Globalizing Science and Engineering Through On-Site Project-Based Learning

By Jennifer Rudolph

Introduction

Ease of international travel, instant communication, and new corporate structures that span multiple countries all point to the necessity of globalizing the way we teach STEM (science, technology, engineering, and math) fields. In fact, corporations involved in applied research have evolved into operations with fluid frameworks that span multiple countries, with headquarters in one country, sourcing in a second, marketing in a third, and research laboratories in yet another. Scientists and engineers in such companies can expect to be sent for short-term assignments in any one of these and to work "virtually" with colleagues and others in collaborative research. How, then, do we prepare our engineering and science students for such a global work environment? More importantly, how do we overcome the obstacles in current STEM education to prepare the next generation of scientists and engineers to understand the importance of the cultural and societal contexts within which they can expect to work?

The sciences and engineering have lagged behind the humanities and social sciences in highlighting the importance of the global experience and cross-cultural communication skills. Nonetheless, the next generation of scientists and engineers will, like their humanities and social science peers, enter into a changed and increasingly global work environment. According to the National Academy of Engineers, American engineers will need area studies training in the coming decade, as they "will be based abroad, will have to travel . . . around the world to meet customers, and will have to converse proficiently in more than one language." Moreover, "US engineers … will have to be open to different religions, different ways of thinking, and different social values. Flexibility and respect for ways of life different from ours will be critical to professional success."[1]

The Academy for Engineers is responding to the challenges of globalization. While discussion often focuses on issues of outsourcing and the negative impact on American workers, increasing attention in education circles is being paid to preparing US students—the next generation of American workers and citizens—to compete more effectively in the new interconnected economy. In this constructive approach, we have seen increased emphasis on STEM education, as well as on cultural and linguistic study abroad programs.

STEM and study abroad, however, have not historically mixed well, as evidenced by the fact that fewer than 4 percent of American-educated engineering students study abroad.[2] Despite the low figure, there are models available that manage to successfully marry the realities of applied research in STEM fields with overseas experiences rich in cross-cultural understanding and long-term personal benefits.

The Project-Based Learning Solution

Project-based learning (PBL), an approach where students address real-world challenges with faculty guidance, can bridge that divide. Moreover, it can do so for STEM students while allowing them to acquire the benefits that are more typically attributed to cultural immersion programs: cultural understanding and comparative perspective.

PBL has gained popularity among engineering schools because of the combination of real situational problems and active learning techniques. Benefits of this approach include framing science and engineering problems in their cultural and societal contexts, and the necessity of student adaptation as problems unfold in ways unpredictable in the classroom—just as they do in life. Utilizing the PBL model in sites abroad means students are confronted daily with the cultural, economic, and ethical aspects of their work. In the process, learning becomes a collaborative endeavor that stimulates open and flexible thinking and cultivates appreciation for the host culture.[3]

Here, I will present examples of project work in Asia at Worcester Polytechnic Institute (WPI) to illustrate PBL's impact and the long-term effects on participating students, both in terms of their STEM fields and on their humanistic development. WPI, a small, nationally ranked STEM-oriented university in Massachusetts, manages to send nearly 50 percent of its undergraduate STEM students to off-campus sites around the world each year, far exceeding national averages. More important for this discussion, WPI has evidence from an externally commissioned survey of its alumni that such field experiences positively impact participants' professional skills, worldviews, and personal development far beyond graduation.

Project-Based Curriculum and Experiential Learning

Every student at WPI must complete a PBL interdisciplinary team-based project in the junior year and a PBL team project within the major's discipline in the senior year. These projects can be completed on or off campus.

The Process

Each year, approximately twenty-five WPI students travel to Hong Kong in early January for a seven-week PBL experience, accompanied by two WPI faculty advisers (typically a humanities or social science professor and a STEM professor). Three or four WPI students comprise a team, and each team works with an external sponsor. For the two months prior to travel, they take a site-specific social sciences methodology course in which each team writes a project proposal (including literature review, background, and methodology) for the sponsor. This course also covers site-specific political and economic issues that might impact understanding of the projects and relevant stakeholders. In addition, students take a cultural prep course to facilitate cross-cultural understanding. Students also start working during this time with sponsor liaisons through Skype meetings to begin understanding sponsor needs and context.

