Advances in Engineering Education

SUMMER 2013

Implementing Problem Based Learning through Engineers Without Borders Student Projects

ANN WITTIG
City College of New York
New York, NY

ABSTRACT

Engineers Without Borders USA (EWB) is a nonprofit organization that partners student chapters with communities in fundamental need of potable water, clean air, sanitation, irrigation, energy, basic structures for schools and clinics, roads and bridges, etc. While EWB projects may vary in complexity, they are all realistic, ill-structured and challenging, and so have the potential to provide a unique educational opportunity for problem based learning (PBL). Since the number of EWB student chapters on college campuses is large and growing, this paper explores whether EWB is well aligned with PBL, and the extent to which participation in EWB increased student learning in a cohort of engineering students at the City College of New York. Student learning is assessed for various technical and non-technical learning outcomes (i.e., ABET program outcomes).

EWB is found to be well aligned with the PBL approach. For the student cohort studied, participation in EWB appears to reinforce technical concepts learned in the classroom and to provide a forum for developing an appreciation for or ability in particular concepts that are difficult to adequately address in a classroom setting: ethical behavior, global perspectives, sustainable solutions, effective communication, decision-making and leadership.

Key Words: Engineers Without Borders, problem based learning

INTRODUCTION

Engineers Without Borders USA (EWB) is a nonprofit organization that partners student and professional chapters of the organization with communities in great need around the world in order to address some of the fundamental needs of these communities, such as potable water, clean air, sanitation, irrigation, energy, and basic structures, roads and bridges. To date, there are over

170 professional and 180 student EWB chapters in the United States, and these chapters work with communities in over 45 developing countries (EWB-USA, 2012) and are managed by staff at EWB national headquarters. The projects are intended to be community-driven (i.e., communities self-identify their needs and learn to independently operate and maintain the finished product) and collaborative (i.e., communities are consulted on proposed designs and implementation strategies and community members provide manpower to assist in data collection and design construction). EWB chapters are expected to fundraise 100% of the costs associated with a project, including travel and materials.

EWB projects can be ill-defined and technically challenging to solve, and provide opportunities for students to learn or refine their knowledge of technical concepts traditionally taught in a classroom as well as concepts that are difficult to teach in a classroom setting. Further, the general methodology to conduct an EWB project is aligned with a problem based learning (PBL) approach. Since the number of EWB student chapters is large and continues to grow, this means that there may be a large and growing opportunity to use PBL through EWB projects to enhance student learning. This study seeks to establish whether EWB projects that are facilitated by faculty are indeed aligned with PBL, and the extent to which participation in EWB affects student learning.

In the sections that follow, general information about the organization is provided first. Then the applicability of EWB to PBL is discussed, beginning with a background on the PBL approach, and continuing with a discussion of the appropriateness of EWB projects as PBL problems. Then assessments of enhanced student learning of ABET program outcomes through participation in EWB are presented and discussed, and the practical challenges of using EWB in PBL as experienced by the CCNY student chapter are described.

BACKGROUND ON EWB

Organization of an Example EWB Student Chapter

Students volunteer to participate in EWB. The City College of New York (CCNY) EWB student chapter is made up of 4 to 5 active undergraduate students and 10 to 20 total students each year, of various levels and disciplines. Typically, the senior undergraduate engineering students take on the leadership roles and mentor the juniors and sophomores in administrative and engineering activities. The chapter is advised by two civil engineering faculty members, one of whom is a licensed environmental engineer, and mentored by several other civil engineering faculty and practicing engineers. The student project manager is the primary point of contact with EWB national headquarters, but faculty advisors also have ready access to EWB national headquarters staff.

The CCNY EWB club has established a set of expectations for the involvement of students, faculty and professional mentors who want to participate in the chapter. In summary, the expectations for faculty or other professional participants are as follows. The faculty advisor is expected to meet with the entire chapter regularly to address fundraising, administrative, student and faculty recruitment, and project selection. The faculty technical lead is a faculty member who possesses the expertise to design and conduct the project and who is expected to meet with the student project managers and design teams on a regular basis to address engineering design issues, and conduct or arrange workshops to prepare students for travel. This person actively advises the student project manager, approves the final student design before its submission to EWB, and is also expected to travel to assess or implement a project. Faculty and professional technical mentors are recruited as needed and give occasional guidance to the students on one or more aspects of a project. The students also set expectations for themselves, as follows. The chapter president, vice-president and secretary are elected and are expected to take responsibility for general aspects of the club and meet monthly with the entire club. The student project manager is elected to oversee the entire project including design, planning, assessment, implementation, budgeting and reporting. The student assistant project manager is elected to serve as the next project manager, and shares some of the responsibilities of the project manager to help groom them to be project manager. Student design team members are expected to take on the design or planning of a particular component of the project. Each team is led by a team leader who is in the process of or who has already completed the coursework relevant for their component of the design. Student travel team members are the group of students who travel to the community to assess or implement the project design. These students apply to be on the travel team and are expected to have been productive contributors to the club during the semesters prior to travel.

Steps Involved in a Typical EWB Project

A single EWB project is completed in many steps, as shown in Figure 1.

The process begins with a community, which self-identifies their need (e.g., potable water) and its justification (e.g., poor public health as a result of contaminated water). Projects can be acquired by two mechanisms. Projects that are identified because an EWB chapter was already doing work

Figure 1. Phases of a project life in Engineers Without Borders.

in a community, or one nearby, are acquired simply through application; projects that are formally registered with EWB are acquired by competitive bids open to both student and professional chapters. During the bid process, the chapter documents their ability to complete the project and to communicate effectively with the community. Once a project is acquired, the chapter first conducts an "assessment trip" to the community to gather information to more clearly define the project scope, and identify any community preferences or constraints that may affect its design. The chapter then begins work on a design that addresses the community's need, considers the community's input, and is low-cost, small-scale, replicable and sustainable. When the design is completed, the chapter conducts one or more "implementation trips" to the community to build their design and educate the community on its use and maintenance. In later trips for other projects in the area, the chapter returns to the community to check on the design and assess whether improvements are needed. At all stages of the project, the EWB national headquarters requires written and oral plans and progress reports.

