121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #10088

Work-in-Progress: The Platform-Independent Remote Monitoring System (PIRMS) for Situating Users in the Field Virtually

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Dr. Vinod K Lohani is a professor in the Engineering Education Department and an adjunct faculty in the Civil and Environmental Engineering at Virginia Tech. His research interests are in the areas of sustainability, computer-supported research and learning systems, hydrology, and water resources. In a major ($1M+, NSF) curriculum reform and engineering education research project from 2004 to 2009, he led a team of engineering and education faculty to reform engineering curriculum of an engineering department (Biological Systems Engineering) using Jerome Bruner's spiral curriculum theory. Currently, Dr. Lohani leads an NSF/REU Site on "interdisciplinary water sciences and engineering" which has already graduated 56 excellent undergraduate researchers since 2007. This Site is renewed for the third cycle which will be implemented during 2014-16. He also leads an NSF/TUES type I project in which a real-time environmental monitoring lab is being integrated into a freshman engineering course, a senior-level Hydrology course at Virginia Tech, and a couple of courses at Virginia Western Community College, Roanoke for enhancing water sustainability education. He is a member of ASCE and ASEE and has published 70+ refereed publications.

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Work-in-Progress:
The Platform-Independent Remote Monitoring System (PIRMS) for Situating Users in the Field Virtually

Abstract: A recent report on *Challenges and Opportunities in the Hydrologic Sciences* by the National Academy of Sciences states that the solutions to the complex water-related challenges facing society today begin with education. Given the increasing levels of integration of technology into modern society, how can this technology best be harnessed to educated people at various academic levels about water sustainability issues? The Platform-Independent Remote Monitoring System (PIRMS) interactively delivers integrated live and/or historical remote system data (visual, environmental, geographical, etc.) to end users regardless of the hardware (desktop, laptop, tablet, smartphone, etc.) and software (Windows, Linux, iOS, Android, etc.) platforms of their choice. The PIRMS accomplishes this via an HTML5-driven web-interface. One of the strengths of such a design is the idea of anywhere, anytime access to live system data.

In this research, weather and water quantity and quality data and time-stamped imagery from the LabVIEW Enabled Watershed Assessment System (LEWAS) have been integrated with local geographical data in the PIRMS environment in order to situate users within a small urban watershed virtually. Previous studies using exposure to the LEWAS showed increased levels of student motivation. The current research investigates increases in student learning related to water sustainability topics. Bloom's Revised Cognitive Taxonomy is used to link components of PIRMS to water sustainability topics on different learning levels. Using the framework of situated learning, longitudinal true-experimental and pre-test-post-test quasi-experimental designs are applied to students in a senior level undergraduate course and freshmen engineering community college courses, respectively, in order to compare student learning from physical field visits, virtual field visits via PIRMS and/or virtual field visits via pre-recorded videos. In addition to these physical and/or virtual field visits, all students are given LEWAS imagery files and measurement data in spreadsheet formats. Pre- and post-test assessments entail the students writing narrative responses to prompts. These narrative responses are assessed using rubrics to look for increases in student learning. Preliminary results are presented. This work is ongoing.

Introduction

A recent report on *Challenges and Opportunities in Hydrologic Sciences* by the National Academy of Sciences states that the solution to the complex water-related challenges facing society today begins with education.[1] The realization of the need to educate people about water sustainability is not new. At least as far back as 1974, there was a realization that water quality was difficult for people to describe.[2] Around the same time, various indices of water quality were developed to help quantify water quality in a way that could be more easily understood.[3] More recently, Covitt, Gunckel and Anderson assessed students' understanding of water quantity and quality relationships in both natural and man-made hydrologic systems for students in grades 3-12.[4] By coding[5] a subset of student results, they developed a rubric that was used to assess a random sample of other students' work. They determined that water literacy is not sufficiently taught in schools, and recommended that, "Instruction should first address the structure and movement of water and other substances in individual systems, and then it should gradually move toward building connections among these systems to help students develop deep, meaningful understanding."[4 p. 50] This progressive instructional approach suggests the implementation of a spiral curriculum.

