U.S. and International Community-based Sustainability Projects for Deep Learning

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Abstract

This chapter uses a generic framework for deep learning to help evaluate how one such higher education program located at Worcester Polytechnic Institute fits this framework. Data on learning outcomes provides quantitative support from sustainability-related, community-based projects conducted on an international level. The use of such projects dealing with sustainability issues both locally and globally is detailed with potential application to similar programs as part of a sustainability education curriculum. This analysis provides an opportunity to identify and characterize community-based sustainability projects and their contribution to higher order, integrative and reflective learning. Lessons learned and directions for further research and practical implication are presented.

Keywords: Community-based Projects, Engineering Education, Experiential Learning, Deep Learning, High Impact Educational Practices, Stakeholder Management, Study Away, Sustainable Development.

1.0 INTRODUCTION

Sustainability education at the college, or tertiary level, has been in response to a variety of social forces. Communities, industry, consumers, NGO’s, and government agencies have played a role in greater demand for deep knowledge of sustainability, its principles, practices and theories (Yarime, et al., 2012; Wiek et al., 2011). Universities throughout the world are introducing programs, pedagogical techniques, practices, and resources with respect to sustainability (James and Card, 2012; Krizek et al., 2012; Velazquez, et al., 2005).

Sustainability is a complex topic and has been defined in a variety of ways (Arena et al., 2009). We can incorporate all elements of sustainability education. These would include the ‘triple-bottom-line’ dimensions of economics, social and environmental sustainability. Academics and practitioners have observed the need to integrate sustainability into higher education. Sustainability can be integrated by:

- *infusion of sustainability into current courses*
- *new courses* specifically focused on sustainability
- *activities and programs* within and outside of the curriculum
• **modeling of sustainable practices** through the school facilities, operations, governance, and faculty lifestyles.

To aid ‘deep learning’ for sustainability amongst university students is through the use of high impact educational practices (HIEP) such as community based sustainability projects (Hansen, et al., 2012; Kuh, 2008; O’Brien and Sarkis, 2014). In this chapter we introduce how a university wide program at a university, Worcester Polytechnic Institute (WPI), is using community-based sustainability projects as an integral part of a deep learning curriculum offered for management, engineering, arts and sciences disciplines. An overview of the processes, effectiveness, and limitations of these programs is an important question.

This project-based educational paradigm with a strong underlying sustainability orientation introduced at WPI through its “Plan” has been in effect for decades. Its interdisciplinary sustainability focus is especially unique. This project based education is part of the HIEP that will help students achieve deep learning outcomes.

Study away, defined as off-campus experiential learning in either domestic or international settings, provides an alternative to study abroad, and can be designed to promote many of the same global engagement outcomes as study abroad while overcoming some barriers. The engineering education community could benefit from understanding the long-term impacts of study away experiences in order to inform curriculum decisions. (Vaz and Quinn, 2013).

In the next section some background on the HIEP, deep learning and stakeholder outcomes framework is overviewed. This background sets the foundation for introducing the application of community based sustainability projects courses at WPI. Some background on the design of this program is provided. Findings from the many projects completed with various feedback and results are summarized. General findings and lessons learned are also summarized with avenues for future
development on this evolving instructional method and topic also presented in the concluding sections of this paper.

2.0 BACKGROUND – HIGH IMPACT EDUCATIONAL PRACTICES, DEEP LEARNING AND STAKEHOLDER OUTCOMES

High impact post-graduate education includes the development of intellectual powers and capacities; ethical and civic preparation; personal growth and self-direction (Kuh, 2008; Barth, 2012). HIEP for higher education can help achieve long-lasting, deep learning and outcomes. HIEP practices represent the antecedents in our framework for deep learning and outcomes summarized in Figure 1. 

Figure 1 about here

HIEP include: common intellectual experiences that link various courses; a focus on ‘big questions’; writing intensity; collaborative projects; research; and community based experiences and service oriented activities (Kuh, 2008).

Many HIEP have been targeted at undergraduate students. Similar practices at the graduate level, especially for relatively inexperienced graduate students, provide deep learning outcomes. The more complex a subject, the less possible it is for participants to achieve mastery through passive educational practices. HIEP are especially conducive for education in complex and socially integrated issues exemplified by sustainability (von Blottnitz, 2006). Sustainability requires a systemic ‘big picture’ and asking ‘big questions’ perspective to fully comprehend the myriad issues that are faced by this topic and discipline (Feng, 2012; Frisk and Larson, 2011; Hansen, et al., 2012; Porter and Cordoba, 2009).

