



Comparison of Two Project-Based Learning Experiences in Panama City, Panama

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Abstract

In 1970, Worcester Polytechnic Institute adopted The WPI Plan, a project-based educational philosophy that requires students to complete three research projects during their undergraduate careers, each the equivalent of a full term's worth of work. Almost immediately, this curriculum evolved to incorporate off-campus project opportunities, with the first off-campus Project Center established in 1974. This paper compares two groups of undergraduates that recently carried out NSF-funded research at the Panama City, Panama, Project Center in order to fulfill one of their project requirements. The first group was composed of five seniors, selected based on academic standing, each working under the guidance of personnel from the Panama Canal Authority on a specific technical project as part of their capstone design project. The second group, selected based on financial need, investigated the effects of the ongoing Panama Canal Expansion Project on the Food-Energy-Water (FEW) nexus in the canal watershed to fulfill their junior year 'Interactive Qualifying Project' requirement. The findings of each team, logistical considerations for advisors, the results of student evaluations of the experience, and unique difficulties faced by the students are discussed, as well as lessons learned for the improvement of the program in future years. These projects represent two distinctly unique examples of project-based learning.

Background

In 1970, Worcester Polytechnic Institute adopted The WPI Plan, a project-based educational philosophy that requires students to complete three term-length research projects, advised directly by faculty, during their undergraduate careers [1]. During their junior year, students generally complete their "Interactive Qualifying Project" (IQP). This is a critical time in a student's professional development, as junior-year students have the technical skills necessary for a productive research project, but likely have little research experience and are close enough to graduation to be seriously thinking about the future and focusing more on academic work [2, 3]. The final requirement is the "Major Qualifying Project" (MQP), generally completed during a student's fourth year of study. The MQP is similar to senior design projects implemented at other universities, focusing specifically on developing engineering solutions to technical problems; as such, student teams are generally major-specific.

The IQP is in many ways the cornerstone of the WPI Plan; whereas in 1970 there were other schools that had capstone design and humanities projects as a part of their STEM curriculum, the faculty observed a need for a project in which engineering skills would be built in a societal context. This was due primarily to the failure of post-war technological progress to deliver on the utopian promises of the 1950s: despite incredible scientific breakthroughs, domestic and international social, economic, and political goals were not being met. The authors of the WPI plan reasoned that this was because technological innovations were being implemented without careful consideration of the social context – that a technology cannot exist in a void, but must be developed, implemented, and refined in a space as close to the stakeholders as possible [4].

Project-based learning has been shown to improve student outcomes in various professional competencies, including communication and teamwork skills; to prepare students for self-directed research projects in industry or academia; to demonstrate to students the value of

interdisciplinary inquiry; to encourage students in seeking graduate degrees; and to provide students with a better understanding of core concepts [5, 6]. In recent decades, many in the engineering education community have concluded that professional competencies alone will not be sufficient for success in the increasingly transnational world of industry – students must develop global competencies that will enable personal and professional success outside of their home countries. These skills include the ability to work in diverse teams with individuals that hold differing perspectives; communication skills, including foreign languages and an understanding of etiquette, that enable the transfer of knowledge and inclusion in international networks; and the ability to recognize and adapt to the social factors that may determine how project partners approach research problems and tasks [7]. While it is generally agreed that curricula aiming to instruct students in global competency require coursework in international studies, a study abroad experience, and the building of foreign language skills, Lomann *et al.* argue further that these three factors must be connected, and that they must be relevant to a student's major, to be effective [8].

While the number of students studying abroad has risen dramatically over the past few decades, the length of the average student experience has steadily declined, with programs of one to five weeks duration becoming increasingly popular. In a study of over 3,700 alumni of study abroad programs, Dwyer concluded that longer programs were not necessarily better – students participating in study abroad opportunities as short as six weeks in length reported statistically significant gains in a variety of personal and professional outcomes [9]. Almost immediately after its inception, the project-based system at WPI evolved to incorporate off-campus opportunities for global competency development, in which students perform project work for one quarter (seven weeks). Study abroad itself is not necessarily the only means by which to develop global competencies, however – Parsons concluded from a study of 1,302 students that experiences such as attending cultural events at home, having friends with diverse national backgrounds, and taking conventional courses with international content were also strong predictors of higher development of key competencies such as cognitive and behavioral adaptability and respect for other cultures [10]. For this reason, all WPI students travelling to an off-campus project center are required to take a pre-departure orientation course to supplement their off-campus experiences and prepare them for travel. In academic year 2015/2016, 712 IQP students and 84 MQP students applied to pursue a project off-campus. This paper reviews recent experience with both IQP and MQP teams at the project center in Panama City, Panama.