Given that the sustainability of water resources is one of the major engineering challenges facing us in this century[6] and that humans play a major role (for both good and bad) in this process[1], it is vital that students on every level are exposed to this challenge. Spiral curricula[7-9] allow for water sustainability education to be integrated into academic programs by introducing increasingly difficult water sustainability concepts as students progress academically. However, prior to this integration, it is imperative to determine how students at various academic levels are best able to learn such material.

In this research, we focus on students at the freshman and senior undergraduate levels. At these levels, Armstrong and Bennett proposed MoGeo (mobile computing in geographic education) to integrate mobile computing technology and field visits in order to bring geospatial capabilities to the field using location-aware mobile computers.[10] Iqbal supplemented classroom learning for senior-level hydrology students by having them visit on-campus and off-campus habitats and analyze the chemical, biological and hydrological characteristics of various water samples.[11] Habib et al. discuss the use of HydroViz, a "web-based, student-centered, educational tool designed to support active learning in the field of Engineering Hydrology."[12 p. 3778] They integrate geospatial, in-situ and model-generated data in a "highly-visual and interactive" web-based interface with the goal of creating "authentic and hands-on inquiry-based activities that can improve students' learning."[12 p. 3771] However, their study investigates only water quantity rather than water quality and its relationships to water quantity as is essential for water sustainability education. They found that student learning of hydrologic concepts was impacted by the learning environment and that using HydroViz increased students' motivation.

Two themes emerge from these studies. One is the desire to provide students with a more authentic learning experience by exposing them, either physically or virtually, to the physical environments where their theory becomes practice. The other entails the utilization of technological advances in order to integrate this exposure into the students learning experiences. This leads to the question, "Given the increasing levels of integration of technology into modern society, how can this technology best be harnessed to educated people at various academic levels about water sustainability issues?"

The present research, developed by an interdisciplinary team of faculty and graduate students from Virginia Tech (VT) and two community colleges in Virginia (i.e., Virginia Western Community College (VWCC) and John Tyler Community College (JTCC)), examines the potential of a Platform-Independent Remote Monitoring System (PIRMS) in water sustainability education for students pursuing various academic pathways within engineering.[13] The PIRMS uses real-time (delivering data to end users within a few seconds), high-temporal-resolution (sampling at least once every three minutes) water quantity, quality and weather data from a small urbanized watershed to generate various water sustainability learning scenarios in a platform-independent environment. The research is accomplished by deploying the PIRMS into courses at VT, VWCC and JTCC. Before discussing the development and classroom implementation of the PIRMS, we briefly discuss our prior work that has led to the development of the PIRMS.

The LabVIEW Enabled Watershed Assessment System (LEWAS)

The LabVIEW Enabled Watershed Assessment System (LEWAS) was developed starting in 2009 as a practical implementation of LabVIEW for use in a large freshman-level engineering course at VT.[14-15] The LEWAS is a unique real-time water and weather monitoring system which is installed at the outlet of a water quality impaired creek that flows through the campus of VT. The watershed measured at the LEWAS field site contains about 2.78 km^2 with approximately 95% urban/residential land use. This creek was chosen as the site of the lab because of its location and its environmental significance. This creek was found to be benthically impaired for 8 km starting at the outfall of the pond immediately below the LEWAS field site. Some of the stressors of the stream include sedimentation, urban pollutants, increased development, and stream channel modifications[16] Examples of stressors include specific conductivity rising from a normal range of 600-800 µs/cm to nearly 5000 µs/cm during a winter storm salt wash[17], turbidity in the stream ranging from 0 to 450 NTU, flow varying from 0.02 m^3/s at base flow to a peak flow of 13.2 m^3/s on July 3, 2013, and water temperature jumping 4.7 deg. C in 3 minutes on July 23, 2012.

