AC 2007-543: PROBLEM-BASED LEARNING OPPORTUNITIES THROUGH ENGINEERS WITHOUT BORDERS

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Problem-based learning opportunities through Engineers Without Borders

Abstract

Engineers Without Borders (EWB) is an international organization that seeks to improve the quality of life of disadvantaged peoples around the world through water, sanitation, power, and structural engineering solutions. The City College of New York inaugurated their student chapter of the organization in 2005. Most of the 40 students who are involved in the chapter are in pursuit of undergraduate degrees in Civil, Mechanical, and Chemical Engineering, but there are also a handful of students pursuing degrees in Economics, Public Health, Spanish, and Communications. The student chapter is advised by a professionally licensed Environmental Engineer and faculty in the Civil Engineering (CE) Department at the CUNY City College of New York (CCNY). The chapter also receives guidance from a licensed Structural Engineer and CE faculty, and from a practicing licensed Environmental Engineer.

Our first project is nearing completion. In this project, we are developing a potable water supply to serve over 350 people, distributed across several valleys in a mountainous region in Honduras. Even by Honduran standards, the people in this community are poor, with limited education, no power or sanitation system, and a periodically contaminated water supply that leads to infectious stomach and skin diseases. Our design will protect a spring, collect water from it, conduit the water over a mile of hilly tropical rainforest with dense vegetation and inconsistent geology, disinfect the water in a centralized tank located close to the community, and then distribute the treated water to several locations throughout the community. As a result of public health issues that were observed during our assessment trip, the chapter will also educate the community on practices to manage solid waste and improve ventilation in homes. The approximate cost to assess and implement this project is $35,000.

EWB projects undertaken by student chapters follow the problem-based learning (PBL) approach by definition. Students work in small groups to investigate and solve an ill-structured real-world problem under the guidance of a facilitator in several steps: describe the problem, identify learning issues, conduct research and incorporate knowledge, and finally, assess. The PBL approach is believed to alter traditional teaching and learning patterns by allowing students to take charge of their own learning, develop a varied and deeper perspective and knowledge of the subject area and mimic the problem-solving that takes place in professional practice and in the normal workplace. Students participating in the CCNY EWB chapter assert that their participation in EWB helped them to develop new skills not taught in the classroom, such as proposal writing, project management, multi-disciplinary collaboration, assessment of social and economic impact, and social responsibility. They also assert that EWB has provided a unique opportunity for them to refine their grasp of concepts learned in class by applying their engineering and professionalism skills to important problems in real environments.

Introduction

Engineers Without Borders (EWB-USA) is a non-profit humanitarian organization that partners with developing communities worldwide in order to improve their health and quality of life. Between 2002 and 2006, the organization grew from fewer than 100 members to more than 6,000 members. As of January 2007, there were 105 active student EWB chapters and 39 active professional chapters nationwide, and approximately 600 chapters in development.[1] Most professional chapters provide support and mentoring for the student chapters, although some also take on projects on their own.

Although most EWB projects require engineering design, environmental monitoring, public health assessment, accounting, and fundraising, few student or professional chapters have members that are not engineers or engineering students. The City College of New York (CCNY) student chapter of EWB is unique in that it has actively recruited engineering students as well as students pursuing degrees in Economics, Public Health, Spanish, and Communications. The CCNY EWB chapter is mostly made up of undergraduate students with varied levels of education, but also includes a few graduate students. Typically, the senior undergraduate engineering students possess the leadership roles and mentor the juniors and sophomores in administrative and engineering activities. The chapter is advised by a civil engineering faculty and licensed environmental engineer, and mentored by a few other civil engineering faculty and practicing engineers.

Examples of EWB projects

EWB projects occur in communities throughout the world, but a majority of them take place outside of the US. EWB projects are initiated by the communities themselves. The communities submit applications to EWB-USA, normally with the help of a Peace Corps volunteer or non-government organization representative working in their region. The application must identify and justify the need for the assistance of EWB.

Most EWB projects are small in scope since the student or professional chapters are responsible for fundraising 100% of the costs of the project, which can range from $10,000 to $35,000.