Building on Kuh’s (2008) HIEP, cross-disciplinary and multiple course perspectives may also be integrated into environmental sustainability understanding and education (Feng, 2012; Yarime et al., 2012). Collaborative projects, writing intensity, research, community, service-oriented practices are all experiential and are recommended for sustainability education practices (Ferreira, et al., 2006; Bergea et al., 2006; Sipos et al., 2008).
Deep learning has been defined as a key learning strategy from which students extract meaning and understanding from course materials and experiences (Warburton, 2003). Deep learning is defined to go beyond simple intellectual development becoming more transformational, which includes physical, emotional, aesthetic, moral, social, personal, and spiritual growth (Bentz, 1992; Grauerholz, 2001; Miller, 1999; Sterling, 2010). Although there are many scales for deep learning (see Nelson Laird et al., 2005 for a review), in our conceptual framework of deep learning the scales of the national survey of student engagement (NSSE) (NSSE, 2012), based on Nelson Laird’s work (2008), are used. These elements and scales are some of the most comprehensive and tested and thus serve as a solid basis for evaluating deep learning in academic settings.

The deep learning elements of this comprehensive scale include higher order learning, integrative learning, and reflective learning (Nelson Laird, et al., 2008). A summary of the specific elements in the NSSE Deep Learning Scale are shown in Figure 1.

The next stage of the conceptual framework includes the outcomes of the practices and deep learning that occurs. We summarize the outcomes as various stakeholder benefits from deep learning and HIEP, which include (Schantz and Louge, 2008):

- Academic gains and school connectedness by students (Scales & Roehlkepartain, 2005),
- Greater civic engagement of students helping to build ‘town-gown’ relationships and future community engagement in the future (Boyle, et al., 2011).
- Building non-discipline, personal and social competencies of students (Hoxmeier and Lenk, 2003).
- Building social capital for students and schools. (Koliba, Campbell, & Shapiro, 2006).
- Protective factors such as greater retention rates and higher quality relationships.
- Broadened career exploration for students.

The variety of stakeholders that benefit from HIEP and deep learning with sustainability as a focus includes students, the university, college or school, and the broader community. A systems perspective of sustainability higher education not only requires consideration of the content and the pedagogical delivery, but the stakeholders that will benefit from this broad education. Thus, in the final stage stakeholder outcomes are identified and measured.
3.0 Worcester Polytechnic Institute – Interactive Qualifying Projects

Worcester Polytechnic Institute (WPI) is an engineering and technology university founded in 1865. At WPI, the WPI Plan was introduced in 1970 (Grogan and Vaz 2003). An integral dimension of the WPI Plan was to apply knowledge in authentic settings, meeting the University’s motto of Theory and Practice related to the origination of WPI which focused on classroom instruction in addition to actual workshops where students worked. This theory and practice was part of the ‘two-towers’ history at WPI which included one building (with a tower) for academic instruction and another building (with a competing tower) for actual production in workshops.

Integral to this plan are required student projects. All WPI students are required to complete two projects in addition to standard degree and general education requirements. One project, the Major Qualifying Project (MQP), are oriented towards the professional discipline of the student, or their major. The other project is the Interactive Qualifying Project (IQP) focuses on projects “at the intersection of science, technology, and culture, and emphasizes the need to learn about how technology affects societal values and structures.” (https://www.wpi.edu/academics/catalogs/ugrad/wpiplan.html).

These projects support the education goals of WPI “to form a deep appreciation of the interrelationships among basic knowledge, technological advance, and human need.” (http://www.wpi.edu/about/mission.html). The deep appreciation has significant connotations and relationships to deep learning and why WPI and its Plan are extraordinary examples of deep learning. We now focus more on the IQP.

3.1 The Interactive Qualifying Project

The structure of the IQP is as a nine-credit-hour interdisciplinary requirement which includes undergraduate students, typically in their junior year, from a variety of disciplines. The interdisciplinary nature of this work is critical to a deeper understanding of the multiple facets and the messy
complexities of the real world. Faculty members from all disciplines offered at the school are involved in IQP advisement.