Collaboration (i.e., between the student chapter and the community members) occurs throughout the project and may include defining the problem, identifying and deciding between possible design strategies, and identifying and deciding between possible implementation strategies. Typically, the community members have much to contribute to these discussions as they are vastly more familiar with their environment than an EWB chapter that is new to the area, as they might possess experience negotiating construction challenges specific to their area.

The CCNY EWB chapter raises the money required to conduct each of the steps in a project through grants from nongovernmental organizations, gifts from large construction companies and individuals, and through an ongoing agreement with the administration of their college.

DESCRIPTION OF THE INNOVATION

The innovation presented in this work is the use of student participation in EWB as a unique opportunity to engage students in PBL. The types of projects undertaken by EWB vary in complexity, but all are realistic and ill-structured by definition. The projects may be used to develop or refine ability in various technical and non-technical learning outcomes (e.g., ABET's program outcomes). Some of these outcomes are typically learned in the classroom, such as technical approaches, an appreciation of constraints and the importance of uncertainty. Other outcomes may be difficult to adequately address in a classroom setting: ethical behavior, global perspectives, sustainable solutions, effective communication, decision-making and leadership. As opposed to service learning opportunities at home, participation in EWB also provides opportunities for students to learn about another culture and broaden their understanding of global social justice issues.

In addition to being well aligned with the PBL approach, EWB projects have the potential to challenge students with varying learning preferences (e.g., Kolb's experiential learning model), as will be discussed next.

SUPPORTING LITERATURE AND EXAMPLE APPLICATIONS

Problem Based Learning

Some of the core characteristics of PBL are problems that are ill-structured and authentic (Jonassen, 2000; Weiss, 2003) and that provide opportunities for students to use self-direction and collaboration (Weiss, 2003) to identify learning issues, gradually build and incorporate knowledge, and evaluate themselves. While there are differing viewpoints on the role of the educator in PBL, there seems to be compelling evidence that PBL is the most efficient and effective when the educator acts merely as a facilitator and scaffolds mindful and productive engagement with a problem, tools, or peers (Collins et al., 1989; Hmelo-Silver et al., 2007; Hmelo-Silver and Barrows, 2006; Kirschner et al., 2006, 2007).

While some, including the author, believe that PBL facilitates a deeper knowledge of a subject area, most believe that the pedagogical merit of PBL is to prepare students to be self-directed, life-long learners and practical problem solvers (Gijselaers, 1996; Hung et al., 2003; Dochy et al., 2003) by helping them develop higher-order skills that can be flexibly applied to other situations such as reasoning skills (e.g., Hmelo, 1998), problem solving skills (e.g., Gallagher, Stepien, & Rosenthal, 1992; Polanco et al., 2001), and self-directed learning skills (e.g., Hmelo & Lin, 2000; Putman, 2001).

PBL has its origins in medical education (Barrows and Tamblyn, 1980) and has been used since then as an alternative to traditional, teacher-centered methods in medicine (Barrows, 2000; Hmelo, 1998), nursing (Alavi, 1995; Alkhasawneh et al., 2008; Amos and White, 1998; Andrews and Jones, 1996; Rideout and Carpio, 2001), business (Capon and Kuhn, 2004), science (Deckard, 2008; Linn & Slotta, 2006), and engineering (de los Rios, 2010; Harris and Briscoe-Andrews, 2008; Jayaram et al., 2010; Woods, 1996). It has even been successfully applied in K-12 education (Mergendoller et al., 2006; Schwartz and Martin, 2004; Torp & Sage, 2002).

The types of problems to be solved in an EWB project align well with those used for PBL. EWB projects are authentic since they address the needs of actual communities and involve real environments and constraints. Since the communities usually lack infrastructure and are fairly remote, very little information is available to EWB participants in advance of their first visit to the community beyond the location of the community and a justification of a need for the project. As a result, the projects are ill-structured, and there are many learning needs for students to identify and much new knowledge to gather and incorporate. Finally, the scale of most EWB projects can be small enough for a team of students to solve, since the student or professional chapters are responsible for fundraising all of the costs associated with the project, including travel and materials.

The approach to solve problems encountered in EWB projects also aligns well with the steps associated with PBL. The typical steps associated with PBL include defining the problem, identifying learning issues, building and incorporating knowledge, and evaluation. In EWB, students organize themselves in small collaborative groups and are self-directed in their approaches to tackle issues pertinent to a project or to the club's functioning. Further, the reporting requirements of the parent organization of EWB reinforce the PBL progression of understanding and solving a problem in that they require, in this order, the following: a bid, an assessment plan, an assessment report, a design report, an implementation plan, and an implementation report.

To illustrate the appropriateness of EWB projects as PBL problems, consider the following example of the types of EWB activities associated with each step in the PBL solution of a problem. The example activities are presented in general terms, and for the case of a potable water system project that has to consider cultural factors, material availability, and environmental factors.

Define the Ill-Structured Problem

Students initiate the PBL method during the competitive bidding process. They select a project of interest to them based on their previous knowledge. They review the summary of the project provided by EWB, identify whether the strengths of the group complement those needed to successfully complete the project, and use the information to assemble their bid to EWB national headquarters.

