Creation of On-Campus Living Laboratories for Improved Student Learning

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Abstract

Experiential learning has been linked with increased content retention rates among students. Traditionally, many of the experiential learning activities in engineering education have occurred in laboratory settings. However, laboratory activities often lack the complexity of real-world problems that graduate engineers will face. This is particularly true in civil and environmental engineering where large projects and systems must be scaled down and simplified to evaluate in a laboratory setting. To remedy this issue and increase student exposure to complex problems, the Department of Civil and Environmental Engineering at Rose-Hulman Institute of Technology has begun to develop living laboratories by leveraging existing and planned facilities on campus. This paper will present the rationale behind the design of the living laboratories, descriptions of the projects that have been completed or planned, challenges associated with implementation of labs, and preliminary results of assessment related to the effectiveness of the labs as teaching tools.

Keywords

Living laboratory, experiential learning, civil engineering, environmental engineering

Introduction and Background

Active learning is essentially a method of education in which students take ownership of their learning experience[1]. Faculty serve as facilitators to the student's learning experience as opposed to serving as the distributors of knowledge in a traditional classroom setting. Active learning can be as simple as small, topical discussions in a classroom to something as complex as project-based learning. The success of active learning is well documented and spans a vast array of science, technology, and engineering disciplines[2-6]. A specific method of active learning is known as experiential learning, in which students engage in a learning activity that promotes intellectual, emotional, and physical engagement[7-10]. Engagement of students in these multiple dimensions, if delivered with thoughtful and targeted guidance, has been proven to significantly promote retention[11-12].

Experiential learning is often implemented in a laboratory setting because the controlled environment can allow students to complete a learning module in a timely manner with relatively reproducible results. While laboratory exercises are extremely important to introduce and observe fundamental concepts in civil and environmental engineering, they typically lack the complexity and scale of real-world projects. One method routinely used to supplement laboratory exercises is field trips to active construction sites or completed civil or environmental projects. These trips can provide important context for the students, but may be problematic in other ways. For example, the quality of the field trip experience can greatly depend on the tour guide, the observed site activities may not directly align with the concepts taught in the classroom or laboratory, students are typically observers rather than active participants, and there are safety and risk concerns with taking students off campus. With these laboratory and field trip limitations in mind, we began to seek an alternative model that would allow faculty to demonstrate fundamental concepts in a more complex environment while providing context for a given topic.

Our proposed model for experiential learning to enhance retention of engineering concepts is to develop and utilize living laboratories on our campus. These living laboratories can be incorporated into existing or planned campus facilities or constructed independently in one of many undeveloped areas on campus. To aid in planning and design of our living laboratories, we established several goals. First, the living laboratory should be used to demonstrate several engineering concepts. Ideally, the concepts would be in at least two sub-disciplines of civil and environmental engineering. Second, the laboratory should be utilized in more than one course. Third, the living laboratory should have longevity to justify the expense and faculty time necessary for design and implementation. Finally, the laboratory should provide additional opportunities such as student or faculty research projects.

By developing the living laboratories to engage students in meaningful experiential exercises, we hypothesize that students will have improved retention and transference of fundamental skill sets. Secondarily, because the laboratories will be used in several courses and sub-disciplines, we envision that the living laboratories will have significant impact on the student's ability to aggregate and synthesize knowledge across disciplines.

Completed or In-Progress Living Laboratories

Since 2008, Lost Creek, a stream that runs through the Rose-Hulman Institute of Technology (RHIT) campus, has been utilized as an outdoor lab in civil and environmental engineering classes. Experiential learning activities have primarily been applied to a stream restoration course where students are introduced through field labs to the concepts of fluvial geomorphology, aquatic ecosystems, and sediment transport for application in restoring impaired streams. During the quarter, the students make frequent visits to Lost Creek for the purpose of collection of baseline monitoring data that is used to classify channel morphology and process, analyze stream habitat characteristics, estimate sediment transport, and analyze stream stability. The experiential learning activities (i.e., field laboratory exercises) were created to guide students in the data collection efforts. Although the activities are most often applied in the stream restoration course, each activity is transferrable and was not designed for any specific course, but instead can function as an independent monitoring procedure or be utilized in other courses. Equipment for the lab was procured using both internal and external sources. A full description of the project can be found in a 2014 ASEE conference paper by Mueller Price and Niezgoda[13].

During the summer of 2016, work began on an addition to the Hulman Memorial Union on the RHIT campus. Construction included a 28-foot high retaining wall that was planned to facilitate a new loading dock adjacent to a relatively steep existing slope. After discussions with campus facilities personnel, we were allowed to coordinate with the general contractor and specialty retaining wall contractor to instrument the retaining wall with load cells, inclinometers, survey points and water level indicators. Because we were not aware of the project details until approximately one month before construction began, we were not able to seek external funding for the project. To aid in the development of living laboratories, the Dean of Faculty and Department Head pledged financial support for the project. The wall is nearing completion, and we are actively obtaining deflection, load, and water level data, as we will continue to do in the future. To date, the living lab has been used as an undergraduate research project and tangentially in a soil mechanics and foundation engineering course. We anticipate that it will also be used in a retaining structure design course and possibly a steel design course. We may also develop an instrumentation short course that will utilize the living laboratory.