The LEWAS has sensors to measure water quality and quantity data including flow rate, depth, pH, dissolved oxygen, turbidity, oxidation reduction potential, total dissolved solids, specific conductivity, and temperature. In addition, weather parameters (temperature, barometric pressure, relative humidity, precipitation and wind speed and direction) are measured at the LEWAS outdoor site. All of these environmental parameters can be accessed by remote users in real-time through a web-based interface for education and research. The LEWAS is solar powered and uses the campus wireless network through a high-gain antenna to transmit data to remote clients in real-time. This lab has provided research opportunities to a number of graduate and undergraduate students, and to date 1 PhD, 3 MS, and 10+ undergraduate researchers have graduated from this lab. In addition, this lab has had 5 NSF/REU students. Currently, 3 PhD students, 1 MS, and 4 undergraduate students work in this lab.

To study the educational applications of the LEWAS, an observational study was conducted as the system was gradually introduced to engineering freshmen at VT between 2009 and 2012.[14, 18] Positive student attitudes on the role of the LEWAS to enhance their environmental awareness led to an experimental design which was implemented to study the motivational outcomes associated with the system. Accordingly, appropriate educational interventions and a hands-on activity on the importance of environmental monitoring were developed for both control and treatment groups, with only the latter given access to the LEWAS to retrieve the environmental parameters for the activity. An instrument was developed on the theoretical foundation of the expectancy value theory[19-20] of motivation and was administered to control and experimental groups in the course. Altogether, 150 students participated in the study. After conducting parametric and nonparametric statistical analyses, it was determined that providing real-time access to environmental parameters can increase student interest and their perception of the feasibility of environmental monitoring – both major components of motivation to learn about the environment.[19, 21]

Motivated by the outcome of PhD research discussed above, the LEWAS was incorporated into a senior level hydrology course at VT and an introductory engineering course at VWCC. Results of pre-and post-tests in both courses show positive learning gains, and students' blogs[22-23] show their active participation in the LEWAS-based water sustainability learning modules.[24] This prior LEWAS research provided motivation for the development of the PIRMS.

The Platform-Independent Remote Monitoring System (PIRMS)

Development of the Platform-Independent Remote Monitoring System (PIRMS) was undertaken with the goal of interactively delivering integrated live and/or historical remote system data (visual, environmental, geographical, etc.) to end users regardless of the hardware (desktop, laptop, tablet, smartphone, etc.) and software (Windows, Linux, iOS, Android, etc.) platforms of their choice. The PIRMS accomplished this via an HTML5-driven web-interface, as discussed below. One of the strengths of such a design is the idea of anywhere, anytime access to live system data. Another strength is the graphical and visual integration of the data that virtually situates the user at the remote measurement site. The PIRMS addresses four shortcomings of the LEWAS system: 1) it adds the ability to use historical data, 2) it does not require users to install of the LabVIEW runtime engine, 3) it does not crash when accessed simultaneously by a large number of users and 4) it virtually situates users at the LEWAS field site.

The PIRMS was developed via the storyboarding process[25] (including the development of a process book and a design document) as an open-ended learning environment.[26] Figure 1 shows the site map view of the PIRMS storyboard in the context of the LEWAS. The camera icon in the upper right allows the user to capture the current view as an image for later use. The SPLASH SCREEN transitions automatically to the HOME SCREEN, from which the user is able to navigate in any of eight different directions. For example, from the HOME SCREEN, a user can follow arrow number 5 to select an overhead view. From, e.g. the SREET MAP VIEW, the user can see the watershed boundary, waterways in the watershed and data collection sites within the watershed all overlaid on a local street map. By selecting one of these data sites, the user will be taken to the DATA SITE SUMMARY, which includes information about which instruments are measuring which parameters. From this view, the user can go to the SINGLE GRAPH VIEW to plot these parameters. From this graph, the user can access a time stamped image of the field site in the SINGLE IMAGE VIEW. In this way, the imagery data serves as the users eyes into the remote system. This spatial and visual situational context serves to increase the user's insights into the meaning of the data displayed in the single graph and six graph views. Case studies then use this integrated environment to investigate particular events that occur in the system being studied.