Considering the example of the potable water project, the summary information provided by EWB may be limited to the need for a potable water system to address a water contamination problem in a small farming community of 50 inhabitants located at a specific latitude and longitude. With such limited information, much of the problem is still undefined.

Identify Learning Issues

At this stage in the PBL process, the chapter begins to identify unknown information that they will need to complete their design. The learning issues are identified by considering possible design approaches and constraints and the information needed to support them. As a result of this brainstorming, the chapter develops their assessment trip plan. They discuss resources and make contact with other EWB chapters, Peace Corps volunteers, or other non-government organizations working in the area to learn about environmental and material resources.

Considering the potable water system example again, there are many possible learning issues that the team might identify given the paucity of information provided in the project summary provided by EWB. Such information includes details regarding the social factors that influence the project such as the community's potential uses of water and their preferences in a water system, and the current health issues in the community and their relationship to current water use practices. Other likely information includes technical information needed to complete the design, such as the quantity and quality of possible sources of water to develop, the topography of the area between the water source and the community, the need for reinforcement of water transmission lines, and the strength of locally available materials to be used in the construction of the design. The team will likely need to gather information that affects the implementation of the design, such as the schedule of availability of the community to assist in the construction, the availability and cost of materials, and transportation and energy constraints that may limit the ability of the team to convey materials or use powered tools during construction. Some of the technical and implementation information will be obtained through discussions with the community members, since they are more familiar with their environment than an EWB chapter that is new to the area and as they might possess experience negotiating construction challenges specific to their area.

Research and Incorporate New Knowledge

The travel team educates the larger group on their assessment findings, and the larger group then integrates the information into their previous knowledge. The team also incorporates their knowledge into an assessment trip report, which summarizes the information that was gathered during their trip. The design team leaders then lead their respective teams to refine their learning issues and repeat the cycle of questioning, researching and integrating as necessary to refine the proposed design approach. Teams identify and prioritize methods of solution and justify why certain approaches are better than others, and many develop diagrams, lists, and concept maps to support and illustrate the design to the larger group. When the design alternatives have been compared and the final design selected for its cost, scale, ability to be replicated, and sustainability, the team once again incorporates their knowledge into a design report and an implementation plan that is submitted to EWB for approval. This report identifies the problem, the considered methods of solution, available data, design assumptions, material specifications, and the final design complete with quantity of materials and tools needed to implement the design. Before permission to travel is granted, the report must be reviewed and approved by the EWB technical advisory committee, and the students must orally present their design.

Consider the potable water project example mentioned earlier. In this example, the chapter formally incorporates new knowledge twice: once in the assessment report and once in the design report and implementation plan. In between these two milestones, the chapter also informally incorporates knowledge in the refinement of the problem statement and in the design process. The data obtained during the assessment trip allows the chapter to refine the ill-structured problem statement of “construct a potable water system” to “construct a water system that collects a specific source of water, protects the water from contamination in a specific way, disinfects the water as required by local laws, and conveys the disinfected water at a minimum specific flow rate over a specific terrain in order to meet the specific capacity needs of the community”. The data gathered during the assessment trip also facilitate the design of various components of the project such as water wells and pumping systems or covered retention embankments around natural springs with overflow and drainage systems; covered water storage tanks with foundations, overflow systems, valving, and drainage systems; trenched and/or above-ground water pipelines with joint reinforcement and drainage systems; water purification systems with or without purification; and water distribution systems of tap stands or smaller conduction lines to homes.

Conduct Self-Assessment

Self and peer assessment is facilitated on several levels. Design teams meet regularly to make progress towards their self-directed design. The student project managers write up aspects of the design as they are finalized, review the work of the team members, and meet with the design teams to suggest refinements to the report. Throughout these self-assessments, additional feedback is provided internally by the faculty advisor facilitator, and externally by the EWB technical advisory committee.

During assessment and implementation trips, the travel team also meets regularly to distribute work assignments, and update each other on their progress and any issues they encounter. These meetings also provide students with opportunities to self-assess.

Considering the potable water project mentioned earlier, this step in the PBL process is facilitated through weekly working meetings, and nightly progress reporting while in the field. Most of these meetings involve open discussions.

Kolb’s Experiential Learning Theory

EWB projects have the potential to stimulate different types of learners across multiple domains, and at different levels of difficulty, as students individually define their involvement in a project. According to Kolb’s experiential learning theory (1984) there are two modes of learning based on perception: abstract conceptualization (AC) or “thinking” and concrete experience (CE) or “feeling”, as well as two modes of learning based on processing: reflective observation (RO) or “watching” and active experimentation (AE) or “doing.” AC involves the development of an intellectual

