Preparation for Global Engineering Practice in the Twenty-first Century

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Abstract: The rigorous curriculum in science, engineering, management and computer science offered by Worcester Polytechnic Institute (WPI) develops implicit problem-solving skills by requiring two nine-credit-hour projects, one in the major discipline and one at the interface between society and technology, as well as a capstone experience in the humanities. About sixty percent of its students choose to complete one or more of these requirements by working full-time at residential, off-campus project centers distributed all over the globe.

WPI's experiences in Asia illustrate the organizational issues required to enable students and faculty advisors to focus on the key academic elements. These include cultural immersion in a professional working environment, building strong relations with corporations, government agencies, and non-governmental organizations through a knowledgeable local agent, and provision of local infrastructure. One example of the outcome of such a project is the work of a team of WPI undergraduates who were in Taipei during November and December of 1999. That team joined graduate students from the National Technical University to examine from several perspectives the impact of the Chi Chi earthquake of September 23. Their final report incorporated recommendations to reduce future earthquake damage, including greater centralization of earthquake response command.

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1. Introduction

Worcester Polytechnic Institute (WPI) offers a rigorous curriculum that instills disciplinary skills, societal awareness, and a global perspective in its undergraduate students of engineering, science, and management. This curriculum requires graduates to complete two nine-credit-hour projects in addition to a capstone experience in the humanities. One project addresses a problem of significance in the major discipline while the other solves a problem at the interface between society and technology. The second, interdisciplinary project is especially effective at nurturing sustained lifelong learning. Together, these projects instill in students the know-how or implicit knowledge that is very difficult to teach in a traditional program.

WPI introduced these two intensive projects as part of a major philosophical and curricular reform in the early 1970's, the goal of which was to shift responsibility for learning from faculty to students. Now, thirty

years later, these two projects constitute an important way that WPI students can demonstrate educational outcomes increasingly of interest to employers and professional societies. Specifically, the new learning outcomes-based "Engineering Criteria 2000" from the Accreditation Board for Engineering and Technology requires programs seeking ABET accreditation to present hard data on how they measure student success in applying the knowledge they acquire. Merely passing a course no longer counts as learning the material since student retention and application of "what they learn in class" are notoriously unsatisfactory. Assessing the two WPI projects that require students to articulate, orally and in writing, the solutions they derive for open-ended problems in both the technical and societal domains enable WPI to report on student outcomes effectively in all eleven areas of interest to ABET. The interdisciplinary project is of special value in providing data on student abilities for the following ABET learning outcomes: functioning on multi-disciplinary teams; understanding of professional and ethical responsibility; understanding the impact of engineering solutions in a global and societal contexts; the need for, and an ability to engage in, life long learning; and a knowledge of contemporary issues.

2. Preparing for global projects

Students have the option of completing projects by working full-time at residential, off-campus project centers. Between the fall of 1999 and the summer of 2000, 398 students (about two-thirds of a graduating class) will have completed projects at off-campus residential centers including Melbourne, Australia; Silicon Valley (San Jose), California; Pratt & Whitney (East Hartford), Connecticut; San Jose, Costa, Rica; Washington, D.C.; Copenhagen, Denmark; London, England; Darmstadt, Germany; Limerick, Ireland; Venice, Italy; Boston, Massachusetts; Goddard Space Flight Center (Greenbelt), Maryland; San Juan and Mayaguez, Puerto Rico; Johnson Space Flight Center (Houston), Texas; and Bangkok, Thailand. At any one time, such centers typically accommodate five to ten teams of three or four students each. Individual project teams have also worked this year in Morocco and Taiwan, among other locations. This successful approach is being integrated into graduate programs, with the first offerings planned for academic year 2000-01.