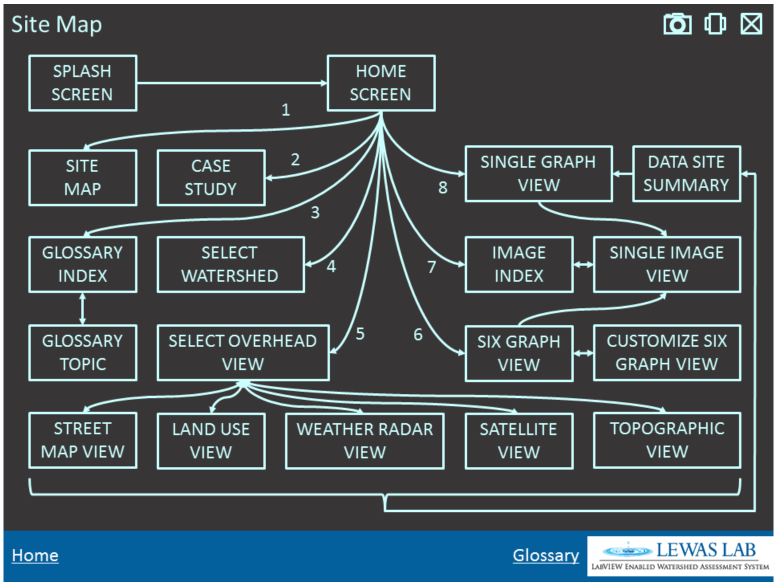

Figure 1. Site Map view of the LEWAS-specific PIRMS storyboard. In addition to the connections shown, every block except GLOSSARY TOPIC, SPLASH SCREEN and HOME SCREEN links to a specific glossary topic. Every block except SPLASH SCREEN and HOME SCREEN links to the HOME SCREEN.

Suppose that an instructor wants to use the PIRMS to discuss a water sustainability case study with her or his students. He or she would ask students to go to a website to access the PIRMS on the platforms of their choice and follow arrow 2 to select a case study. Figure 2 shows an example case study in the single graph view. In this view, the user is able to select up to six of the measured parameters in the system for display on either of the two vertical axes, which allows for the display of parameters on highly different scales. In this case study, precipitation on the LEWAS' watershed began as rain around 2PM on April 4, 2013, before quickly changing to snow and changing back to ice and rain between 6PM and 7PM. Another small rain storm passed over the LEWAS site around midnight on April 5.

This case study shows several examples of the types of insights into the system that users can gain by the data integration of the PIRMS. For example, specific conductivity usually drops and turbidity usually rises during rain events as compared to base flow conditions. This allows the user to estimate that precipitation began around 2PM despite the absence of temperature and precipitation data from just before 12PM to just before 4PM on April 4. A time-stamped image at 3:42 PM confirms that it was snowing at the LEWAS site and appears to have been doing so for some time (Figure 3). Around 4PM the specific conductivity level began to climb rapidly, which is the result of road salt being washed into the stream. This road salt resulted in an acute chloride toxicity event in the stream, which would have gone unnoticed if not for the high-temporal-resolution of the data.[17] The small rainfall around midnight on April 5 resulted in some residual salt being washed into the stream. Finally, the specific conductivity and turbidity levels suggest a precipitation event between 9AM and 6PM on April 5, but negligible precipitation occurs during this period. Rather, the air temperature indicates that the event is the result of melting snow from the previous day's storm. These insights can be gained by the integration of the data when users are virtually situated at the field site. A camera currently being integrated into the LEWAS will provide regular imagery.

