

Sustainability Service Learning as a Mechanism for Acquiring New Knowledge

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Abstract

Evolving infrastructure needs of our society call for development of engineering students who have “an ability to acquire and apply new knowledge using appropriate learning strategies,” as stated in ABET student outcome 7 [1]. Parallel to the learning strategy need is an emerging need for students to understand the role of sustainability in infrastructure design. Intertwining these two areas with a service learning case study on sustainable infrastructure design provides learners with access to modeling of practitioner’s ability to apply new knowledge in real time. This study reports on a pilot semester-long project, in which students develop learning skills, with a focus on sustainability by working with a non-profit developer to document Envision credits for a transit-based development. In this case study, weaving learning theory, sustainable infrastructure design and service learning together provides students with 1. access to tools for identifying new knowledge needed, 2. an understanding of the complexities of sustainable infrastructure design and 3. a service learning opportunity with a non-profit developer. The Institute for Sustainable Infrastructure (ISI) Envision rating system is used as the mechanism for providing the service learning partner with an infrastructure sustainability rating and students with access to the design professional experience.

The purpose of this research is to add to the literature on students’ ability to identify and use learning strategies, specifically within the context of a sustainability rating tool and service learning situation. A mixed methods research approach is used for assessment. Specifically, mechanisms used for assessing students’ ability to identify new knowledge needed and appropriate learning strategies are based on 1. Ability of learners to apply new knowledge to ISI Envision credit ratings, 2. student motivation metrics which are linked to students’ ability to employ learning strategies and 3. student reflective observation and conceptualization on their own ability to apply new knowledge. Findings of this study are preliminary and include qualitative measures but point to potential teaching/learning mechanisms which may be further explored in successive studies.

Introduction

The civil engineering profession faces an increasing range of demands including preparing students for evolving challenges including design and maintenance of aging infrastructure, development of sustainable infrastructure and resilient design. The shift from an industrialized economy to the knowledge economy means that successful graduates will encompass the design mindset needed to be creative, innovative, flexible, adaptive, curious and imaginative problem solvers [2]. Civil engineering programs are responding to shifting industry requirements as well as revised ABET student outcomes, including “an ability to acquire and apply new knowledge as needed using appropriate learning strategies.” Engineering education, in general, may strive to more closely represent the complexity and ill-defined nature of real world problems by presenting case studies, open-ended problems, and other activities that bridge multiple disciplines [3]. Teaching-learning frameworks which offer greater exposure to the complexities

of real world engineering, such as experiential learning, and the more focused service learning, offer potential innovations including a learning environment that incorporates the complexities of real engineering design problems, an ability to better serve more diverse student learners, an ability to serve diverse communities and technology transfer [4].

Setting and evaluating a student outcome centered on an ability to use appropriate learning strategies requires students to identify and articulate specific learning strategies and to practice using learning strategies to acquire and apply new knowledge. Incorporation of basic learning theories and learning strategies within engineering course contexts has the added benefit of deepening students' understanding of their role in learning course material, as well as preparing students to anticipate and self-identify future learning needs and learning strategies. While the research base on teaching engineering instructors about educational theory is expanding, the research base on how engineering instruction might teach engineering students learning theory and strategies is an emerging area with the potential for rich development and thus is the primary concern of this study.

Sustainability within infrastructure design is a timely mechanism for exploring learning since this is an area that is also emerging, and therefore is an area in which students will need to continue to develop knowledge. Sustainable infrastructure design and resiliency will continue to evolve and engineering graduates will need to acquire and apply new knowledge in this area as theoretical content and new practical applications emerge. Practitioners are meeting the needs of sustainable infrastructure design in diverse ways, so it follows that understanding case studies of sustainable infrastructure design provides innovation and insights as they occur. Service learning, a community-responsive expression of experiential learning, is a reciprocal learning framework which provides access to practitioner's innovations alongside an opportunity for students to strengthen engineering design and analysis skills, with the potential for substantive community impact [5]. In this case study, students reciprocate the insight gained from the practitioners with ISI Envision credit assessments, an area in which these practitioners do not have experience.