A vast majority of EWB projects address water, energy, and infrastructure needs, and involve the assessment of the viability of a proposed design, the construction and implementation of the design, and the evaluation of the impact of the design on the community. Explicit examples of components of typical EWB projects are listed below.

Components of potable water system projects:

- Assessment of terrain by surveying, soil type with borings, water availability by flowrate measurement, water quality by collecting samples for lab analysis of toxic compounds and turbidity and by plating water samples for coliform analysis
- Assessment of community need for and potential uses of water
- Assessment of current community health and relationship to current water practices
- Assessment of the availability and specifications of locally available materials needed for design implementation
- Design and construction of ground water wells and pumping systems

- Design and construction of spring boxes or covered retention embankments with overflow systems and erosion management drainage systems
- Design and construction of covered water collection tanks and foundations with overflow systems, flow regulation valving, and erosion management drainage systems
- Design and construction of trenched and above-ground water conduction pipelines with PVC or GI pipe, slip and treaded unions and couplers, flow regulation and drainage valving systems, overflow systems, erosion management drainage systems, and pipeline reinforcement with rebar and geosynthetics
- Design and construction of water purification systems including settling, filtration and solar or chemical disinfection
- Design and construction of water distribution systems of tapstands or smaller conduction lines to the homes
- Education of community on safe washing practices that do not contaminate drinking water, need for disinfection, methods of disinfection, public health indications for the need for disinfection

Components of ventilation systems projects:

- Assessment of air quality issues inside and outside of the home
- Assessment of community health and relationship to current ventilation practices
- Assessment of the availability and specifications of locally available materials needed for design implementation
- Design and construction of stoves that produce less smoke
- Design and construction of chimneys to route cooking fumes out of the home, or natural cross-ventilation systems for the home
- Education of community on safe incineration of solid waste including types of materials that can be safely incinerated, the use of masks, public health signs that indicate a need for ventilation

Components of energy systems projects:

- Assessment of opportunities for energy generation including surface water velocity, wind velocity and direction, or cloud coverage and solar intensity, and community need and potential uses of electricity
- Assessment of the availability and specifications of locally available materials needed for design implementation
- Design and construction of watermills and driveshafts, windmills, and solar panels
- Design and construction of support structures for electricity generation systems
- Design and construction of electrical storage and distribution systems
- Education of community on maintenance of energy systems and safe disposal of batteries

Components of infrastructure projects:

- Assessment of terrain by surveying and soil type for purposes of siting and erosion management
- Assessment of the availability and specifications of locally available materials needed for design implementation
- Design and construction of toilets and bathing areas

- Design and construction of simple buildings on slabs within communities
- Design and construction of roads and bridges to improve access to the community

Project roles in EWB projects

Even when EWB projects are not used as a problem-based learning opportunity, faculty and students must make much larger time commitments to the project development, design, and implementation than in student clubs such as Concrete Canoe and Steel Bridge. As with these other clubs, however, students of all levels and all disciplines can participate meaningfully.

Faculty advisor: The CCNY EWB faculty advisor meets with the entire chapter regularly to address fundraising, administrative, student and faculty recruitment, project selection, and address issues related to the current project.

Faculty technical lead: The technical lead is usually the faculty advisor, unless this faculty does not possess the expertise needed to conduct the project. The technical lead meets with the entire chapter once weekly for 2-4 hours to address engineering design issues, and conduct workshops to prepare students for travel. This person also actively advises the student project manager and approves the final student design. The technical lead should also travel with the team to support students in onsite design changes as needed.

Faculty (and professional) technical mentors: Additional faculty are recruited as needed to give guidance to the students during the project design phase.

Student project manager: This is a student who oversees the entire project including design, planning, assessment, implementation, budgeting and reporting. The project manager is also the primary point of contact with EWB-USA.

Student assistant project manager: This is a position developed by the CCNY EWB chapter. This student shares some of the responsibilities of the project manager and is groomed in the process to be the next project manager.

Student design team members: The design teams are students who take on a particular component of the project. Each team is led by a team leader who has already completed the coursework relevant for their component of the design.

