experience to work alongside individuals from Kenya while implementing the design."—Respondent 6
- "The communications between groups was a huge challenge, but that was the fun part—learning about international communications."—Respondent 5
- "It was a positive experience but could have been more organized. There needs to be more communication with the international affiliates, and I felt like more ownership could have been placed in the hands of the students."—Respondent 6
- "There were many situations when we had to think on our feet and implement a solution to a problem as quickly as possible."—Respondent 3
- "We had to consider many different aspects in our final design included, but not limited to, social, economic, cultural, and technical constraints."—Respondent 6

Feedback from the domestic project partner indicated that the final design was technically sound and appropriate, but communication between all stakeholders in the project was difficult. The partner states, "[The design] will be very useful, as the main thrust is to have a constructed and regularly evaluated large-scale bio-sand filter." The partner also indicates, "There was difficulty in communication with their counterparts at Moi, which made planning more difficult, but those hurdles will now be removed as relationships have been forged and experience gained." This feedback indicates that while the experience is generally positive for students, there is room for improvement with regard to organization and partner involvement.

8.2 Case Study 2: Water resources assessment, Jericho, Palestinian West Bank

In Spring 2010, Purdue University partnered with the Palestinian Hydrology Group (PHG) for the second time to develop plans for an Integrated Environmental Management and Planning Tool for Jericho City. The design incorporated environmental and socio-economic aspects of efficient management of water supply/resources for the area. The Purdue team partnered with students from Birzeit University who offered collaboration and feedback to the Purdue team during their design process. Travel was funded by Aramex and allowed the students and their faculty leader to stay for 7–14 days in Jordan and the West Bank. This time allowed for multiple visits to the field site and discussion with project partners, as well as cultural events and tours. Seven students participated in the experience, and six completed both the pre- and post-assessment. Three students (two seniors, and one graduate student in engineering) traveled to the project location with their faculty leader. The results of these assessments are illustrated in Figures 5 through 8. The student scores are on a Likert scale of 1 to 5, with 1 being Strongly Disagree, and 5 Strongly Agree. The items (I. 1 through III. 4) can be found in Table 1, and the respondent demographics are available in Table 5.

This particular design team experience provides an interesting look at the types of students that are attracted to different projects and how academic level may affect perceived global competence. The composition of this group was much different than that of other Global Design Teams in the past. Initially, the program had difficulties attracting enough students to work on the project, perhaps due in part to political conflict in the region, but in the end it attracted four graduate students and four seniors in engineering, three of whom were international students. This group was on average more mature, with regard to age and year in school, than the other teams, which leads to the second notable difference with this group: the decrease in scores between the pre- and post-assessments. In particular, the responses to items II.2, 3, and 4, the "global professional" competencies, saw negative change over the course of the project. It seems possible that the more we learn about our own self and the world, the more we realize all the things we do not know or understand and as a result feel less globally competent. Especially in this case, the experience of working on a project based in the Palestinian West Bank was so complex and illuminating for the students: once they understood the complexity of the social, cultural, political, and economic situation, they felt less competent than they did before they began learning about the project and the region.

Again, journal entries from students were submitted inconsistently and in low numbers, so as a result, the data were not analyzed. Qualitative responses from the students who participated in the Jericho GDT provide an interesting look at their experience with this project. These responses

Table 5. Palestine GDT student demographics

Respondent	Gender	Major	Year	International Student?
1*	Male	Industrial Engineering	Junior	Yes
2	Female	Civil Engineering	Graduate Student	No
3	Male	Ag. & Bio. Engineering	Senior	No
4*	Male	Civil Engineering	Graduate Student	Yes
5	Male	Ag. & Bio. Engineering	Senior	No
6*	Female	Ag. & Bio. Engineering	Senior	No

* Did not travel to Palestine.