The IQP is not a part of any individual course and its cross-disciplinary focus falls more into the general education perspectives of students, although knowledge from their major disciplines is utilized. Given that the projects are team-based the interactions and knowledge sharing that occurs also allows for peer learning, although faculty guidance is still required. Most projects are targeted to aid a broad spectrum of stakeholders and has a strong community and non-profit focus. Most student projects occur away from campus, with an increasing portion occurring internationally at University sponsored project centers. Given the social focus of these IQPs, there are strong social and environmental sustainability dimensions to most projects. (Vaz 2012).

4.0 INTERACTIVE COMMUNITY BASED PROJECTS AND DEEP LEARNING

In this section we frame the analysis of community-based sustainability projects within the deep learning framework introduced earlier and summarized in Figure 1. We describe and map the HIEP covered in the projects, how these HIEP relate to deep learning dimensions, and the eventual outcomes from these projects based on a recent study conducted by WPI of alumni who had participated in IQPs during their education at the university.

4.1 High Impact Educational Practices

The objectives and approaches identified for IQPs can also be translated into specific HIEP experiences. Although many HIEP can be introduced into IQPs, we focus on four HIEP which are most evident and unique in the team project assignment design. It is a given that the project is focused on the ‘big question’ of community and sustainability. These four include service-oriented activities, common course linkages, collaborative team-based projects, and community based experiences.
Service-oriented activities – were designed into the IQPs by having most of the projects focus on or encourage community service at some level. The students learned from serving actual communities and reflecting on lessons learned to reinforce the new found knowledge. In some cases the project was designed around a specific community, with multiple organizations in that community as a focus of each project. IQP examples include:

1. Promoting a Lead Free Community: An Educational Program for Schools in Thailand
2. Sustainability of Water and Sanitation in Monwabisi Park, Cape Town
3. Hydroponic Farming in Mahasarakham: Integrating Hydroponics into the Agricultural Curriculum While Introducing Entrepreneurial Skills
4. Renewable Energy Study for Leicester, Massachusetts, USA
5. Developing a Sustainable Waste Tire Management Strategy for Thailand

Note that the IQPs not only included service to localized communities (e.g. Leicester, Massachusetts), but also numerous international locations. Part of the broader sustainability service focus was to on developing areas of the world where infrastructure, education, or resources necessary to complete some of these social activities were missing. Given these characteristics, the balance of service efforts meant that multiple dimensions of sustainability were covered.

Common course linkages, the second HIEP, were completed by addressing the community’s requirements through application of broad-based knowledge gained in the classroom and from many courses. Students learn through integrating knowledge from across the curriculum in this IQP experience. For example, students gained knowledge through various broad based case study readings and theories that organizations will respond to sustainability initiatives if there is a ‘win-win’ eco-efficiency outcome can be generated for the community. Thus, when students were making recommendations and identifying solutions, they realized that local communities would respond more quickly and be more motivated when substantial improvements could be made to living conditions, health and/or economic development. Rarely did they experience a situation when a community would
agree with a recommendation just for the sake of one dimension of sustainability without consideration of quality of life of community residents, economic and technical feasibility.

The knowledge necessary to integrate these multiple dimensions required knowledge from a wide variety of disciplines. Thus, the IQP was designed to cross disciplines, for example the IQP “Promoting a Lead Free Community: An Educational Program for Schools in Thailand,” involved students who majored in science, engineering, and social sciences (management) majors to be able to help understand the science and social aspects to their recommendations. Each of the IQPs requires some form of marketing and economic feasibility analysis for the programs, which requires knowledge and understanding of economic and financial principles. Many times, students will seek expertise in areas where they may be weak to help understand particular project concerns. An example of this was that non-Business major students were seeking to evaluate the sustainability of a for-profit hotel in Moscow Russia. These students sought out help from business faculty to further understand the linkage between economic and environmental sustainability as the hotel sought to green its operations.

Collaborative team-based projects begins early in the IQPs with the formation of teams. Student teams are established with a reasonable level of diversity, where practical; e.g., science students working with students majoring in engineering or business. Faculty members from all disciplines are involved in advising IQPs. This diversity enhances the learning experience of all team members on the project team (Vaz, 2012). WPI, although traditionally a science and engineering school, has well established business, social sciences, and humanities programs. Each program contributes to IQP management and is part of the teaching and service requirements of tenure track faculty.

Student teams range from 2 to 5 students. The goal is to maintain a cross-disciplinary perspective and balance in the teams.