This case study draws upon the transfer and application of learning strategies, innovations in infrastructure sustainability and the service learning framework for considering new ways in which students may develop and demonstrate "an ability to acquire and apply new knowledge using appropriate learning strategies." This study is focused on the teaching/learning mechanisms and preliminary assessment methods. The program in which this course is located is a new program with small class sizes. Four students within the construction/engineering economics class in which this study is anchored consented to participate in this research. Background knowledge on service learning and infrastructure sustainability, which are central to this case study, is outlined before the discussion progresses to key components of the course project and assessment.

Service Learning Framework

The experiential learning framework grows out of a long line of educational theorists and theories including Jean Piaget's theory of cognitive development which posits that a learner self-

constructs a mental model based on interaction with environment [6]; Lev Vygotsky’s learning theories which stress the critical role of social interaction in learning [7]; and John Dewey’s pragmatism which delineates the learner’s role in identifying constructs based on successful human interaction and active manipulation of the environment to test hypotheses before moving on [8]. David Kolb draws upon these educational theorists and theories and posits a four-stage cycle of the learning process which is a “holistic integrative perspective that combines experience, perception, cognition and behavior” as represented in Figure 1. Kolb posits that people “learn best through experience.” The basic theoretical model for experiential learning includes four stages: concrete experience, abstract conceptualization, reflective observation, and active experimentation [2]. Experiential learning emphasizes the process of learning rather than the outcomes.



Figure 1: Kolb’s Experiential Learning Model

By offering students freedom from the more traditional and structured classroom settings, experiential learning can cater to a wider range of learning styles, making the method more accessible to a wider range of students. Additionally, experiential learning and place-based education can give students an insight to this “real world” by providing the active experimentation that is essential for engineering careers. Furthermore, experiential learning methods can be used to meet an ability to “acquire and apply new knowledge as needed, using appropriate learning strategies” by offering a foundation for learning as a life-long process.

Service learning is a subset of experiential learning and integrates a community service component. Service learning in the context of this case study relies upon a university’s commitment to a non-profit entity which is supported by the university through multiple course commitments through the university Sustainable Communities Partnership (SCP). SCP works in

partnership with vetted nonprofit entities, including public entities such as cities, to improve the local community as SCP faculty integrate partner identified projects into university courses [9]. Both the partner and students benefit from the SCP reciprocal relationship. Projects are based on the partner's goals, needs and timelines. SCP provides students with a service learning opportunity to develop an understanding and empathy for real-world problems in their local communities, while improving their critical thinking, communication, and creative problem-solving skills. Additionally, students learn how to navigate the dynamic and ambiguous nature of sustainable projects, which prepares them for the complexities which they will face in their post-graduation career. The partnering cities and organizations benefit by gaining innovative solutions and approaches which help them achieve their sustainability initiatives without expending limited resources.

The community partner for this case study is Place, a nonprofit development organization with a mission baked right into their acronymic name: Projects Linking Art, Community & Environment. The Place mission is to create affordable living and work for people of all income levels and backgrounds within sustainable, mixed-use, transit-oriented communities. Place develops sustainable communities for both the arts and economic development. These urban "ecovillages" are equipped with luxury living, affordable housing, access to education, child development, teacher housing, public transportation, greenspaces and arts and culture. The facilities are entirely powered by renewable energy, including but not limited to solar, wind, geothermal and waste-to-energy methods. Place communities seek to provide life-long education, healthcare, and jobs that are related to the arts, science, and clean technology [10].

Currently, Place is collaborating with a Midwest city to create a mixed-use, mixed-income, transit-oriented community demonstrating environmental design and LEED certified buildings. Located on future light rail line, this urban eco-village and creative center will offer 299 healthy apartments, affordable and market rate, along with space for local businesses, a new hotel, an automated agriculture system and live/work spaces designed for creatives [10]. The eco-village project provides an opportunity for students to investigate the intersection of project management, engineering economics, sustainability and metacognition on a live project. Students directly interact with the Place team to learn about innovations in infrastructure funding, project design challenges, development ethics and innovation in sustainability as they consider their own learning progression.