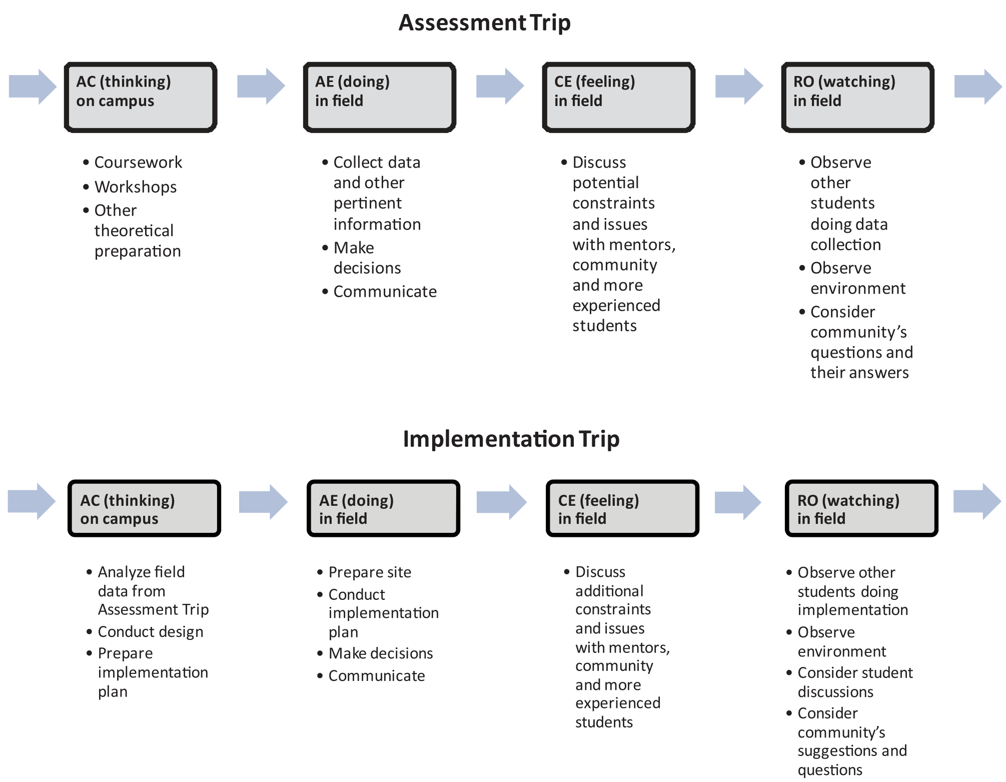

Figure 2. Kolb's experiential learning theory as it applies to EWB projects.

understanding of a theoretical concept such as through coursework. In comparison, CE involves the development of a practical understanding of a theoretical concept based on specific experiences. RO involves the observation of others as they apply theoretical concepts and, in the process, the appreciation of different perspectives and a search for meaning. In contrast, AE involves the application of theoretical concepts to real problems, and in the process, the development of an appreciation of practical constraints.

Generally, all of the modes of learning are facilitated in a single step of each EWB project. Figure 2 provides examples of how EWB project activities complement all the phases in the cycle of Kolb's learning theory. For example, during EWB projects, AC provides the technical theories that will need to be applied to a project, such as a hydraulic analysis or a structural design. CE, on the other hand, is needed to adapt the engineering analysis to the constraints of the environment where the project will be located and the preferences and needs of the communities. RO is needed to learn new skills (e.g., construction, leadership) from more experienced students or to learn from the issues or mistakes made by students on prior similar projects. In contrast, AE applies to decision making, communication, information gathering, and the actual implementation of a project design.

In conclusion, EWB projects are well-poised to engage students in PBL and across all of the modes of learning.

ASSESSMENT

Student Cohort

The CCNY student chapter of EWB was founded in 2005. The active membership of the chapter has remained small over that time period, at approximately 4 to 5 students in any given year (i.e., the total membership in any single year is larger, at 10 to 20 students). Since some students participate over multiple years, the total number of students who could be considered to be active participants numbered 14 as of 2011. All 14 of these active student participants formed the cohort investigated in this paper. The small sample size is the primary limitation of this assessment. However, while small, the cohort does include students participating in EWB in different years, on different projects, and with different interests (i.e., as evident by their majors).

The cohort includes 14 undergraduate students total: 10 civil engineering students, 2 mechanical engineering students, and 2 environmental engineering students. All 14 students contributed technically to a project. When asked how they spent most of their time in EWB, 6 students identified technical design of hydraulic, ventilation, structural engineering and environmental engineering components of a project; 6 identified construction (i.e., field work); and two identified preparatory activities to support travel such as fundraising, workshop planning, and management activities such as logistical planning, budgeting and management. In addition to these technical contributions, all of these students also served in leadership positions for at least one semester of their participation in the chapter. Some served in positions that supported the regular activities of the chapter such as president, vice president, secretary, or treasurer and others served in positions that supported a specific project such as project manager, assistant project manager or design team leader.

These students contributed to 4 different projects, all conducted within the same region of Honduras, consistent with the EWB mission to dedicate service to a single geographical area for a minimum period of five years. Three of the four projects involved the development of gravity fed potable water systems that captured and pipelined spring water to a central location where it was disinfected and then distributed to populations of 50 to 100. One of the projects involved the development of ventilation systems for indoor stoves to reduce indoor air pollution in the main cooking areas of homes within a community.

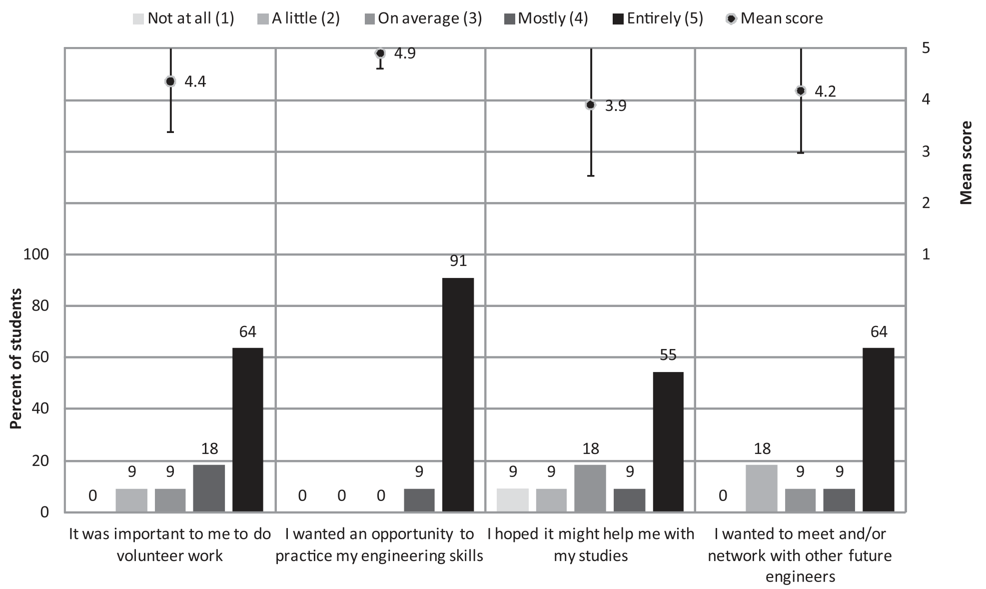

Figure 3. Students' perception of their motivation for participating in EWB.