WPI's experiences in Asia and elsewhere illustrate the organizational issues required for successful project center operation. Cultural immersion in a professional working environment is the *sine quo non* of global projects. To this end, strong relations with corporations, government agencies, and non-governmental organizations, best achieved with a knowledgeable local agent, are essential. Provision of local infrastructure, including adequate living and working environments, enables students and faculty advisors to focus on the key academic element, educationally sound projects involving real-life problems.

A typical established project center is managed by a Center Director through the University's Division of Interdisciplinary and Global Studies. In addition, most centers have a local coordinator, an individual familiar with local culture and, more importantly, able to establish connections with corporations with governmental and non-governmental agencies who can sponsor projects.

Global centers often benefit from a university affiliation as well. Such arrangements are normally formalized with an agreement of cooperation that might include faculty or student exchanges in return for such support of WPI's students as access to classrooms, computers, the Internet, the library, and health and other student services.

Preparation for successful project work begins on campus with the organization of a well-researched project proposal during one of WPI's seven-week academic terms. The key components of such a proposal are the Introduction or Problem Statement, Background Research or Literature Review, and Methodology. For the Interactive Qualifying Project, development of such a proposal is supported by a special course that surveys research skills, oral and written communication, frequently used concepts and methodologies from the social sciences, etc.

Throughout the preparation phase, the student teams work closely with their faculty project advisor, typically meeting once a week with the advisor to review progress. The students communicate as well with their liaisons in the sponsoring organization to insure congruence between their work and the sponsor's expectations. Much of this interaction is supported through web-based instructional tools.

Additional support is available for team dynamics, cultural adjustment and preparation, health and safety concerns, depending upon the needs of particular sites and student teams.

Students leave for their project site with a clear problem statement and a plan of action for achieving specific objectives. In fact, many find upon arrival that the nature of their project has shifted and that their objectives and methodology must be refocused. The experience of the preparation phase has equipped them for these inevitable changes, and they quickly redirect their work to reach the new goals within the allotted seven or eight weeks of on-site project work. The final result is a well-documented written report and a professional oral presentation to the sponsor and other interested parties.

3. Examples of global projects

Major Qualifying Projects allow student teams to tackle significant problems focused on their major disciplines. Some examples include

- *Limerick, Ireland:* Echoes and feedback severely limit the utility of speakerphones in as much as they prevent full-duplex operation. A WPI student team working at Analog Devices Corporation designed and implemented an adaptive filtering system using a coder/decoder coupled with a digital signal processor in a new speakerphone system that effectively removes echoes.

- *Mayaguez, Puerto Rico:* Shape memory alloys were incorporated by a student team as structural elements of scale steel frame buildings in order to explore the feasibility of controlling these structures under earthquakes. A model of a three-story building was subjected to simulated earthquakes so that the effectiveness of shape memory alloys as structural elements could be measured. The students' work demonstrated that it was possible to use electric current to switch these elements on to change the structural behavior of the building in the event of an earthquake so that damage was minimized.

- *Greenbelt, Maryland (Goddard Space Flight Center):* The particles of the solar wind may provide clues to the formation of the universe. Detecting them requires diamond films of extreme purity. To achieve such films with requisite resistivity, a student team used chemical vapor deposition in a reactor with varying concentrations of methane to demonstrate that resistivity could be decreased and the number of detected twins increased.

Interactive Qualifying Projects engage students in problems with both social and technical dimensions:

- *London, UK:* A student project team developed a specialized electronic text transcription tool to assist a member of the WPI faculty of Humanities and the Arts working at the Victoria and Albert Museum in the transcription and analysis of the so-called Robinson papers, letters and other documents describing the circumstances under which the foundation of the Museum's collection was assembled during the latter part of the eighteenth century.

- *Melbourne, Australia:* Beginning with the initial challenge of producing a smoke detector installation manual using diagrams to assist those with little or no ability to read English, the student team developed a variety of sophisticated tools to assess the effectiveness of various types of diagrams in conveying different actions and ideas. The result was both a tested visual guide and a set of principles for designing manuals for similar tasks.