The development of the class partnership with Place is based on the goal of giving students an in-depth and professional experiential learning opportunity that provides them with insight into managing the social, economic, and environmental aspects of a live infrastructure project. One of the most important factors of the SCP partnerships is that both parties have their needs met. For Place, working cooperatively with the class in person, by email and on an electronic platform, Podio, allows the Place professionals to learn more about the Envision rating system as well as options for optimizing their project in real-time. Place is seeking the Envision credential and is relying upon the service learning instructor and class for professional experience and documentation. In turn, the students receive access to design professionals, experience with sustainability aspects of infrastructure, experience in professional communication and access to innovations in infrastructure funding. This experiential sustainability experience is interwoven

within sustainability content, reflection and meaning making in a construction/engineering economics course.

Institute for Sustainable Infrastructure Envision Sustainability Rating

Objective sustainability constructs come from various sources, and the American Society of Civil Engineers (ASCE) defines sustainable development as “a set of environmental, economic and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or availability of natural, economic, and social resources.” One of the more difficult aspects of environmental and social sustainability specifically is how we, as engineers, quantify the environmental and social impacts of a project [11]. Business writer John Elkington coined the moniker triple bottom line (TBL) in 1994 to capture the social and environmental implications of development which accompany the traditional economic bottom line. While engineers have traditionally used economic tools including engineering economics to quantify project impacts, quantitative tools for the social impact and environmental impact are less utilized and accepted in project assessment. A holistic tool which incorporates TBL economic, environmental and social components is the Institute for Sustainable Infrastructure (ISI) Envision sustainability rating.

The ISI Envision rating system is endorsed by ASCE, American Public Works Association (APWA), and American Council of Engineering Companies (ACEC), and is being used by infrastructure professionals to design, plan, build, and maintain sustainable infrastructure. The metric is comprised of sustainability credits in five categories: quality of life, leadership, resource allocation, natural world, and climate and resilience. Credit areas have variable points, levels of achievement, and a list of documentation needed to achieve each level. The levels of achievement range from “improved” to “restorative”, and projects may gain extra “innovation” points for exceeding the credit requirements. After the Envision checklist is complete for a project, the project is evaluated by an ISI sustainability professional for certification.

Envision as a sustainability tool in the classroom shows promise: a University of Utah study demonstrated using Envision in their civil engineering capstone course helped improve the student’s sustainability literacy [12]; and at the University of Colorado – Boulder, an Envision active learning assignment for first-year engineering students scored an average grade 86%, indicating that most students had reached the knowledge and comprehension cognitive levels of sustainability [13].

Methods

Development of Partnership

The course director worked in partnership with the university SCP director to establish the course and non-profit developer partnership. The project scope included the course director, a registered Envision professional, vetting student documentation of credit areas. In return for the Envision documentation, the non-profit professional team committed to 3 face-to-face meetings as well as project documentation support on requests for information.

The non-profit development is a multi-disciplinary team of developers, designers, and attorneys who have established expertise in sustainable infrastructure development. This group of individuals has unique expertise in integrated project delivery systems and infrastructure sustainability practices. In addition to the team's commitment to sustainability and education, the team was open and curious about the Envision sustainability rating but they did not have direct experience with the metric.

Development of Appropriate Learning Strategies

Students' understanding of their role in the acquisition of new knowledge begins on the first day of class with an introduction to and a discussion on Carol Dweck's growth mindset and the agency that students have in determining their knowledge acquisition [14]. This baseline introduction grows during the semester as students are introduced to and monitor their own ability to identify and apply new knowledge using appropriate learning strategies. Learning theorists and theories which students interacted with through the semester included Lev Vygotsky's zone of proximal development, John Dewey's pragmatism, and David Kolb's experiential learning cycle. Additionally, STEM models including the Lesh Translation model for mathematics and crosscutting concepts from science education were explored in the course context of exploring how students learn.