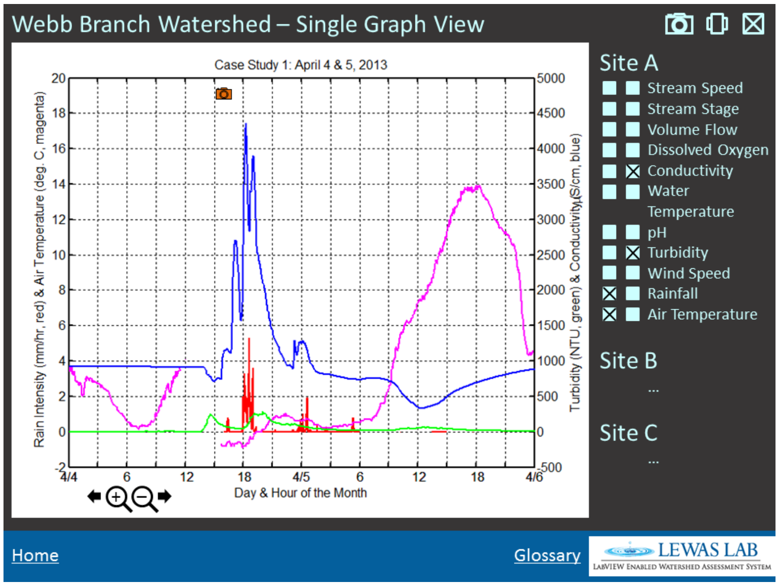

Figure 2. Single graph view of the LEWAS-specific PIRMS storyboard using measured case study data.

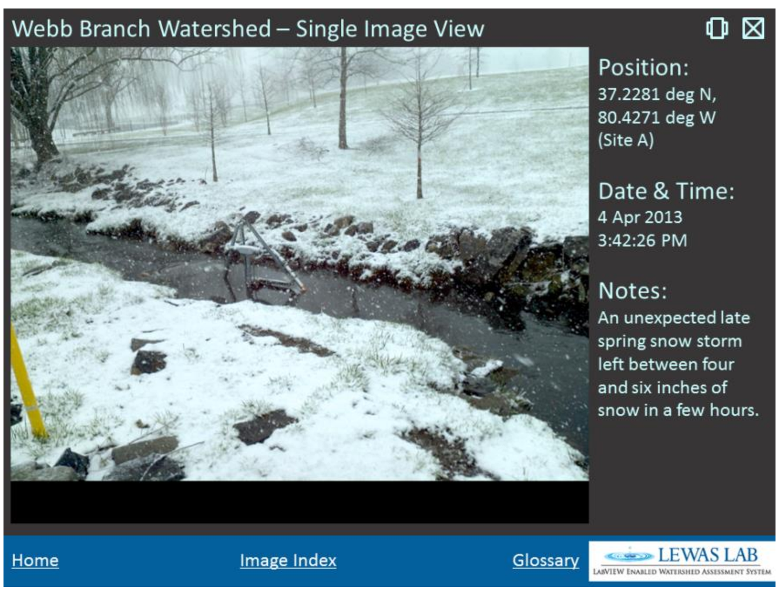

Figure 3. Single image view of the LEWAS-specific PIRMS storyboard.

In addition to the clickable time shift and zoom buttons shown in Figure 3, the interface allows the user to alter the time axis using one and two finger motions on touch screens. The six graph view (Figure 4) acts in a similar way to the single graph view except that each of the axes can display only a single parameter but can display that parameter from multiple measurement sites. All six graphs and the imagery axis move synchronously in time.