Community-based experiences work in conjunction with service-oriented activities by focusing on local and global communities to aid in deep learning. As mentioned in the service-oriented activities
context specific communities were identified where students were allowed to focus on problems related to energy, environment, sustainable development, education, cultural preservation, and technology policy. The connections that student teams establish in working with communities in developing countries provide a valuable real-world experience which enhances the students’ maturity and academic development. Thus, not only is the goal to provide deep knowledge related to curriculum based topics, such as engineering design or economic analyses, but also with more general ‘life lessons’ of understanding cultural and socio-political issues facing communities. Frequently, the students are not only prepared for the particular project, but have to study and understand the communities that they will be entering, especially if the communities are foreign to the background of the students. Instead of just reading about these areas and cultures, students are embedded in the communities for weeks at a time to more fully comprehend the various social, environmental and cultural issues that will be faced by whatever recommendations they make.

4.2 Deep Learning Dimensions

Taking the IQP HIEP into consideration we now describe some of the resultant deep learning dimensions and outcomes. Described below are the three major deep learning dimensions and how the IQP experiences relate to each.

*Integrative Learning* – in order for the students to accomplish the goals of the IQP it is essential that they integrate ideas from the non-profit or government organizations and/or community residents. Ultimately the project must address the requirements of the community. At the same time, students are integrating ideas and information from the diverse team members to construct project solutions. The integrative learning aspects are also evident by the cross-disciplinary characteristics of the teams. Sharing and studying in fields and disciplines outside their major areas of study, which, in the case of
WPI, are technical and engineering knowledge, is a prerequisite to effectively address the ‘messy and complex’ issues facing real world problems.

*Higher Order Learning* – the challenges for the IQP students involve understanding synthesizing the requirements of the community. The work requires conducting research, often using social science methods, directed at a particular problem, typically posed by a non-profit organization or government agency. Next, the students are required to apply theories and knowledge gained in the classroom. As part of the consultative process, such judgments made by the student team are validated through discussions with the community leaders and faculty advisors. The goal is to achieve buy-in from the agency and community for specific recommendations which will be included in the final version of project solution.

The higher order learning is derived through the integration of knowledge and getting a more complete picture of the situation. Also, the actual implementation of some of their recommendations and multiple loops of feedback result in deepened, higher order, learning. Instead of just finding one solution using a specific tool to solve a problem, as in traditional classroom settings, students are required to think about the complexities involved with the problem and the solutions. These complexities and rethinking, with multiple dimensions of feedback from the various information sources, allows students to adjust their perspectives and think more creatively in solutions development. Thus, reinforcement from their peers, community members, external organization participants, and faculty advisors (both formal and informal) cause students to carefully gather data, develop knowledge and learn and relearn the environment, problems and solutions.

*Reflective Learning* – for the student team to be successful, they need to not only listen and understand the point of view of the non-profit or government agency but ultimately convince the organization that the teams’ recommendations may actually work for the local community. This ‘selling of ideas’ is a skill that many of the students develop during the IQP process through understanding and
respect of the organization’s and community’s (and other stakeholders) points of view. At the same time, the process involves taking knowledge from the classroom, conducting additional research and testing the concepts in the local community, which also contribute to higher order learning. It is therefore quite common that the student team comes away from a meeting with a non-profit or government agency with an entirely new perspective on a topic; e.g., a solution to the challenge of providing potable water or renewable energy for a village.

As part of the deeper learning and higher order learning, understanding and reflecting on solutions for the IQP problems is critical. Built into the project and project reports are critical thinking requirements related to, for example, the feasibility of such projects actually occurring. For example, in the IQP guidelines provided to students and faculty advisors, critical, reflective thinking is derived from understanding the limitations of the work.

“Point out any limitations of your project, and be careful not to make the scope of your claims more broad than is justified by your results. Your argument will be more persuasive if you acknowledge limitations and alternatives you considered.” (http://www.wpi.edu/Images/CMS/IGS/qp-writing-guidelines.pdf).

This type of specific guideline points to the need to reflectively and carefully think of any proposed solutions to problems that are identified. Throughout the guidelines provided to the students, a number of reflective questions are posed to the student group in writing up their final report. It is not only in the conclusions section, but also in background, methodology, and analysis of their project that specific reflectively-oriented questions are posited to the students.

4.3 Deep Learning Outcomes
Clearly, each IQP is evaluated by faculty advisors on the various outcomes of the actual, specific projects. But, further, broader analysis has also been completed over the years on the IQP program and the overall WPI plan.