Once on-site, students work full time at the sponsor location, with weekly presentations to the sponsor on their progress and concerns. They begin to implement their methodology and collect data, commonly utilizing surveys and interviews. With data, students analyze and write their findings. Finally, each team submits its final report to their advisers and orally presents findings and recommendations to the project sponsor. Hong Kong projects tend to focus on issues of environmental sustainability, urban planning, or education, with sponsors coming from NGOs, government ministries, and universities. Table 1 below illustrates the scope of the 2014 projects in Hong Kong, along with the interdisciplinary composition of teams and advisers.

Table 1: 2014 Junior-Year Hong Kong Projects

Team	Student Majors	Advisor Disciplines	External Sponsor	Project Title
1	Electrical Engineering (EE) (2); Computer Science (CS); Biomedical Engineering (BME) (1)	History; Mechanical Engineering	Designing Hong Kong, Ltd., and Harbour Business Forum	"An Assessment of the Connectivity, Accessibility, and Vibrancy of Victoria Harbour"
2	Chemistry (1), Chemical Engineering (CHE) (1), EE (1), Robotics Engineering (RE) (1)	History; Mechanical Engineering	Friends of the Earth, Hong Kong	"Investigating Transportation Policies to Reduce Air Pollution in Hong Kong"
3	CHE (2); BME (1)	History; Mechanical Engineering	Business Environmental Council, Ltd	"Indoor Air Quality in Commercial Buildings in Hong Kong"
4	Physics (1), Industrial Engineering (1), Mechanical Engineering (ME) (1), CS (1)	History; Mechanical Engineering	Green Building Council	"Understanding and Improving Green Building Standards in Hong Kong"
5	Architectural Engineering (1), CS (1), ECE (1), RE (1)	History; Mechanical Engineering	Chinese University of Hong Kong, Architecture and Planning faculty	"Effect of Urban Design on Community and Society in Hong Kong's New Towns"
6	CS (1), ME (1), and Management Information Systems (1)	History; Mechanical Engineering	Urban Renewal Authority	"Quality Urban Living in Shrinking Spaces": How Low Can It Go?"

By pairing advisers from different disciplines, WPI reinforces that the emphasis of the project experience is not mastery of a particular discipline or topic, but rather the systematic research process that is necessary for tackling interdisciplinary topics, as well as the collaborative nature of effective teamwork.

Hangzhou Senior Year Case Study

Senior year projects in China all occur in a mixed-team setting, with WPI and Chinese students working together. Like the junior year projects, senior projects begin before the students start their field work. Unlike the junior project, senior projects are tied to a specific major, and teams consist of students only from that major. The projects should demonstrate the students' ability to apply their discipline's major skills, methods, and knowledge to a problem typical of what they will encounter in their careers. Just as important, the students must be able to effectively communicate, in oral and written forms, results to their sponsors, typically from the corporate world.

Final presentation for project sponsor Designing Hong Kong from March 2014. Photo credit: Dorothy Lam.

WPI students from a number of STEM fields work at multiple sites with students from six Chinese universities.[4] Students begin working with each other two months prior to WPI student arrival on-site. Here, an industrial engineering team working in Hangzhou illustrates the senior year process.[5] Students from WPI and Hangzhou Dianzi University (HDU) comprised this team. Such mixed composition affords daily opportunities for technical, cultural, and social exchange related to the project and beyond.

The sponsor, Hangzhou Omnipay Company Ltd., wanted to explore a car-share model for the city of Hangzhou. Omnipay successfully established China's first profitable bike-share program in Hangzhou and was interested in expanding this concept to cars. The company, therefore, sponsored a WPI senior team to conduct the feasibility study. Like many southern cities, Hangzhou has experienced rapid growth since 1992, and like all Chinese cities, it struggles with environmental degradation caused by the growth and rapid expansion of car usage. Hangzhou, an ancient capital, must find a balance between economic growth, consumer culture, environmental preservation, and historic site maintenance. Increases in already-substantial tourism expected by 2020 (from the current 878,000/day to 1.6 million/day) will further exacerbate challenges.

In spring 2011, a team consisting of three WPI students and seven HDU students took on the car-sharing project for Omnipay and Delta Consulting. For WPI students, preparatory work began two months prior to arrival in Hangzhou. The first step was to understand how car-sharing had developed in North America and Europe. Students learned about techniques and practices employed in car-sharing, as well as the status quo for the practice in China. In this first phase, the teams regularly communicated findings and questions with each other and with the sponsor via Skype and email.