Student travel team members: The travel team is the group of students who travel to the community to assess or implement the project design. At CCNY, students apply to be on the travel team. Students who are productive during the semesters prior to travel are given priority. The student project manager reviews the applications and makes recommendations to the faculty advisor.

Problem-based learning opportunities in EWB projects

Problem-based learning (PBL) is facilitated by having students work in small groups to investigate and solve an ill-structured real-world problem under the guidance of a facilitator. The stages of problem solution as described by Deckard include describing the problem, identifying learning issues, conducting research and incorporating knowledge, and assessment.[2] The educational objectives of PBL are to develop systematic approach to solving real-life problems using higher-order skills, to assimilate an extensive knowledge base that can be flexibly applied to other situations, to develop effective self-directed learning skills and effective teamwork skills, to acquire a drive to acquire knowledge and skills needed for effective problem resolution, and to develop habits of self-assessment. [3] James and Baldwin assert that PBL alters traditional teaching and learning patterns by allowing students to take charge of their own learning, develop a varied and deeper perspective and knowledge of the subject area and mimic the problem-solving that takes place in professional practice and in the normal workplace. [4] Polanco et al statistically demonstrated that PBL increased student performance on written and oral exams, and students reported a higher perception of the acquisition of skills. They observed no significant increase in positive perception of the subject matter addressed through PBL. [5] However, at CCNY, the EWB students consider meaningful participation in EWB projects to be a more substantive culmination of their engineering educations than the even their senior design course, and attribute to EWB an increased passion towards their soon-to-be profession.

EWB projects naturally follow the PBL progression of problem solution, as described below.

The 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 project and identify whether the strengths of the group complement the project, and use the information to assemble their bid to EWB-USA.

Learning issues: Learning issues are identified during the development of the assessment trip plan and during the assessment itself. Students identify key issues associated with the project and key components of the design to determine the information needed to support the design that is known and unknown. They then develop a preliminary set of objectives for the assessment trip. 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.

During the assessment trip, students assess the accuracy of the original problem statement, obtain environmental and health data to support the design, evaluate sources of materials and obtain specifications for available materials, and evaluate any extenuating circumstances that will affect the implementation of the design.

Research and incorporating the 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 design team leaders lead their team 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 other, and develop diagrams, lists, and concept maps to support and illustrate the design to the larger group.

Group report and whole class discussion: Each design team compiles a written report and presentation which 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-USA technical advisory committee, and the students must orally present their design.

Assessment: Self and peer assessment is facilitated on several levels. Design teams meet regularly to internally assess the products of the self-directed design. The student project managers also review all components of the design report and meets with each design team to suggest refinements to the report at the end of each weekly group meeting. Facilitator assessment is conducted internally by the faculty advisor/technical lead and externally by the EWB-USA technical advisory committee. A cursory internal assessment is conducted weekly during group meetings, and a thorough assessment is conducted in the review of the draft and final design report and presentation slides.

Example – the potable water project in Nueva Suiza, Honduras

The potable water project in Nueva Suiza calls for the development of a water purification and distribution system for a community of 350 people located in several valleys in the Cortez region of the Sierra de Omoa Mountains of Honduras. Even by Honduran standards, the people in this community are poor. They possess limited education and lack basic amenities such as electricity, telephone, public transportation, and an infrastructure for water supply and wastewater treatment. They also have a history of water-borne infectious stomach and skin diseases.

The existing water system in the community provides water to the homes of less than a quarter of the community. The remaining members of the community laboriously carry water from nearby streams to their homes. The water that feeds the water system and the streams can become contaminated with runoff when it rains, which occurs frequently and year round in the region. There is evidence that water stored in basins at the home is also self-contaminated.