Experiential learning is an essential construct which is explored in depth through scaffolded learning through the semester. First, the theoretical construct of experiential learning is explored as a learning model which requires the learner to dialectically engage in the "grasping experience" which is a continuum from concrete experiences to abstract experiences and the "transforming experience" which is a continuum from active experimentation to reflective observation. This framework is used for multiple course construction site visits which cover a wide range of public and private infrastructure projects. Students use the course content as the basis for which they view the site visit. Collective reflection in debriefings better brings into view the constructs which are reflected upon in written reflection. This practice of being oriented to a subject, interacting with it, identifying key components and integrating the complexities into one's understanding is the first step in the experiential learning model used throughout the course.

An equally important key to knowledge acquisition is an understanding of the interplay of motivation. Deci and Ryan's self-determination theory is shared as the basis for understanding the interplay between one's sense of choice with intrinsic motivation being the state that provides the greatest satisfaction; extrinsic motivation with external regulation occurring with rewards that avoid negative consequences; extrinsic motivation with identified regulation occurring when the behavior is perceived as chosen by oneself but performed as a means to an end; and amotivation which occurs where there is no sense of purpose or expectation of reward [15]. Clearly intrinsic motivation leads to optimum learning outcomes yet the interplay of extrinsic motivation and amotivation is important to understand for self-regulation when identifying the need for new knowledge. In addition to a cognitive understanding of these elements, students participated in a vetted measure to understand their own motivation status in various points of

the project. The scale, the Situational Motivation Scale (SIMS) was developed and vetted by Guay, Vallerand and Blanchard [15].

The SIMS tool is unique in that it measures students' motivation on a specific task versus generalized motivation responses. The assessment tool includes 16 questions which ask students to identify why they are engaged in this activity. Responses are on a 7 point Likert scale from 1. Corresponds not at all to 7. Corresponds exactly. Sample items include "because I think this activity is interesting", "There may be good reasons to do this activity, but personally I don't see any", "personal decision" to "because I believe that this activity is important for me".

Development of Class Project

The class project is named the Triple Bottom Line project to draw attention to the social and environmental attributes in addition to the economic bottom line. The project is scaffolded and includes applications on construction project delivery systems, scheduling, estimating, project management, safety, sustainability, and engineering economics. Site visits, related to the project site and transportation components served as the basis for understanding experiential learning context with the interplay of experiencing, reflecting, theorizing and testing concepts. This project is embedded within a junior level construction/engineering economics course is a new civil engineering program with exceptionally small class sizes, as small as three students in some of the upper level courses. The enrollment in this course was 4 students. The timing of this project, at the beginning of their civil engineering focused coursework, is calculated in order to build students' identification of the need to acquire and apply new knowledge along with the development of appropriate learning strategies so that they can learn material which is still experiencing shifting frameworks, that is sustainability is a relatively new construct, which with a newly developed framework; it allows for the students to identify and articulate strategies for learning; and it sets the expectation, through the sustainability partner's actions, that the need to identify, acquire and apply new knowledge in the future will continue throughout their professional career.

Four major project milestones provided the framework for project submittals. The first milestone included instruction in learning theory and the triple bottom line infrastructure sustainability with student delivery of the first draft of the five Envision categories. Students fulfilled the first milestone by identifying a credit area in which an application of the Envision credit would improve the sustainability of the Place project. The first milestone was iterative in that students needed to dive into the credits to determine credits which best matched the project's strengths and the students completed "request for information" (RFIs) documentation to the non-profit developer to get additional information needed for credit documentation. Students were given feedback from the course instructor which redirected and/or refined student understanding of the credits and documentation needed to fulfill the credit requirements. For the second milestone, students focused on a specific course content, such as project delivery systems, scheduling, estimating, construction operations, and completed literature research and a comparative system analysis of projects. The third milestone included an engineering economics sensitivity analysis of a project component. Lastly, the fourth milestone was a presentation to Place with the Envision findings.

Assessment and Analysis

Assessment of this exploratory instruction model to develop students' ability to acquire and apply new knowledge using appropriate learning strategies and sustainability service learning success is based on three primary indicators: completion of the Envision credit ratings, assessment of student motivation with the SIMS assessment tool and student identification of their ability to identify, acquire and apply new knowledge using appropriate learning strategies.