Omnipay had earlier identified Zipcar of Boston as a model of interest; the students, therefore, investigated how Zipcar worked and whether it was an applicable model for Omnipay in Hangzhou. Students also researched main characteristics of cities where Zipcar had become successful. Their research revealed that the success of Zipcar in the city of Boston was tied to the involvement of the city government. They also assessed the Hangzhou municipal government's City Planning Bureau and learned of its advocacy of innovative policies. For example, it supported bike-sharing with a RMB $5 billion investment, as well as an additional investment in software and operational costs. Knowing the role of the City Planning Bureau and its interest in bike-sharing, as well as the importance of the city of Boston in Zipcar's success, the team contacted Hangzhou's City Planning Bureau to explore car-sharing. The Planning Bureau shared valuable information with the team about traffic patterns, perceived obstacles, and the meaning of the national-level Economic and Technology Zone (ETZ) established in 1993 in Hangzhou.

The team investigated what residents, one of the main stakeholders for a car-sharing enterprise in the city, knew about the practice. Over a two-week period, the team administered a ten-question survey, interviewing a total of 414 randomly selected people in densely populated parts of the city. A significant finding from the survey was that over 50 percent of Hangzhou's population did not have a driver's license, making the market for car-sharing quite different from Boston. Moreover, Zipcar could not rely on the same college student population that forms a significant portion of its customer base in Europe and the US because most college-age students in Hangzhou do not have a driver's license.

One of the most interesting aspects of PBL is to watch students interrogate their own assumptions and work. Once in the field, everything changes and students must question what they accomplished in the first stage of the project in Massachusetts. The reality of being on-site, meeting with the sponsors, and experiencing the environment requires the team to step back and adjust its understanding of the project. It is a good lesson in having to adapt to new cultural norms and expectations. In addition, students have to adapt classroom work to a nonacademic environment, requiring a blending of theory and practice.

Short- and Long-Term Impact of PBL

Regular assessment is part of the PBL experience at WPI. All students upon return are asked to evaluate their WPI advisers for their off-campus work. Students participating in China projects receive additional follow-up surveys to help gauge the value of their experience. Two survey responses from engineering students speak to the impact of their China experience:

"Without a doubt the most impressive accomplishment on my resume is the work that I did … for Nypro China. After this experience, I am confident that I can successfully collaborate with people from any country, in any country" (M.F., '10).

"The cultural difference has influenced how I deal with people from different backgrounds. I try to understand people well before I deal with them. The many challenges that were faced and overcome during the project period have equipped me to be able to handle similar life-challenging situations" (E.A., '09).

At the institutional level, WPI wanted to learn whether the off-campus PBL approach has an impact on students beyond the actual project. Does it prepare them for lifelong education and satisfying employment? To gain insight, WPI contracted with an external evaluator to conduct a survey of thirty-eight years of alumni who participated in PBL at WPI at off-campus sites. The study incorporated multiple approaches for data collection, including a web-based asynchronous ideation exercise to generate survey questions, a web-based alumni survey, individual interviews with a sample of alumni, and interviews with representatives from employers of large numbers of WPI undergraduates.[6]

The various methods of the study asked alumni about perceptions regarding:

- Critical thinking skills
- Creative and interdisciplinary problem solving skills
- Communication abilities
- Professional behavior
- Ability to collaborate effectively
- Leadership skills
- Worldviews
- Personal attributes

Through the study, WPI has learned that undergraduate alumni view their off-campus PBL experiences as formative and as having great impact not only in their professional careers, but also on their personal development.

Findings indicate that alumni identify project work as a significant component of their undergraduate education. Responses differed somewhat by gender, participation in on or off-campus projects, and the respondent's field of studies (engineering vs. nonengineering respondents). Overall, the survey identifies very important benefits of WPI's project-based work, especially in shaping personal character and in contributing to professional success. Over two-thirds of the students reported that PBL experiences had "much" or "very much" impact on their ability to solve problems, integrate information from multiple sources, and take responsibility for their own learning. More interestingly, perhaps, they thought that PBL enriched their lives in ways that were not necessarily academic or work-related. PBL contributed to their feeling of being able to make a difference in the world and achieving a work-life balance.

Most striking, perhaps, is how the survey reveals gender-based differences in perception of the value of PBL at off-campus project sites. Table 2 presents data from the survey items concerning worldview.