MQP Research at the Panama City Project Center

An off-campus Project Center was established in Panama City in 2009 through networking with WPI alumni, who are particularly active in Panama. The Panama Canal is the most important single civil engineering structure on earth, reducing the distance of maritime travel between the east and west coasts of the United States by over 12,500 km (7,800 miles) and accommodating nearly 10% of global trade [11, 12]. In 2007 the people of the Republic of Panama voted in favor of expanding the Panama Canal by a roughly three-to-one margin at a total cost of over \$5 billion, and ports worldwide have invested billions of dollars in upgrading their facilities to accommodate the “New Panamax” ships that will soon be able to transit the Canal [13].

The Project Center initially hosted only MQP teams working with the Panama Canal Authority (ACP) on technical projects such as the energy efficiency of water pumping stations;

investigating water quality in Lake Gatún; and helping to design grouting systems for the Borinquen 1E dam [14, 15]. MQP students are currently supported by Grant #1357667, titled *IREs: Environmental Impact of the Panama Canal Expansion Project*, funded by the National Science Foundation's Office of International Science and Engineering. This grant aimed to provide students with projects related specifically to the sustainability of the Panama Canal Expansion Project, as well as to improve the MQP experience by doubling project length to roughly 15 weeks; providing additional cultural programming; supporting students in presenting their work at a professional conference; and encouraging students to submit manuscripts based on their work to journals.

The first cohort of grant-supported students carried out five distinct projects in 2015, which the students summarized in a report titled *The Panama Canal Expansion Impacts: Connecting Us to the Future* [16]. The first project involved investigating the practicality of updating lighting at the El Prado and Corozal complexes and the Gamboa Dredging Division, from high-pressure sodium high-intensity discharge systems to more energy efficient LED-based systems. It was concluded that replacing a total of 211 light poles hosting 343 individual fixtures would reduce ACP energy usage by two thirds (over \$60,000 each year) with a payback period of 7.1 years. The second project investigated land usage on the banks of Lakes Gatún and Alajuela. The raising of the operational level of Lake Gatún by 0.4 m (1.5 ft.) as part of the expansion project has led to the ACP working to identify unauthorized habitations on shore and either evict the individuals, or establish legal certifications and appropriate taxes. The student prepared a framework for a carrying capacity study as well as a shoreline management plan for Lake Gatún. The third student compared several options for visual navigational aids along the path of the expanded Canal. Such aids, which include buoys, lighthouses, and range towers, help a navigator align a ship to the center channel of a waterway, and are often preferred by mariners over more advanced, computerized systems. This project recommended the implementation of glass-reinforced plastic towers as navigational aids in cases where existing aids were being removed or replaced. The fourth project investigated new designs for the replacement of the Gatún spillway, which is no longer sufficient for regulation of the water level of the manmade lake at the center of the Panama Canal system, and recommended that the ACP emplace large steel pipelines through Lake Gatún and pump spillway construction debris off-site in the form of a slurry. The final project analyzed drinking water from several tugboat landings and the storage tanks of two in-service ACP tugboats, the *Veraguas II* and *Guía*. Water quality was checked against health targets based on World Health Organization benchmarks for the presence of total coliforms, residual chlorine, and turbidity.

IQP Research at the Panama City Project Center

In the spring of 2015, the NSF released a dear colleague letter requesting proposals for research on the Food/Energy/Water (FEW) Nexus. Introduced to the environment and development literature in 2008, the FEW Nexus is one of the more recent methods used to understand the varied ways in which livelihood dimensions affect, and are affected by, each other and are dependent on 'chains' of environmental goods and services. These relationships are often reciprocal. Agriculture, for example, requires energy inputs but may also provide energy outputs in the forms of food or biofuels. Although it has been widely considered a logical and efficient way to think about resource and livelihood interconnections, the FEW Nexus approach has been criticized for not being explicit about the politics and inequality surrounding outcomes and

policies, and in particular, for avoiding questions of environmental justice [17, 18]. The economic impacts of the Canal Expansion Project are generally agreed upon, with projections showing Canal revenue increasing by roughly 12% and roughly 40,000 jobs being created. The environmental impacts, and the impacts on local ecosystems and livelihoods, are much less clear. The government's optimism is dogged by the criticisms of environmental experts regarding the wider impacts of the Canal expansion on local livelihoods, rural communities, and regional water supply [19]. The benefits and damages of the Expansion Project are not likely to impact all stakeholders equally – despite rapid economic growth, Panama is routinely ranked as one of the most unequal countries in the world, with nearly 40% of the population living in poverty [20]. Supplemental funding was awarded to the above-mentioned IRES grant, which was used to support a five-person IQP team that investigated the effects of the Expansion Project on the FEW Nexus in the Panama Canal watershed.