One of the more recent overall evaluations occurred in 2012. WPI conducted a study of alumni who graduated from WPI between 1974 and 2011. Each alum had previously completed two nine-credit hour projects: one involving a problem at the intersection between technology and society (the IQP), and one in their particular engineering field (the MQP).

“The study’s respondents, reported high levels of impact in the following areas:

1. **Professional abilities:** Taking responsibility for their learning, developing ideas, integrating information, solving problems, understanding ethical responsibilities, using current technology.
2. **Interpersonal and communication skills:** Teamwork, project management, effective leadership, written communication, spoken communication, management of interpersonal dynamics, effective professional interactions.
3. **Professional advancement:** Succeeding in business or industry, having opportunities that students at other universities did not have, gaining knowledge to inform future plans.
4. **World views:** Understanding connections between technology and society, awareness of how their decisions impact others, awareness of global issues, understanding of other cultures.
5. **Personal impacts:** Developing a stronger personal character, achieving work/life balance, feeling connected to the WPI community, having their lives enriched in non-academic ways.” (Vaz and Quinn 2013)

Much of the study focused whether the IQPs and MQPs were based on-campus, or off-campus. In almost every situation and questions, off-campus projects were viewed by a greater percentage of respondents to have greater impact on each of these major areas (Vaz and Quinn 2013).

For example (Vaz and Quinn, 2013):

1. 44% of off-campus- project alumni indicated (responding “much” or “very much”) that their project experience expanded their understanding of global issues whereas only 24% of alumni with no off-campus projects indicated the same.
2. 70% of off-campus-project alumni believed their project work enriched their lives while only 28% of non-off-campus project alumni thought so.
(3) Those who completed off-campus projects reported that their project work positively impacted their abilities to both speak and deliver presentations was 19 percentage points higher than those who did not. 

(4) Interpersonal Skills and Ethics Off-campus project work was also more positively impacted professionally-relevant interpersonal skills of managing interpersonal dynamics when compared to on campus projects.

Although many of the projects completed on-campus do have many of the dimensions of HIEP, the additional deep learning and HIEP have greater potential off-campus. The contributions and evaluations from IQPs would need to be compared to students who do not complete any of these. This type of study would need to compare programs from different schools, but a step in the direction of understanding a more complete, embedded and immersed IQP (off-campus) shows that there is a strong implication that IQPs in general would contribute more to each of these areas. Of course, the impacts to communities and other stakeholders, by observation and conjecture, is greater when IQPs are physically embedded in those communities.

5.0 COMMON CHALLENGES

Although many advantages do exist for following the deep learning framework for sustainability-related IQPs there are significant limitations and challenges. Based on critical examination of the desired deep learning model and outcomes, it is clear that we have experienced challenges in a number of areas, where IQPs are conducted. We provide an overview of these challenges based on the stakeholders involved.

5.1 Students

Financial and logistical barriers limit participation by engineering students in study abroad, despite increasing calls for global engagement skills among engineers. (Vaz and Quinn 2013). Many of the students involved in teams excelled and gained deep knowledge through the IQP experience, especially off-campus IQPs. There were some students who were less engaged and there was question as to whether deep learning occurred. This situation may have been caused by lower levels of
commitment, interest and motivation of some students. Freeriding has been observed where some students allowed more highly motivated team members to complete the preponderance of the work for the IQP. Thus, a clear moderator in the successful outcome of HIEP designed programs is the level of motivation, intrinsic or extrinsic, that exists within each student for the topic (Guay et al, 2004, Holdsworth, 2010).

Although a well-designed deep learning project may result in intrinsically motivated students (Lawson, 2012), this result may not occur with passive students. One approach which has enabled the instructor to better address this situation of having students rely on a ‘free-rider’ approach and passive learning is to utilize a very traditional project management approach, of having a project manager for each student team. The project manager must be selected by the team members and empowered by the faculty advisor. The faculty advisor is then able to monitor progress more easily throughout the IQP to ensure that each student is contributing and engaged, and take corrective action if this is not the case. Of course, some limitations and concerns will arise from this peer leading/facilitating effort. Careful examination and investigation of project leaders and how well teams will perform is an issue that requires additional investigation.