Table 2: Gender differences in impact of project-based learning on world views[7]

	% Responding "Much" or "Very Much"			
Area of Impact	**Engineering Majors**	**Males**	**Females**	***p***
Ability to understand people of other cultures	33 (*n*=1376)	**29** (*n*=1082)	**49** (*n*=294)	<.001
Respect for other cultures	30 (*n*=1443)	**26** (*n*=1138)	**46** (*n*=305)	<.001
Ability to understand people of other backgrounds	31 (*n*=1391)	**27** (*n*=1090)	**45** (*n*=301)	<.001
Understanding connections between technology and society	53 (*n*=1750)	**50** (*n*=1372)	**63** (*n*=378)	<.001
Understanding of global issues	33 (*n*=1645)	**30** (*n*=1299)	**43** (*n*=346)	<.001
Ability to view issues from several different perspectives	58 (*n*=1747)	**55** (*n*=1367)	**67** (*n*=380)	<.001

Differences between men and women occur in all thirty-nine PBL categories included in the survey, but they are most pronounced in worldview items, especially the first three listed above: ability to understand people of other cultures, respect for other cultures, and the ability to understand people of other backgrounds. In these, women reported a significantly higher rate of impact than their male counterparts. In fact, women responded that off-campus project work impacted them "much" or "very much" at a rate 20 percent higher than the men. The survey demonstrates that although many WPI students continue to see the positive effects of PBL experiences long after graduation, female students especially recognize the value of PBL in domains that include both their professional and personal lives.

Conclusion

By placing technology in its societal setting, the PBL model promotes cultural and social awareness and aids STEM students in acquiring cross-cultural competency. Moreover, project center work moves students away from passive learning in the lecture hall, dependence on the instructor, and an expectation to gain knowledge toward a process of discovery that fosters independence and encourages the making of knowledge.

With off-campus project work, the responsibility of learning rests squarely with the students. Mastery of course content is no longer the simple goal. Rather, students are tasked to incorporate a higher level of learning that requires not only figuring out how to work as a team but, more importantly, the higher order of learning that comes from dealing with the unscripted challenges and complexities of issues as they play out in front of students in ways that impact more than their grades. Faculty, in turn, transform from lecturers into mentors, tutors, and examiners in a more meaningful way than possible in the traditional classroom. Most importantly, students gain understanding and skills that help them in the lifelong process of learning and meaningful employment.

NOTES

1. The National Academy of Engineering, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* (Washington, DC: The National Academies Press, 2005), 152.
2. According to the Institute of International Education's "Open Doors" database, 3.9% of engineering students studied abroad in 2009-10, the latest year for which data is available at http://tinyurl.com/m9pnhld.

3. See Henry Goodrich, *Teaching Through Projects: Creating Effective Learning Environment* (Menlo Park: Innovative Learning Publications, 1995) and Jane Henry, *Teaching Through Projects* (London: Routledge, 2005).
4. WPI has partnered with Huazhong University of Science and Technology, Beijing Jiaotong University, Tsinghua University, Shanghai University, Shanghai Jiaotong University, and most recently, Hangzhou Dianzi University (HDU) for senior year projects. Starting in fall 2014, junior-year projects will begin in Hangzhou, hosted by HDU.
5. I thank Amy Zeng for sharing her senior project advising experience with me. For a complete write up of this case study, see Amy Z. Zeng, "Car-sharing: a feasible business expansion at Hangzhou Omnipay?," *Emerald Emerging Markets Case Studies* (Bingley: Emerald Group Publishing Limited, 2012). For the student report, see Lory Aragon, Alp Humbaraci, and Joseph Papotto, "Feasibility Study of Car-Sharing Service in Hangzhou, China," *WPI MQP Project*, last modified August 13, 2011, http://tinyurl.com/mfhe2hb.
6. I want to thank Richard F. Vaz, Dean of WPI's Interdisciplinary and Global Studies Division, for sharing survey results and initial findings with me by giving me advance access to Richard F. Vaz, Paula Quinn, Arthur C. Heinricher, and Kent J. Rissmiller, "Gender Differences in the Long-Term Impacts of Project-Based Learning" (presentation, 120th American Society for Engineering Education Annual Conference, Atlanta, GA, June 23-26, 2013).
7. Vaz, Quinn, Heinricher and Rissmiller, "Gender Differences in the Long-Term Impacts of Project-Based Learning"

JENNIFER RUDOLPH is Associate Professor of Chinese History and Associate Head of the Humanities and Arts Department at the Worcester Polytechnic Institute (WPI). She is also the Director of WPI's Hangzhou Project Site. As principal investigator for a US Department of Education UISFL grant, she leads an initiative to integrate China area studies into the WPI STEM curriculum through course and field work. She is currently writing a book entitled *Claiming Taiwan* in which she explores the repeated re-interpretation and manipulation of the memory of and rhetoric surrounding Zheng Chenggong (Koxinga) to build political power and construct identity on the island by the various regimes that have ruled it.