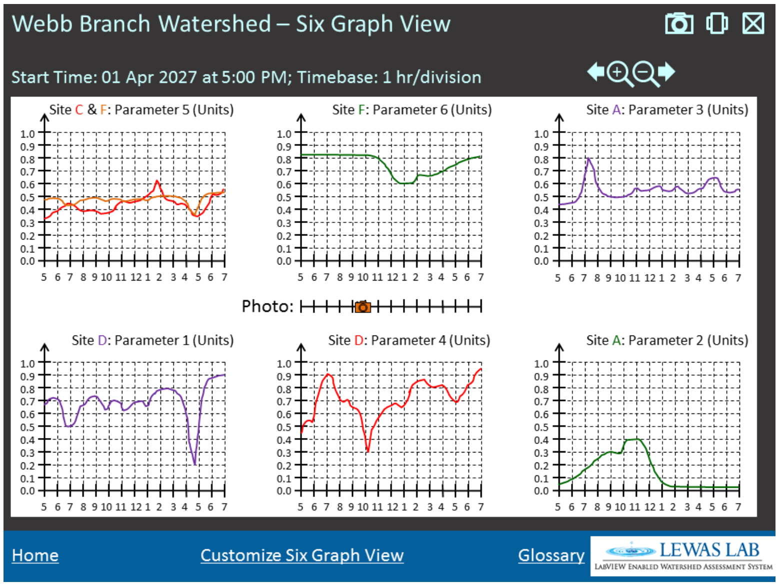

Figure 4. Six graph view of the LEWAS-specific PIRMS storyboard using artificial data.

The PIRMS is an adaptable system that can be used with other watersheds or generalized to other remote measurement systems. Without the watershed context, sitemap in Figure 1 can be adjusted such that the watershed becomes simply a system and the overhead views of the watershed become various system views.

Conversion of the storyboard into an end product is ongoing. During the summer of 2013, a database was developed to act as an interface between LabVIEW and the PIRMS in order to automate data storage and retrieval.[27] The PIRMS uses HTML5 to allow for device and platform independence. In this setting, the canvas object is being used to generate interactive graphs.[28-29] The PIRMS focuses on the benefits of integrated visualization rather than on computational power. However, the final product will allow the user to save data locally for further computational analysis.

PIRMS classroom implementation

Theoretical framework

While the prior studies of water sustainability education do not subscribe to specific theoretical frameworks, they contain a recurring theme that students learn more about the environment they are studying if they have the opportunity to connect classroom learning to experiences in that physical environment. Furthermore, several of these studies indicate that these experiences can be a combination of physical field visits and virtual field visits. These results fit under the framework of situated learning, which argues that knowledge is "distributed among people and their environments."[30 p. 17] This definition divides situated learning into two primary areas, i.e. knowledge is distributed across people, e.g. a community of practice[31], and knowledge is dependent on the learning environment.[32] The former follows the sociocultural tradition, while the latter follows the sociocognitive tradition.[33] While no two learning environments are exactly alike,[34] we are able to make judgments about the best previously learned knowledge to apply to new learning environments based on common features.[30, 35]

According to Newstetter and Svinicki, "Effective learning environments support the learner in developing an ability to integrate the external environment structures and internal knowledge in problem solving."[36 p. 39] Graphs and images are types of data representations that engineers often use to help them understand systems, and these representations are increasingly being communicated via digital technology. Within the context of water sustainability, technology advances have increased our ability to integrate remotely sensed environmental data into the learning environment.[37] The ways by which physical objects and data representations alter the learning environment is called mediation.[33] One of the strengths of the PIRMS is its ability to interactively integrate graphs and images in order to virtually situate users at the LEWAS field site. In this way, the PIRMS can be used as a remote lab. Remote labs, which allow users to be situated at the study site without physically being present, are spreading within engineering curricula.[38-41] Additionally, it has been estimated that more than half of U.S. internet users will access the internet via mobile devices by 2015,[42] and platform-independence allows the PIRMS to reach a larger number of people by working across mobile platforms.