Envision Rating

Each student chose a discrete credit in each of the five Envision credit categories and researched the components of the category. Deliverables included credit analysis documentation. This provided a real life credit analysis with unknowns and the need to complete a request for information (RFI) to the developer. Several of the students noted an initial discomfort in interfacing with new content and the professional communication needed with the developer but at the completion of the project students noted a deep sense of accomplishment with the completion of authentic credit analysis. Students prepared a professional credit cover sheet, constructed requests for information from Place, and wrote a succinct memo. Most students chose credits that were easily applicable to the transportation goals of the Place project, showing that they were effectively able to apply sustainability metrics to a live project. The students conveyed that there were elements of the Envision rating system that they were unsure of but their submittals demonstrated that they had at least a foundational understanding of both the project and Envision credits. Sample credits that the students chose for the first category included QL 2.1 Improve Community Mobility and Access, QL 2.2 Encourage Sustainable Transportation, QL 1.1 Improve Quality of Life, and QL 1.3 Improve Construction Safety. Student ability to address Envision credit requirements improved dramatically from the initial exploration to the final credit documentation. Students were given course instructor scaffolded feedback at each step in the process.

The final assessment of the Envision rating came at the end of the semester after RFIs were processed and documentation was finalized. Two weeks before the final presentation, preliminary findings were shared with the Place team in an informal meeting and students shared specific steps which would provide Place with higher credit ratings. The Place team responded with additional documentation which resulted in yet higher ratings. The final findings and presentation provided the non-profit developer with documentation that can be submitted directly for the Envision rating documentation. The Envision product which has been vetted and graded by the course instructor, an Envision Sustainability Professional, may be considered evidence of students' ability to identify new knowledge needed and apply appropriate learning techniques. The primary strategy was experiential learning, a framework which mirrors how many professionals acquire new knowledge with reflective observation and conceptualizing.

The Place team expressed gratitude for the findings and requested that the student team present their findings to the city council. As design professionals, the Place team noted that the students prepared high quality materials which had the potential to make a significant impact on the community. The rating on this first project was positive with the following acknowledgement:

The students in this course worked with PLACE on Via, a 300 unit mixed use mixed income transit oriented development in St. Louis Park, Minnesota. Their work was focused around the infrastructure and site components of Via as they relate to achieving Envision criteria for the Via project as a whole.

Before working with this class, Envision and its applicability to our work in resilient community development was unknown to PLACE. With the Professor and her students' help, we were able to determine that Via may qualify for Envision Platinum status based on the credits studied. PLACE will work with the Professor's class to continue our study of Envision's applicability with a goal of fully certifying Via as we work toward completing construction.

This certification will help communicate the resilience and sustainability of Via to local funders, partners, and municipalities, likely resulting in an increase in opportunity and capital for our organization. We thank the Professor and her students for outstanding work and look forward to continuing our partnership with the Civil Engineering department and St. Thomas as a whole.

Additional community partners have learned of the work which came from this service learning project and have expressed an interest in cataloging projects for use in the course library for similar partner outcomes.

Student Motivation and Perceptions

The second metric used to assess the success of students' ability to identify, acquire and apply new knowledge, within appropriate learning frameworks with appropriate strategies is based on student motivation assessment for sustainability knowledge. This is a key tool since educational psychologists, including Dweck, point to the important role that student motivation and self-assessment play in student learning [14]. Several snapshots of student motivation were measured throughout the semester using the Situational Motivational Scale or SIMS. The SIMS tool may be analyzed quantitatively or visually by plotting the motivation against student motivation responses.

The survey was analyzed using visual "worm" graphs that fall into general worm clusters which visually represent stages from highest intrinsic motivation to amotivation. Students responses shown in Figure 2, which summarizes students' self-assessment at the beginning of the project, illustrate a cluster which indicates that the students are interested in the course activity, but also are sensitive to external rewards or pressure. On the scale on intrinsic motivation to amotivation this cluster tends towards the ideal of intrinsic motivation.