5.2 Worcester Polytechnic Institute

The topic of Sustainability is a new topic to many colleges and universities as well other professional schools (e.g. engineering). Simultaneously, many faculty members are in the process of understanding and applying deep learning. Building these relationships and exposing faculty to these approaches is still a major effort at many universities. Classroom learning through traditional lecture mode or through on-line education based on passive learning techniques is still the norm. Whether faculty will embrace sustainability topics and/or HIEP is still a question. Although many advisors have been in the WPI plan for years, these faculty have become attuned to the social and sustainability aspects of the IQPs. A more difficult consideration is more seasoned or new faculty who have been
recruited from outside WPI. These faculty may have been trained in traditional teaching and advising roles and need to build up speed to serve as effective cross-disciplinary advisors.

However, given WPI’s experience and success with IQPs since the early 70s with a strong from the commitment of the faculty and staff, these issues have been overcome. WPI has seen substantial growth in its student population over the past decade, which also means a large influx of new faculty. Given the increasing number of students and increasing new faculty, many faculty may not have enough time to learn the IQP and WPI Plan. The number of students seeking to go off-site has also increased greatly, having faculty willing and able to advise these off-site locations has become a large challenge. This situation is because of the success of the program and has resulted in challenges with these growing pains.

5.3 Communities

The process of managing the teams and organizing IQPs for the student teams is not trivial. The level of faculty involvement and institutional support required is substantial. WPI operates Project Centers in Africa, the Americas, Asia, Australasia, and Europe, where student teams and faculty advisors spend two months addressing problems for local organizations. Since 1974, over 8,000 students have completed off-campus projects. Off-campus project work is preceded by rigorous preparation, typically involving culture and language learning but focused primarily on research, methods, and skills for the project students will tackle. (Vaz 2012)

6.0 LESSONS LEARNED

Experience and results from the IQPs have indicated that this approach of Deep Learning can be effective. The IQP approach enabled students to achieve many deep learning objectives. The lessons learned have both practice and research lessons and implications.
6.1 Student Impact

The findings from the study above suggest that experiential learning away from campus can convey a wide range of long-term gains, as evidenced by alumni responses. These gains extend well beyond those associated with global engagement, such as cultural awareness and self-efficacy, to include areas related to professional success, interpersonal skills, leadership, project management, and communication. Alums have stated that the new world views have influenced almost all aspects of their life. Expanding the scope allows students to be outside their comfort zone. Many comments from students and alums essentially described the new deep knowledge and experiences gained altered them intrinsically, helping to work within the ambiguities or real world situations. The complexities and expanded world view are deep learning aspects that are difficult to capture in standard projects or on-site lecture learning activities (Vaz and Quinn 2013).

The major issue here is that these global IQP and regular IQP experiences are occurring in a technical university situation. That is, the preconceived notion that high tech and engineering schools should only be concerned with ‘hard science’ and ‘technology’ is clearly not the case. These types of deep learning activities, expanding the horizons of technical students, may attract greater interest in STEM-based disciplines and degrees across the board. Given that there is a large gender imbalance in these fields and schools, IQPs may be a policy instrument that can aid governments and communities increase and balance participation in STEM-based education from a gender perspective as well. Socio-economic status issues may also be addressed since students who come from underprivileged backgrounds can provide valuable insights to these projects especially considering that the projects focus on areas of the world and regions that are underserved and under resourced. Community and global based projects can have these practical broader equity implications and need to be studied.

6.2 Research
The research implications of the deep learning framework and its various elements begin with the applicability of such a model. We only focused on certain HIEP. More than the four or five HIEP overviewed in this chapter exist. Significant other approaches may be integrated into the instructional setting, e.g. simulation games, in-class exercises, etc. that are not considered in this study of IQPs.

We made some general conjectures and relationships between the deep learning dimensions and the different practices. Direct linkage between specific HIEP and the deep learning dimensions were not made. This type of analysis would require a careful empirical design and could be used to generate scales for sustainability-focused community-based project research that links up the various factors throughout the framework. Although the scales for the deep learning dimensions have been developed and studied, the HIEP, as described in our context are a little more ambiguous. For example, community based experiences and service-oriented activities have significant overlap. To be able to capture the influences of each of these on deep learning dimensions requires a very careful and discriminatory definition that clearly defines the boundaries of each.