The water system design protects and collects water from an artesian spring, conduits the water over a mile of hilly tropical rainforest with dense vegetation and inconsistent geology, disinfects the water in a centralized tank located close to the community, and then distributes the treated water to several locations throughout the community. The water will be collected by encasing the most productive and elevated spring source with a reinforced concrete retention embankment. The dam will have a sealed removable lid made of concrete which prevents runoff from entering the water supply, an overflow system that directs excess water away from the embankment, and a shut off valve allowing the dam to be taken offline of the system. Due to the soil instability surrounding the existing earthen dam, much excavation will need to be done to reach rock. The pipeline will conduit the water from the embankment over 0.5 miles of a hilly dense tropical rainforest to a central location in the community. A majority of the pipeline will be trenched. This portion will be made of 1.5” SCH40 PVC and buried 1.5” below the surface. Portions of the pipeline that cannot be trenched will be made of 1.5” galvanized iron pipe and affixed to exposed rocks on the surface. The water will be collected at the community into a 14’ by 26’ reinforced concrete tank made of CMU blocks with wetted surfaces coated with a water-proof sealant, installed on a 9” think concrete foundation. The site will need to be cleared of its dense vegetation and over 50% of the volume of the tank will need to be excavated since there are no large flat sites within the community. The disinfection system will be an inline, non-powered, tablet feeder which uses chlorine, since this is mandated by Honduran law. The distribution manifolds will be made of concrete and 0.5” galvanized pipe and will allow space for 5 homes each to gravity feed water from the system. The chapter will also educate the community on practices to avoid water contamination at the home, manage solid waste and improve ventilation in the cooking areas of the homes.

The project serves the entire community, and as a result, has the potential to directly impact the health and the economy of the community. At the very least, the new water system improves the health of the community by disinfecting the water. The system also has the potential to allow time spent by women and children bringing water to the home to be used towards other productive activities, and to increase in the availability of water used for agricultural purposes and thus the community’s economy. The cost to assess and implement this project is just in excess of $35,000, and includes money needed to travel to and stay in Honduras, the equipment used during the assessment, and the materials and tools needed during the implementation. Approximately 15% of the budget was obtained by grant and 85% by solicitation.

After the students won their bid on this project, they prepared for a semester for the assessment trip. Students assigned themselves to small teams that would ultimately become the design teams. Each team was responsible for only a small component of the preparation. This approach was effective and helped to distribute the work load more evenly across the chapter. Each team had a team leader who was ultimately responsible for the work and who motivated their team and interacted with the PM and APM. The teams identified the information needed to do a water system design: health of the community, community water flow rate needs, spring productivity, water quality at the most productive spring, topographical survey along the pipeline path, and stores to obtain materials and tools for the project. They investigated data sources to learn as much as possible remotely, and found that little information was actually available. They prepared the health surveys and practiced surveying on several weekends.

The assessment trip took place over spring break and lasted for one week. The faculty advisor traveled with 3 students, two of whom held leadership positions in the chapter: student project manager (PM) and student assistant project manager (APM). The entire group met with each of the female heads of household to assess family health, time spent collecting water, water use rates, and future water needs. The group also visited the site of the embankment, walked several potential pathways to the community, and discussed possible locations for a tank in the community. The group then divided into teams to complete the assessment. The faculty and PM collected water samples, assessed spring productivity, met with the mayor and Peace Corps Volunteer who would serve as our point of contact in our absence, and made arrangements with local hardware stores to purchase goods when back in the US. The APM worked with the other student to conduct the topographical survey and survey all potential pathways to the community, survey possible locations for the tank, and identify the latitude and longitude of all homes to be served by the water system. The group reassembled each night to review data and discuss issues. The group struggled with the result of the assessment trip analyses, which showed that it would actually be impossible to gravity feed the water to the entire community, that the pipeline would have to follow a tortuous path since the terrain was hilly and random portions of the path could not be excavated, and that erosion management on steep reaches of the path would be critical to maintain the integrity of the pipeline. They also wrestled with the water quality measurements that did not confirm the need for microbial disinfection.

Upon returning to the US, the travel team presented their information to the rest of the group. The teams were reassembled and began their work reviewing the data acquired during the assessment trip and designing the system. The student PM orchestrated the design, provided technical guidance to the team leaders, filled in gaps of the design as necessary, and solicited the frequent guidance of the faculty advisor. While the design team leaders shouldered most of the responsibility, students who were interested in traveling for the implementation trip also contributed meaningfully on both the design and the development and presentation of the written report to the EWB-USA technical advisory committee. Many students who didn't travel on the first trip and who weren't able to travel for the implementation trip were meaningfully invested in the design and two were actually design leaders. However, many students who lacked the experience of traveling to Honduras prioritized other commitments over EWB as the semester wore on. In the two months prior to traveling for the implementation trip, the students practiced mixing concrete, connecting PVC and galvanized pipe, surveying, and microbiological testing in workshops arranged by the APM and faculty advisor with volunteer practicing engineers.