Students' Perceptions of their Motivation for Participating in EWB

Student motivation for volunteering free time to an organization like EWB is likely to vary across student chapters and individuals in the chapters. The CCNY EWB cohort members were asked why they participated in EWB and were given four options to select from as well as the option to identify their own reason. They were asked to rate their preferences as: "not at all", "a little", "on average", "mostly" and "entirely". The results of this survey are presented in Figure 3.

The primary motivation identified by the cohort was the opportunity to practice engineering skills already learnt. According to one student, "It brought to life a lot of what I had learned in engineering classes and my internship in construction."

The secondary motivation for student participation was service. In the words of another student, "Engineering should not be about the biggest building, the money, or the largest structure. For me it is about making the biggest impact to the less fortunate."

In fact, a review of all of the comments suggests that the combination of opportunities to both practice engineering and to do public service motivated the students to participate. For example, one student commented: "I wanted to use my skills to help other people." Another explained: "I participated in EWB because I was looking for a way to do real engineering work (including construction) in a real life project that actually helped hundreds of people. I loved the idea that I could use my basic engineering skills to help others live easier lives."

Students also participated in EWB to meet other students and practicing engineers, and because they hoped it would help them in their coursework. A few students identified other motivations for their participation, such as the benefits of participation on their résumes or on scholarship applications.

These comments suggest that students are motivated to participate in EWB to stimulate their preferred mechanism of student learning (i.e., doing, feeling) or to learn technical and non-technical outcomes (i.e., studies in general, networking), some of which may be difficult to teach in a classroom setting. Whether intentional or not, participation in EWB may stimulate student learning across the three domains of human learning (Bloom, 1956; Anderson and Krathwohl, 2001): the metacognitive domain, which pertains to knowing; the psychomotor domain, which pertains to doing; and the affective domain, which pertains to feeling. Topics that engage students across domains are expected to enhance student learning, as seen by Denton et al. (2003) who observed a positive effect on student achievement when an integrated affective-cognitive approach was introduced into a first-year computing class.

Assessment of Students' Perceptions of their Preferred Learning Styles

The prior assessment suggested that some students participate in EWB because it facilitated opportunities to learn in their preferred style. As a result, the CCNY EWB student cohort members were also queried on their preferred learning styles. They were asked "how do you prefer to learn new concepts" and "how do you value the concepts you learn?" They were also given descriptions of each of the four modes of learning so that they could make a more informed decision. They were asked to rate their preferences as: "not at all", "a little", "on average", "mostly" and "entirely." The results of this survey are presented in Figure 4.

A statistical analysis of the survey results suggest that all four modes of learning of Kolb's learning preferences are represented in the CCNY EWB student cohort, and that no one learning style is preferred. Therefore, EWB projects complement the broad range of preferences of the students who participate in the organization, since they stimulate students in all of these learning styles (i.e., see Figure 4).

Assessment of Students' Perceptions of their Learning

The cohort was also asked to compare the technical and non-technical skills they developed through their coursework to those they developed through participating in EWB. The skills that were focused on are the basic course learning outcomes identified by ABET. They were asked the following question: "Thinking about your coursework as a whole, or your EWB experience as a whole, please identify how helpful your coursework versus your work in EWB was to your progress

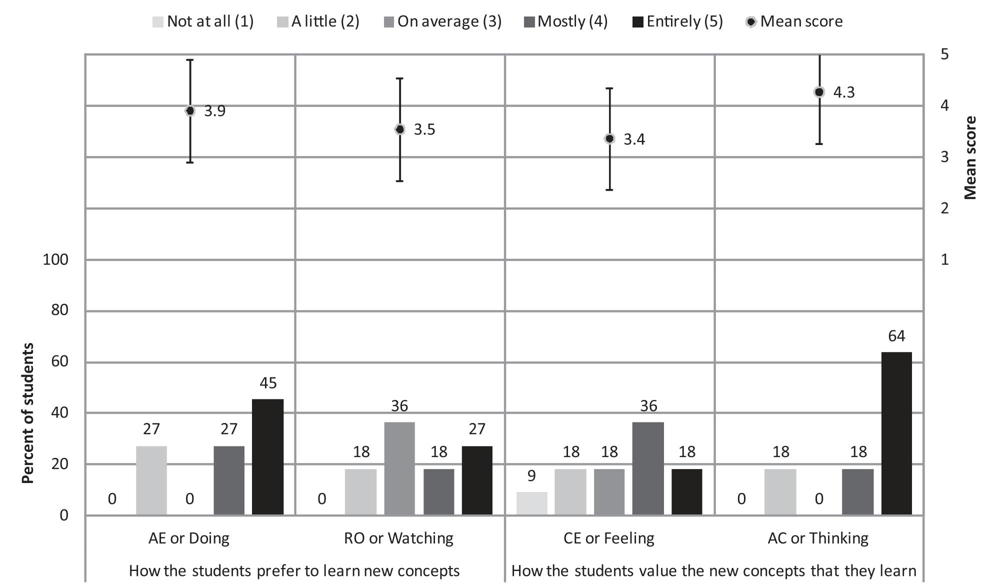

Figure 4. Students' perception of their preferred learning styles.

towards meeting these basic educational objectives held by the CCNY School of Engineering." They were asked to select the best response of five possible responses: "not relevant", "not helpful", "slightly helpful", "helpful" and "very helpful." All students in the cohort responded to the full set of questions.