7.0 SUMMARY & CONCLUSION

In this paper we introduced a deep learning framework for sustainability education with a project focus. We developed this framework based on sustainability and general education research. The framework is composed of select HIEP, deep learning dimensions, and general stakeholder outcomes. Using this framework we evaluated IQPs at WPI. We found a number of HIEP in place in this technically (STEM) based professional school setting. In answer to one of the research questions, the framework was found to be a useful guide to help understand the advantages and disadvantages of using IQPs as a core pedagogical method for deep learning in sustainability education, especially at the tertiary and post-graduate level of education. The second research question that IQPs do aid in deep learning for sustainability education in university students was also answered.
The experience and data from WPI’s 40 years of experience with IQPs and the broader WPI Plan, has also provided a number of lessons learned with direct implications for practice and research. Experiential learning away from campus; i.e., “study away”, can overcome many of the barriers that have limited study abroad in engineering, promotes a wide range of learning outcomes relevant to professional success and personal development, and can be a highly effective strategy to prepare students as global engineers and citizens (Vaz and Quinn 2013).

Overall, deep learning and HIEP have proven to be effective in the off-campus IQPs for community based projects. Based on the data and analysis provided above, students have achieved the stated learning objectives. WPI has connected more fully with the communities around the world by working together to improve the living standards of communities including, in some cases, positively impacting environmental sustainability practices and to help the students to develop personally and professionally. “Survey respondents who had completed at least one project away from campus reported significantly greater positive impact not only in areas in which it was anticipated—expansion of world views and personal development and enrichment—but in very specific areas of professional development related to interpersonal relationships, communication skills, and understanding of ethical responsibilities.” (Vaz and Quinn 2013).

However, this approach is not always effective, and may be mitigated by a number of local and environmental factors. For example, the level and type of motivation of the students for participating in IQPs may provide a moderating effect for the outcome effectiveness. There are also other limitations and issues learned from this framework and IQP implementation which we identified and require further scrutiny.

Extension of this work through additional research study can also be completed using the framework as a foundation. Each of the major aspects of the framework can be scaled for a survey instrument using items we have identified from the literature. Considering gender issues and a
comparative analysis to other schools that do not use IQPs are areas of further investigation. One additional characteristic that can be used to enhance the framework are environmental and individual characteristics that can moderate or control, as mentioned with student motivation, the relationships amongst the scale items and general HIEP and deep learning constructs.

Therefore, additional research should be completed and experience gained and analyzed to address the challenges faced by the continued planning and execution of IQPs. It is the intent of this chapter to establish a foundation for additional opportunities for future research and new knowledge to improve in this emerging role of sustainability education for business and professional; e.g., engineering education, and deep learning. Many insights have been gained, but further refinement and development is certainly necessary for the most effective deep learning environment for today’s students and tomorrow’s leaders.
ABBREVIATIONS

Below are definitions of the abbreviations used in the paper.

**HIEP** – High-Impact Educational Practices

**IQP** – Interactive Qualifying Project

**MQP** – Major Qualifying Project

**NSSE** – National Survey of Student Engagement

**WPI** – Worcester Polytechnic Institute
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Figure 1: Framework for Deep Learning and Outcomes

High Impact Educational Practices
- ‘Big questions’ focus
- Research
- Writing intensity
- Service oriented activities
- Common course linkages
- Collaborative team-based projects
- Community based experiences

Deep Learning Dimensions

Integrative Learning
- Integrating ideas or information from various sources
- Including diverse perspectives in class discussions/writing
- Putting together ideas from different courses
- Discussing ideas with faculty members outside of class
- Discussing ideas with others outside of class

Higher Order Learning
- Analyzing the basic elements of an idea, experience, or theory
- Synthesizing and organizing ideas, information, or experience
- Making judgments about the value of information
- Applying theories to practical problems or in new situations

Reflective Learning
- Examining the strengths and weaknesses or your own views
- Trying to better understand someone else’s views
- Learning something that changed how you understand an issue
- Applied what’s learned in a course to personal life or work
- Enjoyed completing a task that required a lot of thinking and mental effort

Source: Nelson et al., 2008.

Stakeholder Deep Learning Outcomes

Students
- Academic gains and school connectedness by students
- Building non-discipline, personal and social competencies of students.
- Staying in school to completion
- Broadened career exploration for students.
- Building social capital for students

Schools
- Building social capital for schools
- Greater civic engagement of students helping to build ‘town-gown’ relationships
- Greater retention rates and higher quality relationships between students and school
- Informing faculty research

Communities
- Expertise and creative solutions to immediate issues
- Greater civic engagement by students