In the following fall, the chapter retuned to Nueva Suiza for 3 weeks to implement a portion of their design. The faculty advisor and one of the technical mentors traveled with 10 students. The student PM and APM returned, and broke into teams again for more efficient management of activities. The PM arranged for the purchase and transport of materials, met with the mayor, and worked with a small group of community members on the embankment. The APM managed a larger team of students and community members to excavate the tank location and construct the foundation and tank. In addition to their work with the PM or APM, the PM also assigned to each student the responsibility of auxiliary components of the project: safety and first aid, photography, material quantities, and water quality. On a given day, students would break off from the group to count the amount of wood that was still onsite to report to the PM, or collect water samples for microbiological testing. When the team left, the tank was completed and the embankment and pipeline trench were in construction.

The team will return for a final trip over their next school holiday. Their initial assessment was complete enough that this semester will be spent updating the report to EWB-USA and identifying potential next projects, and not design.

Benefits of EWB projects to student learning

In addition to providing a forum for problem-based learning opportunities, EWB projects also introduce students to concepts typically not addressed in the classroom. The Nueva Suiza water project afforded many of these learning opportunities, almost all of which were highly appreciated by the students. This was most evident after observing any EWB student while recruiting a new student to the chapter.

Hands-on experiences: Since limited information is available about the communities at the onset of the project, students must acquire onsite all the information required to complete the design, including material availability and specifications. During the Nueva Suiza project, the students had to acquire the information they would normally be given in a problem statement: they had to survey the topography and measure flow rates and water quality. Even a single project can provide opportunities to apply concepts learned in many classes. The Nueva Suiza water project gave students hands-on application of concepts learned in statics, fluid mechanics, hydraulics, hydrology, environmental engineering, environmental impact assessment, soil mechanics, reinforced concrete, and foundations. Several graduating engineering students commented that their new employers were attracted to students possessing hand-on skills such as those developed while participating in EWB projects.

Engineering of real systems: Since many EWB projects are located in areas that lack the infrastructure students in the US have come to rely on, students also have to develop designs that account for a potential lack of power and water, limited access, and potentially challenging terrain.

Integration of sustainable designs and practices: EWB-USA projects must be affordable and account for the future demands of the community. They therefore provide real examples of the concept of 'sustainability' or 'green engineering', which they had only vaguely grasped prior to participating in EWB project design. Given the remote location and cost of the Nueva Suiza water project, students developed designs that used locally available construction materials and efficient staging of construction. Given the need of the community for a system that would last at least 20 years, they implemented drainage systems to protect foundations and minimize the erosion of soils protecting the pipeline. They integrated redundancy into the design, by building a bifurcated tank. This design also allowed them to consider tank lid designs that could minimize the use of concrete. They also developed a system of valves and bleeds that could be used to troubleshoot flow problems in the pipeline and clean portions of the system at a time.

Use of performance metrics: EWB-USA requires that students collect data at the beginning of and after completion of the project to numerically evaluate the impact of the project on the community. Typical metrics address the physical and economic health of the communities and their environment. The CCNY students obtained tangible evidence of the value of their future professions and the value of their contributions to the chapter by fulfilling this requirement.

Development of social and environmental responsibility: Since EWB-USA projects serve communities in great need, designs need to be sustainable and minimize adverse impact. Students experience this first hand by being challenged to obtain materials locally and by educating communities on public health topics and to make them self-sufficient after the EWB team leaves. They learn the need for minimal adverse impact by observing the current practices and needs of the communities they seek to serve and by combating environmental variables that challenge even the implementation of the projects.

Development of leadership qualities: The student project manager oversees the entire project and leads the design and travel teams in the assessment and implementation of the project. Design and travel teams are lead by upper-level students.