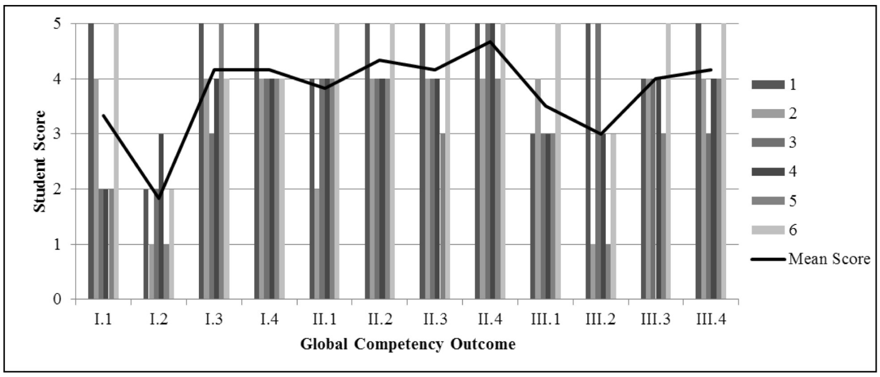

Fig. 5. Pre-assessment results of Palestine GDT by student and assessment item (n=6)

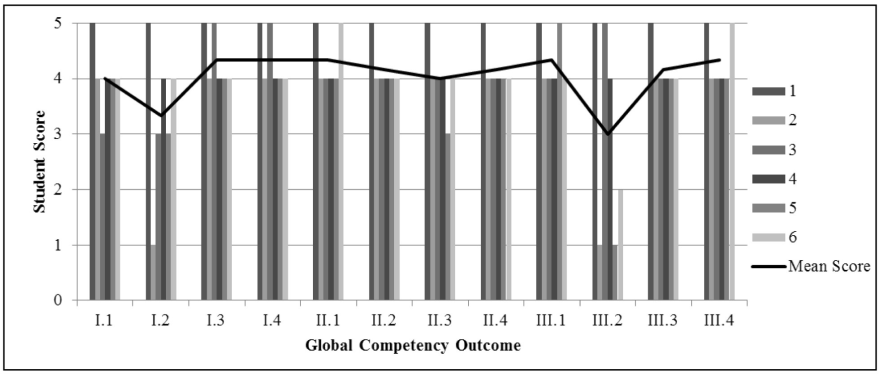

Fig. 6. Post-assessment results of Palestine GDT by student and assessment item (n=6).

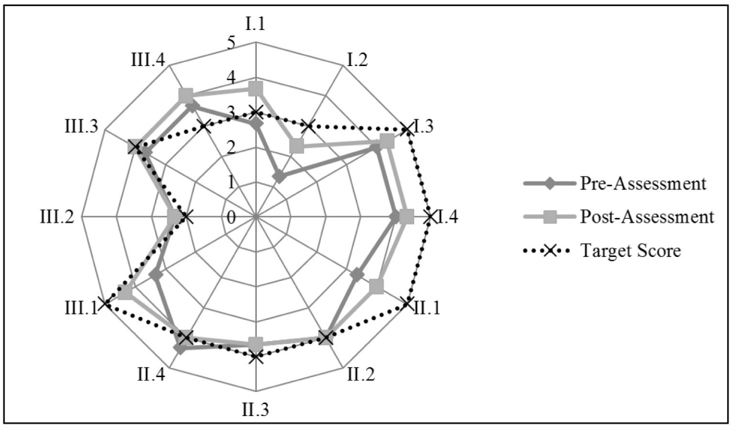

Fig. 7. Averaged pre- and post- scores for students from Palestine GDT (n=3, non-traveling respondents not included).

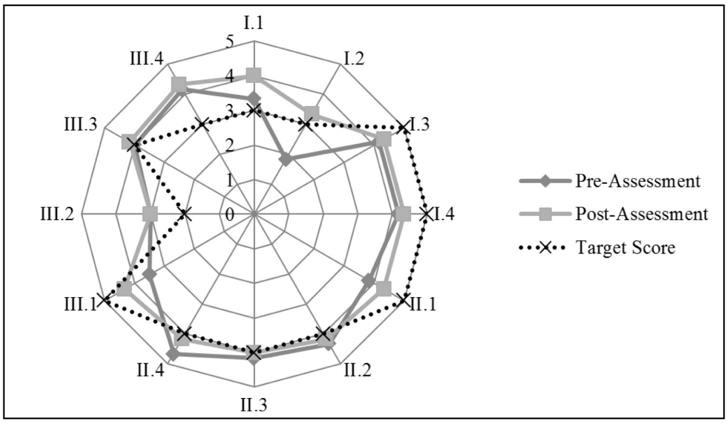

Fig. 8. Averaged pre- and post-scores for students from Palestine GDT (n=6).