The students divided their work into four phases: acquiring contacts, conducting interviews, analyzing findings and identifying stakeholders, and building a framework describing the FEW Nexus in Panama. The team carried out 18 interviews with the personnel from government, non-government, educational, and private organizations. In a final report titled *Food, Energy, Water (FEW) Nexus Analysis in the Panama Canal Watershed* the students identified eight interconnected areas that may be present in any population center, but that have unique aspects in Panama, and made recommendations regarding potential future areas of research. The individuals interviewed by the students expressed a particular concern regarding water security. On a per person basis, Panama consumes twice the average amount of water than any other Latin American nation – and 50 liters (13 gallons) per person per day more than the average inhabitant of the United States [21]. Further, Panama City is experiencing the same stresses of any growing city – water treatment plants are rapidly approaching full capacity, infrastructure is corroding and deteriorating, and newly constructed neighborhoods are experiencing flooding and water management difficulties as they become integrated into the urban fabric. Unlike other cities, the expansion of the Canal will lead to an increase in water usage, even with the implementation of advanced water-saving technologies. Currently, roughly 50 million gallons (190 million liters) of freshwater are expelled into the ocean during each of the roughly 40 daily ship transits through the Canal [22]. Multiple interviewees stated that although there are emergency measures aimed at reducing water consumption in force, and existing laws aiming to prevent the contamination of the drinking water supply, neither carry strong enough penalties to be taken seriously by the local population [23]. Waste management was a concern closely related to water usage. All of the waste produced by Panama City was discharged into the Gulf of Panama without any treatment. In 2010 a wastewater treatment plant was constructed at Tocumen, serving roughly a third of the city; since reaching full capacity in 2013 the plant has been operating at reduced efficiency [24]. Finally, the food supply of Panama is being affected by the expansion of the Canal. The migration of individuals from rural areas to Panama City results in a reduced agricultural workforce – decreasing the amount food produced in Panama, while encouraging remaining farmers to adopt less labor intensive methods such as slash-and-burn land clearing.

Project Evaluation and Comparison

During a recent assessment of WPI's project-based educational model, over 2,500 WPI alumni answered questions regarding 39 areas of long-term impact [25]. The results were unambiguous: In off-campus projects, students consistently achieved learning outcomes at levels significantly

higher than on-campus projects. Students working with partner communities outside of WPI not only showed improvement in terms of professional preparation, but in terms of their outlook and personal growth. In the words of an alumnus interviewed as part of this assessment project: *“My entire experience after the [project] was different than before. I felt like a different person when I came back... I saw the reason why I went to college, because I saw something taken to completion in the real world.”*

Both student teams selected for work in Panama participated in university-standard evaluation activities, which included both quantitative data (Likert Scale ratings) and qualitative data (responses to open-ended questions) focusing on every aspect of the program. Although the sample set was extremely small (five MQP and five IQP students), that roughly 90% of questions were answered with a ‘four’ or ‘five’, on a scale of zero to five, indicates broad satisfaction with the experience. (The other 10%, mostly ratings of ‘three’ received from MQP students, were scattered and did not indicate a clear trend with regards to one particular aspect of the program.)

Reaction to the actual project work was mixed – two MQP students rated their projects as ‘five’ with the others rating theirs ‘two’ or ‘three’. While the topics were *“interesting”*, students expressed some concern that some of the projects were not directly related to the undergraduate classwork they had completed and/or did not include elements considered necessary by the department (i.e. experience with professional licensure and a design element). This may have been due to ineffective communication between the ACP human resources department and the actual supervisors, who did not always know the date on which students would be starting their project. Although the projects sometimes lacked focus or direction, the students ended up viewing this positively in terms of professional development– producing something of value required self-motivation and the development of skills that increased their independence as a researcher. One student wrote *“I think that I personally learned how to research better and formulate my thoughts better from doing this project because it was more independent as it was only me working on it whereas IQP it’s a group. So it really puts the responsibility on you to learn how do these things on your own.”* The IQP team, on the other hand, embraced the unstructured nature of their project, writing, *“I loved the independence and flexibility of our project and the ability to collaborate and figure new things out with our group”* and *“The unstructured nature of the project gave us a great opportunity to be heavily involved in every stage, from formation to completion”*. One student did note, though, that the unstructured nature of the project *“was sometimes challenging, as five voices clashed and caused a lot of tension - especially in the last few weeks”*.