Self-guided learning and student mentoring: While the projects must be approved by the faculty technical lead prior to submission to EWB-USA, students are self-guided to a large extent in the development of assessment and design strategies that support the vision of the student project manager. The assistant project manager is mentored by the project manager for a full year to groom them for the full leadership responsibilities of project manager. The project manager also mentors and advises students in design and travel teams, while team leaders mentor less experienced students in the team in the design and implementation of the project.

Learning the practice: Through working on EWB projects, students develop skills seldom taught in any classroom: constructability and design rules-of-thumb, proposal writing, project management, interacting with clients, leadership, professionalism, truly multi-disciplinary collaboration. The attitude of the CCNY students towards proposal writing and public relations was neutral, but they truly appreciated the benefits of multi-disciplinary teamwork since it gave them the opportunity to make connections between various engineering disciplines and work more productively by exploiting their various skill sets. They valued the experience managing a small or large team, and the organization and people skills that goes along with it.

Networking with practicing engineers: Students interact with practicing engineers who conduct pre-travel workshops, and provide guidance to the students on rules of thumb, practical considerations and project staging. Students may also interact with professionals during travel.

Challenges of using EWB projects for student learning

EWB-USA projects serve communities in great need and provide meaningful and motivational hands-on, real world experiences to students. As might be expected, however, these rewards come with great challenges.

Large time commitment: While the time commitments to design teams and mentors is reasonable, the time commitments for the faculty advisor/technical lead and student project manager are well beyond that typical of most student organizations (e.g., concrete canoe, steel bridge). At CCNY, we address this challenge by sharing the technical guidance provided by the technical lead with other CE faculty with expertise in the various components of the project. The student project manager is assisted by an assistant project manager. Since this assistant is mentored for a full year prior to taking on this role, this reduces the time needed to develop management skills and strategies during their tenure as project manager.

Staying on schedule: The various phases of EWB projects have specific due dates established by EWB-USA. Even though most EWB students are highly self-motivated, coursework and employment commitments challenged their ability to achieve weekly design deliverables. At CCNY, the ongoing participation of student design leaders is 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.

Recruiting students for travel: Although many students are willing to participate in design teams at the university, fewer students are able to travel for the onsite assessment or implementation. At CCNY, this is a challenge we continue to face.

Working in host countries with little infrastructure: The development of a rigorous design requires knowledge of material availability and specifications. Even if the design is completed, the ability to travel is contingent on securing the funds required to support the project. The acquisition of material information is quite difficult. At CCNY, we address this challenge by conducting multiple projects in a single community or region.

Fundraising to support the project: Typical projects cost $10,000 to $35,000. Fundraising this amount of money requires substantial time from both students and faculty. At CCNY, this is a challenge we continue to face. In our most recent project, the faculty advisor shouldered the complete cost of the project and was repaid as funds became available. This solution is unacceptable.

Conclusions

Engineers Without Borders (EWB-USA) is a non-profit humanitarian organization that partners with developing communities worldwide in order to improve their health and quality of life. Projects that address water, energy, and infrastructure needs are the most common.

The project methodology developed at EWB-USA follows the problem-based learning method of problem solution. In addition to providing a forum for problem-based learning opportunities, EWB projects also introduces students of all levels in their education to concepts typically not addressed in the classroom.

At CCNY, the design team leaders and project manager consider the EWB experience to be a more substantive culmination of their engineering educations than the even their senior design course, and attribute to EWB an increased passion towards their soon-to-be profession. Despite the many rewards associated with meaningful participation in EWB projects, however, the extensive time, manpower, and monetary resources needed to complete a single project may limit the consistent use of EWB projects for education purposes.

Bibliography

1. EWB-USA (2007). Student and professional EWB chapters. http://app1.ewb-usa.org/chapters.php, Accessed 1/17/2007.

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

3. 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.

4. James, R. and Baldwin, G. (1997). The University of Melbourne, Australia: Tutoring and Demonstrating. http://www.cshe.unimelb.edu.au/bookpages/pbl.html, Accessed 1/17/2007.

5. Polanco, R., Calderon, P., & 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.