The results of this indirect assessment are shown in Figure 5 for student achievement of technical program outcomes. A statistical analysis of the responses is also presented to demonstrate the significance of differences in the responses.

A comparison of the statistical ratings for each outcome shows that in some cases, students believed they learned a similar amount from their coursework as they did by participating in EWB. This pertains to outcome A, the ability to apply knowledge of math, science and engineering to solve problems; outcome B, the ability to design and conduct experiments; and outcome K, the ability to use particular techniques, skills and engineering tools to solve a problem. However, for several technical outcomes, students believed they learned significantly more by participating in EWB than they did through their coursework. This finding pertains to outcome C, the ability to design a system, component, or process to meet desired needs with realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and/or sustainability; outcome D, the ability to function in multidisciplinary teams; outcome E, the ability to identify, formulate and solve engineering problems; and outcome G, the ability to communicate effectively. These results

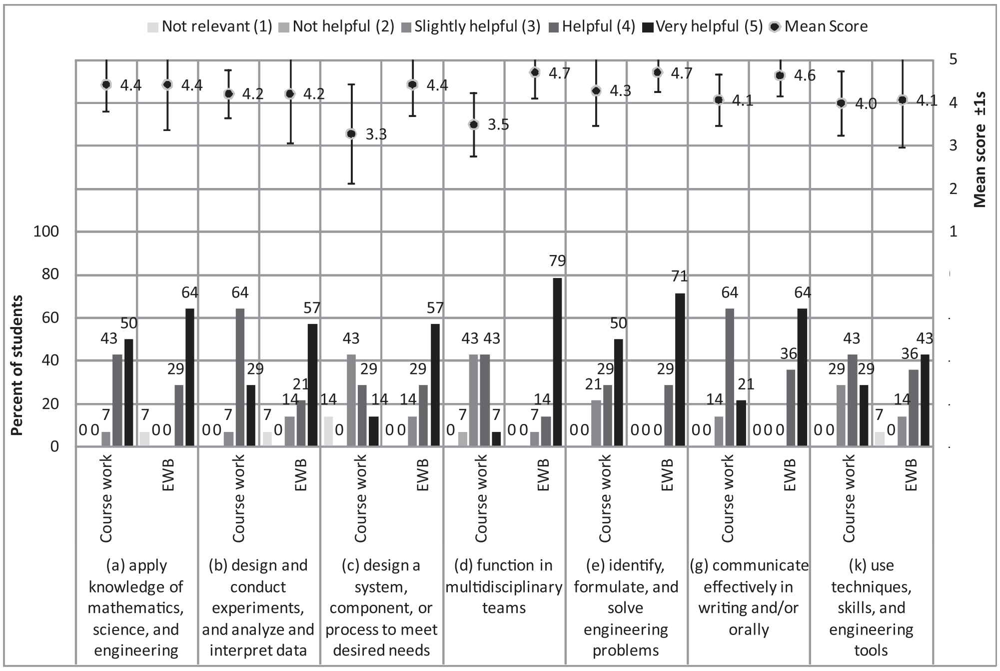

Figure 5. Students' perception of their progress towards achievement of technical ABET program outcomes.

are likely explained by the fact that most EWB projects provide students with realistic problems that require teamwork and communication to solve and consideration of multiple constraints.

The results of the indirect assessment of student achievement of non-technical program outcomes are presented in Figure 6, along with a statistical analysis of the responses.

As far as the non-technical outcomes are concerned, participation in EWB appears to be more helpful to students than their coursework across the board. However, these findings are the most compelling for outcome F which addresses ethical responsibility; outcome H which addresses a broad education necessary to understand the impact of engineering solutions; and outcome L which addresses management, business, policy and leadership. With respect to outcome F, one student commented that EWB is "a good opportunity to learn real responsibility, because we were working with actual communities who were counting on us to improve their quality of life." With respect to outcome L, one student commented: "I didn't expect all of the social lessons it taught me. I had to tackle raising money, working within the college administration system, dealing with difficult personalities, going to bat for projects that lost popularity within the chapter . . . and it all strengthened me in my work after college." Again, these results suggest that EWB projects pose