Interestingly, student motivation at the point of peak project deadline illustrates students generalized shift to external motivation as deadlines loomed. Most interesting is the shift in specific student responses with student 1 shifting to a high intrinsically motivated position from the project introduction to the peak project deadline. Conversely, student 4 and 3 moved from identified regulation to high external regulation; and student 2 moved from predominately

intrinsic motivation to identified regulation. This peak production time correlated with less learning and more documentation, perhaps a correlation for further exploration.

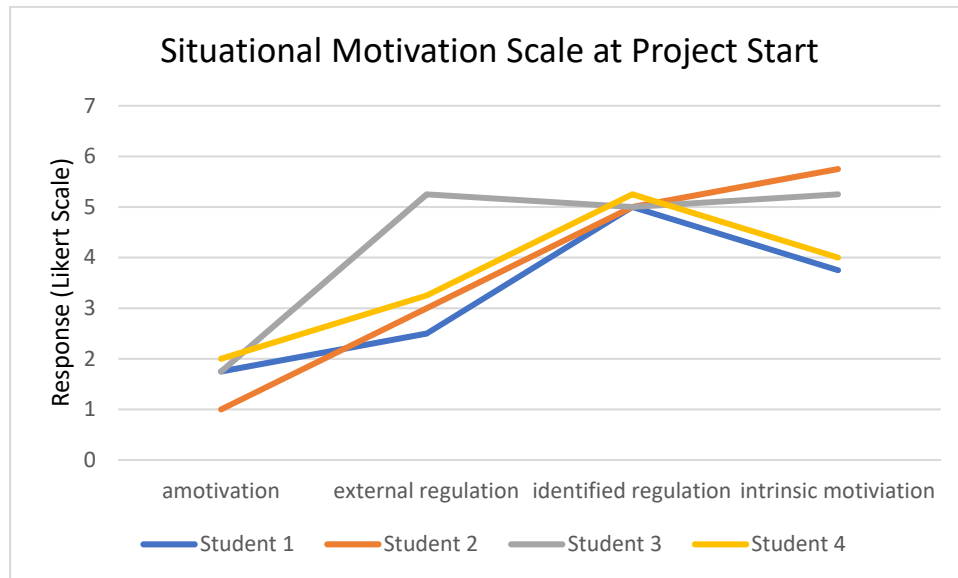


Figure 2: Early project SIMS summary illustrates students' high internal regulation and intrinsic motivation

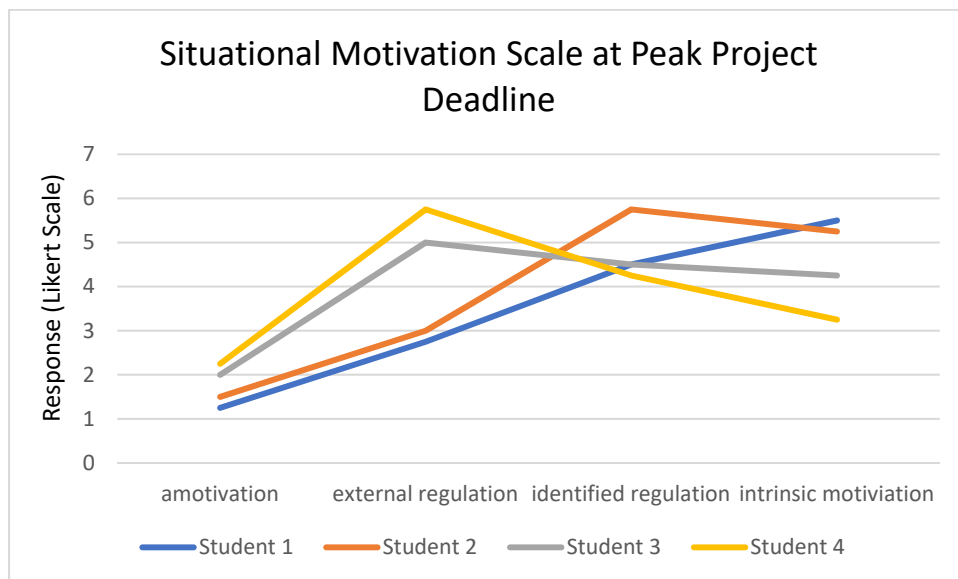


Figure 3: Peak project deadline SIMS summary illustrates students' high external and internal regulation

The SIMS analysis begins to identify interesting motivation and learning-work correlations and will continue to be an assessment tool used as the course moves forward. It appears that intrinsic motivation may be higher at the beginning of the semester and transition to motivation which is more externally regulated as final grades and final project deadlines approach. This is an area that the course instructor will further investigate through multiple semesters and greater attention to student self-reports of motivation as well as specific project deliverable times.