In general terms, these evaluations reflect the experience of Chieffo and Griffiths in a study of over 2,300 students – 93% of students that studied abroad generated unique, qualitative comments about their program experience, while only 57% of their on-campus did so. In general, the comments of the former group were more introspective and related to personal gains, while the latter group commented primarily on classroom learning and logistics [26]. Of the 15 students participating in on-campus projects advised by the author during this time, fewer than half provided qualitative comments, and of those, most were related to logistical issues – *“Our project did not deserve a C”*, *“[I disliked] finding out WPI does not have a proper ball mill”*, and *“[I disliked the] lack of help from grad students at the end of project”* being representative.

While certainly not conclusive, this implies that some aspect of the off-campus experience may lead students to think more specifically and introspectively about their personal competencies.

Students were positive about the social and cultural aspects of their work, particularly the opportunity to improve their Spanish. The MQP students participated in a one-week orientation course at a Spanish Language school in Panama City, of which one student wrote “[I] learned more conversation in that week than I had in 8 years of classes”. This course was not possible for the IQP team, as their work was carried out in the middle of the academic year. A recent paper by Briggs suggests that study abroad experiences alone are not sufficient for building vocabulary in foreign languages, as there is no way to ensure that students will not revert to English outside of classes [27]. This study concluded that students would benefit if the institutions hosting them made concerted efforts to ensure that they had a variety of opportunities to communicate in their non-native language outside of the classroom. Although both groups became involved in cultural experiences based on relationships established as part of their project work, particularly with the personnel of the housing facility, further activities were encouraged. Each team took part in an ‘ecotourism’ trip to the country’s western provinces; attended at least one soccer match (which Panama lost); were invited into the homes of their Panamanian colleagues; and so on. Potentially more important than gains in vocabulary or linguistic ability, studies suggest that even short-term language experience abroad has a significant positive impact on student attitudes towards developing language skills [28].

The final, obvious area of improvement regards addressing homesickness. One of the five MQP students withdrew from the program early for this reason. Although the student’s project was still completed, both the project and the student would have benefitted from completing the 15 week program. IQP students reported experiencing varying degrees of homesickness, although none took the step of returning home possibly because logistical arrangements (finding a replacement project, arranging classes, etc.) would have been significantly more difficult during the school year (as compared to the MQP projects, which begin, and could be potentially abandoned, during the summer). One student wrote, “*I had a difficult adjustment to studying abroad in my first week, but there was never any dislike for the project itself*”. Although the effects of study abroad on the mental health of students has not been as thoroughly investigated as the effects of study abroad on developing language skills or global competencies a recent summary of the literature concludes that stress and homesickness can significantly reduce the likelihood of students attaining learning goals, and that creating genuine social relationships with fellow students, native individuals, or even program administrators is the most important mechanism by which such difficulties can be addressed [29]. This is supported by student responses – one student wrote “*we went from 5 to a gang of friends*” and that becoming socially involved with coworkers “*helped keep us busy ... gave us something to look forward to ... having friends keeps your mind from home.*” One way in which the issues of homesickness and loneliness could be better addressed in future years is by adjustment of the pre-departure orientation course. Goldstein and Keller reported that students are more likely to blame culture shock on external factors (communication difficulties, unfamiliar food, inability to find one’s way in an unfamiliar city, etc.) when, in fact, the educational literature attributes culture shock to internal factors (ineffective coping strategies, identity confusion, prejudice, etc.) [30]. This student attitude was reflected in the pre-departure orientation course, taught by the author, in

which students questions focused on matters of sociocultural adaptation. A future emphasis on psychological adaptation may be more appropriate.

Conclusions

The IQP and MQP projects supported by NSF IRES funding in Panama each had the goals of educating students in engineering sustainability, but were significantly different experiences. The student feedback and advisor experiences have led to two parallel goals for future years of this program: First, WPI faculty will press for better communication with the ACP, including direct contact between faculty and project supervisors at an early stage, rather than all contact being carried out through the ACP's human resources department. Second, preparatory activities will include more of a focus on independent research – if a project is unsatisfying or not appropriate for program goals, students should arrive in-country knowing what steps they can proactively take in order to improve their situations. Ensuring that students work on teams of at least two individuals, rather than independently, may help to meet this goal, by providing students with someone that can help them adapt. Finally, the experience has prompted a review of the methods by which students are recruited to the program – students selected on the basis of financial need rather than academic standing were, generally speaking, more adaptable, more independent, more satisfied with their experience – and may not otherwise have been able to participate in off-campus project work.

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