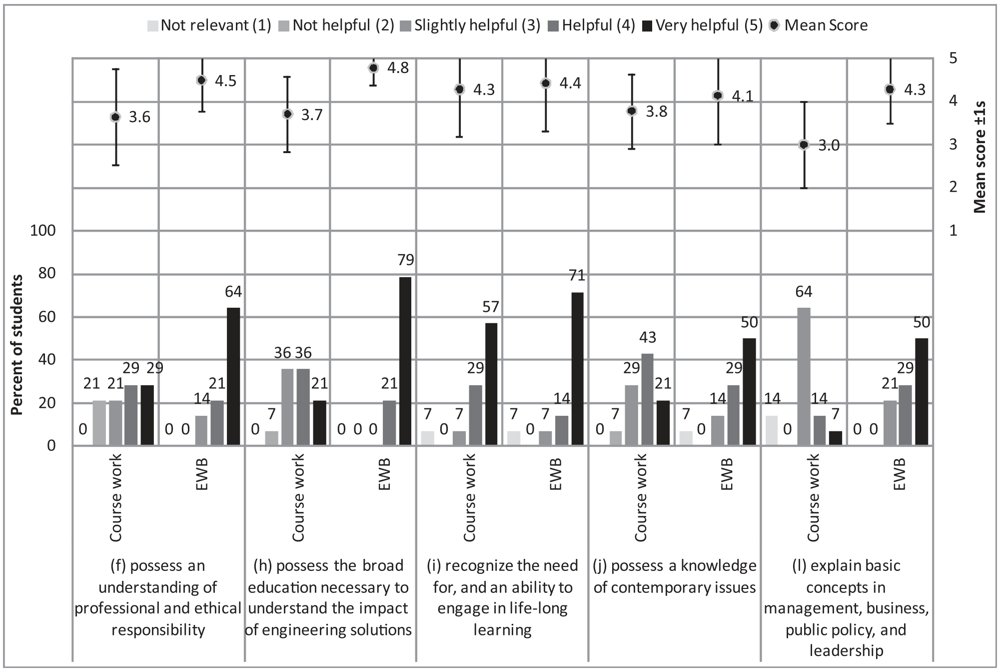

Figure 6. Students' perception of their progress towards achievement of non-technical ABET program outcomes.

realistic problems subject to a number of constraints, and provide opportunities to learn concepts that can be difficult to address in a classroom setting.

In conclusion, this cohort of students indicated that both coursework and involvement in EWB were helpful towards their achievement of the ABET outcomes. However, most students also indicated that involvement in EWB was more helpful to their progress, than was their coursework, as indicated by the larger net percentage of students who found EWB to be generally helpful (i.e., "slightly helpful", "helpful" or "very helpful") and as indicated in the mean of the various student ratings for achievement of outcomes.

CHALLENGES OF PBL THROUGH EWB

EWB projects serve communities in great need and provide meaningful and motivational hands-on, real world PBL experiences to students that help them develop higher-order skills. As might be expected, however, these rewards come with great challenges.

Figure 7: Professor and student in the field.

Cultivating Willing Participants

In order to facilitate PBL, a chapter must be self-organized and self-directed, and the facilitators to the chapter must be willing to act as advisors instead of project managers. Neither of these criteria pose much of a challenge, but participants may need to be made aware of them in advance. A larger challenge is associated with the abilities of the participants. A critical mass of students must be able to complete all of the aspects of the project design and be willing to take on leadership positions. At least one facilitator must be licensed and able to approve the final design developed by the students. Finally, the facilitators must be able to help the students fill in the gaps of their knowledge that they have self-identified.

Negotiating the Time Commitment

While EWB projects are usually small in scope, they still require a substantial amount of time to complete. Given that participation is voluntary, this challenge may affect the ability of the chapter to complete even a small project within a year. At CCNY, we have addressed this challenge by recruiting multiple facilitators, and by advising the students in the chapter to develop assistant leadership positions for the project manager and the various team leaders to help distribute the work load and to cultivate ability in the next generation of leaders in the chapter.

Staying on Schedule

The various phases of EWB projects have specific due dates established by EWB. Even though most EWB students are highly self-motivated, coursework and employment commitments did challenge their ability to achieve weekly design deliverables. At CCNY, the ongoing participation of student design leaders was improved by allowing these students to obtain independent study design credit for their EWB participation, provided that they establish specific design objectives at the beginning of the semester, meet periodic deadlines that they set for themselves, and compile their findings into a report.

Fundraising to Support the Project

EWB chapters are responsible for all of the costs associated with a project, including travel, lodging, materials and equipment. Even a small project completed within a single year can cost $10,000 to $80,000 to implement, and so the challenge of fundraising to support chapter activities is not trivial and can limit the activities of any productive EWB chapter.

CONCLUSION AND SUMMARY

The educational potential of EWB projects is real and large. They are challenging, realistic and ill-structured, and their solutions model the PBL approach. Moreover, they provide a forum for developing abilities that may be difficult to develop in a typical classroom environment, and they stimulate learning in students with various learning preferences. In the words of one of the participants: “EWB feeds your passion for engineering more than any other textbook problem or classroom assignment can ever accomplish. You learn to care about the impact that the steps you take to problem solve has on a particular community or family,” “and you learn information more thoroughly when you feel personally involved.” However, despite the educational benefits associated with using EWB as an innovative teaching opportunity, there are substantial challenges to its sustained use in this manner: an extensive voluntary time commitment of facilitators and of students, a need for a critical mass of participants, and the monetary resources needed to complete a single project.

REFERENCES

Alavi, C. (1995). *Problem-based Learning in a Health Sciences Curriculum*. Routledge, London.

Alkhasawneh, I. M., Mrayyan, M. T., Docherty, C., Alashram, S., and Yousef, H. Y. (2008). Problem-based learning (PBL): Assessing students' learning preferences using vark. *Nurse Education Today 28*, 572–579.

Amos, E., and White, M. J. (1998). Teaching tools: problem-based learning. *Nurse Educator 23* (2), 11–14.

Anderson, L. W. and Krathwohl, D. R. (Eds.), (2001). A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. Allyn & Bacon. Boston, MA.

Andrews, M., and Jones, P. (1996). Problem-based learning in an undergraduate nursing programme: a case study. *Journal of Advanced Nursing 23* (2), 357–365.

Barrows, H. S. (2000). *Problem-based learning applied to medical education*. Springfield, IL: Southern Illinois University School of Medicine.

Barrows, H. S., and Tamblyn, R. (1980). *Problem-based learning: An approach to medical education.* New York: Springer.

Bloom, B. S. (Ed.). (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals*, Susan Fauer Company, Inc, pp. 201–207.

Capon, N., and Kuhn, D. (2004). What's so good about problem-based learning? *Cognition and Instruction 22*, 61–79.