support the previous points of the type of demographic attracted to this project (personality and maturity-wise) and the level of exposure to a diverse environment. Selected excerpts from these responses follow:

- "Really enjoyed the overall structure of the course—I was entirely comfortable working within my group, constantly impressed at the level of expertise and knowledge and willingness to share personal stories/experiences/anecdotes. A very culturally-enriched course, which jives with my learning style. It's good to define a personal stake in a project that seems, initially, unrelated to your present life(style). Really felt like we were doing useful, productive work that strengthened collaborative ideals and let us bond, so to speak, over the desire to truly improve people's lives."—Respondent 6
- "It taught you to think of a holistic design

solution and the implications for all stakeholders involved. It also pushed us to communicate well and be culturally sensitive while addressing the engineering design.''—Respondent 3

- ''I would recommend this type of course to MATURE STUDENTS. There must be sense of cultural sensitivity and respect for other cultures BEFORE the student leaves the country. Cultural sensitivity should not be left to be learned while on the trip or to the [final briefing].''—Respondent 2
- ''Seeing problems in Palestine from the engineers' perspective who worked there was very interesting and taught me to think differently.''—Respondent 3
- ''I had to learn about new technologies, region, culture, and work in a team of different majors.''—Respondent 5

The primary contact person at the Palestinian Hydrology Group, who communicated with the students during the semester and hosted them during their travels, provided feedback on the team's performance. He says, ''The team has done good work and makes use of the available data as much as they can. I can say that, in general, their design and techniques were appropriate to the targeted area.'' Generally, the team's communication skills and ability to acculturate were applauded, however, the partner highlights that the students needed more time in the field in order to fully understand and address the project problem.

8.3 Synthesis

Overall, in Figs 2 and 3, and 5 and 6, it can be noted that items I.2 (familiarity with the concept of a ''global product platform'') and III.2 (proficiency in a second language) seem to be the least addressed by the Global Design Team experience. Many of the qualitative responses indicated that students were not familiar with the term ''global product platform'' used in item I.2. It is possible that addressing this topic of entrepreneurship, business, and economics in a different fashion might elicit a better response. Furthermore, item III.2 does not receive a high score from the students as foreign language practice is not directly addressed in the Global Design Team model. Some students (mostly international students) participating in GDTs are already proficient in a second language, but any gain in language capability through GDTs would happen through immersion while traveling. When looking at the instructor's responses to the assessment, they tended to believe that they provided a more full experience with regard to the professional and technical competencies, than the students believed they had received, and a lesser social-cultural experience.

Aside from these issues, the ''global technical'' outcomes all saw varying degrees of increase between the pre- and post-assessment in both case studies. This is expected as the most tangible objective of Global Design Teams is to design and deliver a solution to an engineering challenge.

9. Conclusions

After review of the survey and assessment results, we note that the Global Design Team is an effective tool for increasing the global competency of engineering students. Furthermore, the GDT model is a mutually beneficial experience, in that both the students and the community partner benefit from the relationship. Both project partners featured here indicated that they would like to work with similar student teams on future projects: a demonstration of the impact these teams have the potential of making on communities in need of technical assistance. However, the model and the assessment have shortcomings. First and foremost, everyone involved in GDTs must be in the mindset that they are participating in what should be a truly sustainable, holistic, community-based and community needs-driven project. This involves moving away from perceiving the community partner as an industrial client in the sense that typical engineering curricula are designed, and toward a partner who can share knowledge and actively shape the outcome of the project. Furthermore, technical and social-type design constraints cannot be separated into two distinct categories, but instead should be viewed as a whole. Second, the reach of Global Design Teams both needs and will benefit from becoming more multidisciplinary and expanding to include students from more disciplines, not only underrepresented engineering disciplines (such as Aeronautical Engineering, Biomedical Engineering, and Nuclear Engineering), but also non-engineering majors. While serving non-engineering majors is not the mission of the Global Engineering Program, providing engineering students with multidisciplinary global learning experiences, including non-engineering disciplines, is among those values. Overall, the Global Design Team is a unique program that offers engineering students in the US and internationally an integrated experience of global, service, and design curricular experience that is proven to add value to both students and international host community.

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