- *Bangkok, Thailand:* Assisted by a private donation of computer equipment, a student team developed a teacher training program to enable a private school serving younger children in a slum area to offer to its students an introduction to computing. This program will continue in subsequent years with a cycle of evaluation and training.

- *Venice, Italy:* Tides, sewage, and other sources fill the canals of Venice with silt, requiring expensive and disrupting dredging to maintain boat traffic and a cleansing flow of water. Measurement and analysis by a WPI project team demonstrated that a significant source of that sediment is plaster falling from the faces of the buildings along that canal. Refacing the buildings every few decades preserves the distinctive visual character of this unique city but it places a substantial burden on its municipal infrastructure.

- *San José, Costa Rica:* Lankester Botanical Garden contains thirteen distinct gardens that present unique opportunities for researchers, students, and tourists. A succession of student projects teams has inventoried the Garden's resources and developed outreach plans to increase public use of and support for the gardens.

4. A project team in Taipei

Because of the carefully structured preparation program in Worcester, students arrive at the project site able to achieve remarkable results in the limited time available. As one example of these outcomes, a team of WPI undergraduates worked from Taipei during November and December of 1999 with graduate students of the National Technical University to examine, from several perspectives, the impact of the Chi Chi earthquake of September 21. The project includes a review of technical issues underlying the earthquake, with detailed information and maps concerning the controversies over the location of the hypocenter, and the movements of the Philippine Sea Plate, and the location of the Chelungpu fault among others in Taiwan. The project itemizes the major after shocks and notes the plethora of almost uncountable minor ones after September 21st and provides a digital photo collection of damages like liquefaction in Taichung harbor, the destruction of the Shi Kung Dam, the collapse of the Kung Fu Jr. High School, and the devastation of the Tsao Ling Landslide.

The project assesses the economic damage of the quake noting particular difficulties in the power industry and the semi-conductor business sector and then, through a series of interviews with victims and helping agencies, sets out the social impact of the earthquake's devastation. The project provides English translations of newspaper articles and government reports on the quake's effects. The project notes the double edged financial effect of the devastation—a higher bank loan failure rate but at the same time an infusion of government expenditure prompting economic growth.

The project also tackles the difficult issue of the political effects of the quake, not only internally on the upcoming elections, but externally in terms of relations with the PRC government in Beijing; in particular the issue of "help" from the mainland played havoc with the delicate dance of "precise relations" between the two entities. What was offered non-monetarily could not be accepted, and the total monetary aid offered by Beijing amounted to less than had come directly in from overseas Chinese.

In terms of popular perception the response of the Taiwan government to the quake at least in the initial stages was considered quite satisfactory and quick. Commentators in the press indicated that Taiwan had done far better than Japan during the first hours and days of its massive earthquake at Kobe. Longer term, however, the popular press seems to have found the Japanese example more satisfactory.

The project also includes a section analyzing the American government's response to the earthquake at Northridge, California in 1994. The American FEMA organization is given higher marks than Taiwan's centralized response, itself far superior organizationally to the Japanese effort. The project suggests that Taiwan adopt some of the greater centralizing structures of FEMA. The project also notes that the Universal Building Codes adopted in America have been accepted in Taiwan, but given the pace of economic development, enforcement of those codes has lagged severely.

The project concludes with recommendations that enforcement be tightened up greatly, and that Taiwan learn a lesson of the lamentable American experience that pre-disaster insurance may tend to encourage people to build and rebuild in basically unsafe areas which simply should not be inhabited, that government payments and loans can be too available and thus not deter construction in unsafe areas.

5. Conclusions

WPI' s global project program demonstrates the feasibility of combining within a curriculum of engineering, science, and management the mastery of explicit and implicit problem solving skills, a significant international experience, and a substantial encounter with issues involving both society and technology. Undergraduate students achieve professionally credible results at project sites around the world. They return to campus and enter their professions having served themselves and society well.

6. References

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