Collins, A., Brown, J. S., and Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453–494). Hillsdale, NJ: Erlbaum.

de los Ríos, I., Cazorla, A., Díaz-Puente, J. M., and Yagüe, J. L. (2010). Project–based learning in engineering higher education: two decades of teaching competences in real environments. *Procedia Social and Behavioral Sciences 2, 1368–1378.*

Deckard, E. (2001). North Dakota State University: Problem based learning in plant sciences. <http://www.ndsu.nodak.edu/instruct/deckard/PBL/index.htm> (1/17/2007).

Denton, L. F., McKinney, D., and Doran, M. V. (2003). Promoting Student Achievement with Integrated Affective Objectives, *Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition*, Nashville, TN.

Dochy, F., Segers, M., van den Bossche, P., and Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction*, *13*, 533–568.

EWB-USA (2011). "About EWB-USA." <http://www.ewb-usa.org/about.php> (1/24/2011).

Gallagher, S. A., Stepien, W. J., and Rosenthal, H. (1992). The effects of problem-based learning on problem solving. *Gifted Child Quarterly 36*, 195–200.

Gijselaers, W. H. (1996). Connecting problem-based learning with educational theory, in: L. Wilkerson and W. H. Gijselaers (Eds) *Bringing problem-based learning to higher education: theory and practice.* San Francisco, CA, Jossey-Bass, 13-21.

Harris, A. T., and Briscoe-Andrews, S. (2008). Development of a problem-based learning elective in "green engineering". Education for Chemical Engineers *3*, E15–E21.

Hmelo, C. E. (1998). Problem-based learning: Effects on the early acquisition of cognitive skill in medicine. *Journal of the Learning Sciences 7*, 173–208.

Hmelo, C. E., and Lin, X. (2000). Becoming self-directed learners: Strategy development in problem-based learning. In D. Evensen and C. E. Hmelo (Eds.), *Problem-based learning: A research perspective on learning interactions* (pp. 227–250). Mahwah, NJ: Erlbaum.

Hmelo-Silver, C. E., and Barrows, H. S. (2006). Goals and strategies of a problem-based learning facilitator. *Interdisciplinary Journal of Problembased Learning 1*, 21–39.

Hmelo-Silver, C. E., Duncan, R. G., and Chinn, C. A. (2007).Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist 42*(2), 99–107.

Hung, W., Bailey, J.H. and Jonassen, D.H. (2003). Exploring the tensions of problem-based learning: Insights from research, in: D.S. Knowlton and D.C. Sharp (Eds.) *Problem-based learning in the information age.* San Francisco, CA, Jossey-Bass, 13-23.

Jayaram, S., Boyer, L., George, J., Ravindra, K., and Mitchell, K. (2010). Project-based introduction to aerospace engineering course: A model rocket. Acta Astronautica 66, 1525–1533.

Jonassen, D. (2000). Toward a design theory of problem solving. Educational Technology Research and Development 48(4), 63-85.

Kirschner, P. A., and Erkens, G. (2006). Cognitive tools and mind-tools for collaborative learning. *Journal of Educational Computing Research 35,* 199–209.

Kirschner, P. A., Sweller, J., and Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist 41*, 75–86.

Kolb, D. (1984). *Experiential learning: Experience as the source of learning and development*, Prentice Hall, New Jersey.

Linn, M. C., and Slotta, J. D. (2006). Enabling participants in online forums to learn from each other. In A. M. O'Donnell, C. E. Hmelo-Silver, and G. Erkens (Eds.), *Collaborative learning, reasoning, and technology* (pp. 61–98). Mahwah, NJ: Erlbaum.

Mergendoller, J. R., Maxwell, N. L., and Bellisimo, Y. (2006). The effectiveness of problem-based instruction: A comparative study of instructional method and student characteristics. *Interdisciplinary Journal of Problem-based Learning 1*, 49–69.

Polanco, R., Calderon, P., and Delgado, F. (2001).Effects of a Problem-Based Learning Program on Engineering Students' Academic Achievements, Skills Development and Attitudes in a Mexican University. Presented at the 82nd Annual Meeting of the American Educational Research Association in Seattle WA, April 10-14.

Putman, A.R. (2001).Problem-based teaching and learning in technology education. Presented at the 75th Annual Conference of the Association for Career and Technical Education in New Orleans, LA, December 13-16.

Rideout, E., and Carpio, B., 2001. The problem-based learning model of nursing education. In: Rideout, E. (Ed.), Transforming Nursing Education Through Problem-based Learning. Jones and Bartlett, Sudbury, pp. 21–49.

Schwartz, D. L., and Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction, 22*, 129–184.

Torp, L., and Sage, S. (2002). *Problems as possibilities: Problem-based learning for K-16 education* (2nd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.

Weiss, R.E. (2003). Designing problems to promote higher-order thinking, in: D.S. Knowlton and D.C. Sharp (Eds.) *Problem-based learning in the information age.* San Francisco, CA, Jossey-Bass, 13-23.

Woods, D. R. (1996). Problem-based learning for large classes in chemical engineering. *New Directions for Teaching and Learning*, *68*, 91–99.

AUTHOR

Beth (Ann E.) Wittig is a licensed environmental engineer and LEED Accredited Professional, and was a practicing environmental engineer before accepting an appointment at CUNY City College of New York. She is an expert in environmental modeling and impact assessment, and has given invited seminars, guest lectures, and full courses on these topics. She is also experienced in the development of pedagogical strategies to enhance student learning, and recently lead her program through a successful accreditation. Finally, she is a founding member of the City College chapter of Engineers Without Borders and one of the chapter's two faculty advisors, and has traveled extensively with the chapter to mentor the students in their projects.