Student Learning Reflection Assessment

Key to the experiential learning process is the need for reflection based on experience as a key component of theorizing and solidifying knowledge. Multiple mechanisms were employed to provide students with the opportunity to provide a reflective observation and reflection conceptualization on their learning experience and specifically their sustainability learning experience. Key reflection elements included structured site visit reflections, final written reflection and oral exams focused on students' self-assessment of learning strategies and sustainability. Oral exam responses were coded with three main themes emerging as key student learning. The first theme which emerged was an understanding of their own student learning. The second theme which emerged was a nuanced understanding of how project delivery systems, specifically, integrated project delivery, interplays with sustainability options and project performance. The third primary theme which emerged was student identification of the role and importance of communication between project stakeholders.

Students' ability to identify their role in unique knowledge acquisition was apparent. Direct student comments on the role of practice experiential learning on site visits included: "I think just the experiential learning aspect was huge, it's probably the most obvious"; "The reflections of the site visits were very helpful"; and "we started with the classroom (material) and with the site visits practice early in the year. I think that mirrored the way I learned." Students expressed some surprise in learning about the interplay of concrete experiences and abstract conceptualization as well as the role of active experimentation and reflective observation in new ways: "I've always thought that I was a do-er, that I had to learn by doing. And I think I'm learning that I learn more by example"; "There would be some vocab where I knew what it was but I didn't know exactly and then I'd just try to work along with it, but then I would eventually look it up and connect to it"; "I think that it is helpful to see that real-life example because then I understand that, 'oh this aspect of the project is documented here in the contract'"; "a lot of our work was outside of the classroom and in the real-life scenario, but that really proved meaningful to me"; and "with all of the requests for information and the presentation we had to give, that was actually put in the real-life context, and that Place actually has a stake in the work we do."

The surprise and novelty in self-discovery of learning in an engineering context may be the greatest take away of this exploratory research project. The course instructor has identified lesson plan strengths and shortcomings and will be incorporating course improvements, including a refined lesson rubric and more opportunities to identify the academic language needed to articulate multiple learning strategies. Additionally, the use of multiple smaller scale learning strategy practice sessions will have the benefit of strengthening students' ability to employ multiple work place learning strategies.

Reflection and Next Steps

Just as engineering student learning needs will continue to evolve as content knowledge and technology evolve, key components of this limited small-scale exploration may continue to be refined in future studies. For example, the qualitative exploration has led to the identification of the need for a refined rubric in which students are assessed on their ability to explain and employ multiple learning strategies. Another key area for exploration includes the interplay between motivation and learning. Clear connections between student motivation and learning abound in literature but how engineering student learning and motivation self-knowledge may be generalized to future work place needs is area rich with research possibilities. In this small study it appeared that student motivation waned as external pressure increased. The intersection of struggle in learning and motivation is a tangential area for investigation as well.

Learning how to learn should be a primary objective of an engineering undergraduate education. Students entering the workforce may enter as professionals who can solve today's problems but engineering leaders will need to be flexible, innovative, curious and open to solving new problems in interdisciplinary teams. Having the experience of identifying new knowledge and how to acquire new knowledge as an undergraduate better equips the student with the language and framework needed to efficiently seek new knowledge in the future. This study reports on one preliminary case study which combines learning theory, service learning and sustainability constructs. This exploratory study may have raised as many questions as were answered, yet the questions cultivated help define inquiry into coaching students to identify appropriate learning strategies. Future offerings of this course will continue to strengthen the learning connections through deeper reflection and meaning making as the sustainability component is strengthened with service learning partners.

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