In close collaboration with the RHIT facilities department, our faculty have leveraged various campus maintenance and upgrade projects for use in the classroom. Primarily in the construction engineering course and the construction methods and equipment course, students partner with facility workers to construct small scale public works projects such as sidewalks, bike racks, and parking repairs. Students are able to work alongside construction workers from facilities and gain direct hands-on experience. Additionally, with effective communication between parties, faculty in structures courses have been able to leverage on campus work with beam and cylinder casting for lab demonstrations. Students again are able to work alongside construction workers in the placing of concrete.

Unsuccessful Living Laboratory

In 2013, we planned a living lab associated with an on-campus pedestrian bridge that was slated to be replaced. The living lab design included outfitting the bridge and immediate surroundings with an array of sensors including strain gauges, load cells, earth pressure cells, inclinometers, tilt meters, displacement transducers, water level indicator, stream velocity meter, water quality sonde, and a weather station. Uses of the full-scale bridge facility would have included laboratory exercises, as well as research potential for faculty and undergraduate students, in the sub-discipline areas of structural, geotechnical, and environmental engineering. Additionally, the instrumentation system allowed for real-time, interactive demonstrations of the behavior of the structural system that could be tailored to high school students within the local community and summer engineering and science camp, to encourage more students to consider careers in engineering and science. Ultimately, the cost of the living laboratory project was high and we could not secure funding for the instrumentation within the limitations of the bridge replacement schedule.

Living Laboratory in Planning Phase

Currently, a senior design team in the Department of Civil and Environmental Engineering is working to design another living laboratory in an undeveloped, wooded and wetland portion of campus. The laboratory facility will include trails, instrumentation, and an outdoor classroom that will primarily be used in laboratory exercises and research in environmental engineering and biology. Additional potential laboratory features include an elevated tree canopy trail and a living building that will be used for storage. Because bridges will likely be required to cross existing streams and wetlands, there is also opportunity for implementation in structural and geotechnical courses.

Challenges

The two main challenges faced in the development of on-campus living laboratories are related to communication and funding. Communication can be problematic because our department is not always aware of the planned upgrades and construction activities on campus with which we could partner to develop a living laboratory. Even when we are aware of upcoming projects, the schedule may be too tight to allow for proper planning and development. To remedy these communication issues, we have found that it is important to get the support of the academic administration, such as the Dean of Faculty and Vice President of Academic Affairs, to act as advocates in upper administration. They can help convince other administrators of the value of the living laboratories to our academic mission. Additionally, it is supremely important to be in regular contact with the institute facilities department. With regular contact, faculty can be abreast to regular work that is happening on campus a ready to leverage real "civil" work being conducted for enhanced learning experience. Especially if facilities is willing to let students participate in the work, these activities can be very successful experiential learning opportunities.

Securing funding for the living laboratories has also been problematic. We have sought funding from traditional, outside, research funding sources such as the National Science Foundation. The lack of success in our proposals is likely because the projects skew more towards educational research rather than traditional engineering research but require a higher initial capital investment than typical educational research. As previously stated, we have received internal funding for projects, thus far. We also plan to develop relationships with alumni and industry to fund future living laboratories.

Preliminary Results

The Lost Creek Living Lab is the only laboratory that has been fully implemented in a course and assessed for effectiveness, starting in 2008. Effectiveness of the living laboratory has been assessed using the index of learning styles and course evaluation responses for students taking the course. The full results of the assessment are contained in an ASEE conference paper by Mueller Price and Niezgoda[13]. In summary, the learning styles of over half of the students taking the course fit well with experiential learning. This connection is reflected in the high student ratings for the overall course and for agreement that the laboratory assignments and course material reinforced one another. Each of these ratings was above the institute average. Finally, written feedback from the students indicated that the experiential, living laboratory exercises were beneficial and provided real-world context to the course.

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Kyle Kershaw, PhD, PE

Kyle Kershaw is an Assistant Professor of Civil Engineering at Rose-Hulman Institute of Technology with 5 years of academic experience and over 10 years of industry experience. His main area of expertise is geotechnical engineering, where he is active in teaching, consulting, and applied research related to retaining structures and slope stabilization. Kyle's pedagogical interests include implementation and evaluation of project-based learning.

Matthew Lovell, PhD, PE

Matthew Lovell has served as an Assistant Professor of Civil Engineering at Rose-Hulman since 2011. He is a structural engineer with expertise in large-scale experimentation and field instrumentation of structures. Matt also has experience working as a consultant for a bridge design firm and as the Site Operations Engineer for the Network for Earthquake Engineering Simulation (NEES). Dr. Lovell engages his students in undergraduate research experiences and focuses on infusing creative design and structured problem solving in undergraduate engineering courses.

Jennifer Mueller Price, PhD, PE

Jennifer Mueller Price is an Associate Professor of Civil and Environmental Engineering at Rose-Hulman Institute of Technology. Her areas of specialty include environmental river mechanics, water quality, and sustainable design. She strives to include experiential learning and provide real-life applications of engineering work in her courses.