Remote labs rely on digital technology to provide remote access to users, and this technology is especially powerful when it is interactive.[43] Multimedia uses digital technology to reach users via multiple types of content, e.g. text, imagery, video and audio. Many types of interactive multimedia can be used in learning, e.g. open-ended learning environments, tutorials and serious games.[44] However, according to Johri, Olds and O'Connor, "The role of technological tools, particularly digital tools, is extremely under-theorized in engineering education and a perspective of mediation can prove useful to develop a deeper understanding of technology use and design."[33 p. 53] They have listed "Empirical studies of mediation by tools used in learning and practice" as a potential engineering learning research topic, which is an excellent match for the present research.[33 p. 55]

According to Prus and Johnson, it is essential to choose assessment methods that are relevant, accurate and useful, i.e. those that provide detailed measures the desired outcomes and indicate areas for improvement.[45] Since this research seeks to assess student learning, it is more appropriate to use a direct measure of learning, i.e. measure what students learned, rather than an indirect measure of learning, i.e. measure what students think they learned.[5, 46] When used with performance measures, rubrics provide a direct assessment of student learning when a judgment of quality is required.[47] Analytic rubrics allow for multiple learning objectives to be assessed using a single rubric. Rubrics have the advantage of being "more objective and consistent" than are other assessment methods.[5, 48]

In its report on the Challenges and Opportunities in the Hydrologic Sciences, the National Academy of Sciences states that, "Ensuring clean water for the future requires an ability to understand, predict and manage changes in water quality."[1 p. 8] These three abilities can be aligned with the levels of Bloom's revised cognitive taxonomy.[49-50] Understanding, as evidenced by an ability to explain the occurrence of changes in water quality, fits with the second level of this taxonomy i.e. understanding. Predicting what is going to happen as the result of a particular event in a watershed fits with the fifth level of this taxonomy, i.e. evaluating. Developing management plans for a watershed requires the synthesis of diverse factors impacting this system. This ability fits with the top level of the revised taxonomy, i.e. creating. As students progress through various academic levels, they should likewise advance through all six levels of cognition. Having a high level of cognition about such water systems allows individuals to move beyond solving water sustainability problems to defining water sustainability problems, which allows them to effectively manage water systems.[51]

Both research designs described below seek to assess students' learning of water sustainability topics. Using Bloom's revised cognitive taxonomy as a guide, Figure 5 suggests topics that are appropriate for each course level and components of the PIRMS that can be used to help students learn these topics.

PIRMS Components:	Bloom's Rev. Cog. Taxonomy:	Water Sustainability Education:
	6 - CREATING	Watershed Management Plan
Case Studies	5 - EVALUATING	Impacts of Land Cover; Impacts of Watershed Events
Single View & Six View Interactive Graphs	4 - ANALYZING	Pollutograph; Rainfall/Runoff Ratio
Single View & Six View Interactive Graphs	3 - APPLYING	Parameter Relationships; Hydrograph; Hyetograph
Linked Imagery & Graphs; Data Sites	2 - UNDERSTANDING	Water Quantity & Quality Parameters Data Sensors; Man Made Impacts
Watershed Overhead Views; Glossary	1 - REMEMBERING	What is a Watershed? Where Does the Water Go?

Figure 5. Lesson plan guide including examples of water sustainability education topics appropriate for each level of Bloom's revised cognitive taxonomy[49-50] and the corresponding PIRMS components that are appropriate for learning these topics. Levels 1-2 are applicable to the freshman-level community college courses, and levels 1-5 are applicable to the senior-level hydrology course. Level 6 would apply to a graduate-level hydrology course.

Research question

Within this theoretical framework, the overall question of this research is

1) How effective is the PIRMS at increasing student learning of water sustainability topics at different academic levels?

Research methods

The current research uses the theoretical framework of situated learning by using the PIRMS to virtually situate students at the LEWAS field site for both the freshman-level and the senior-level courses. However, due to differences in the learning levels of the courses, the research designs used are not identical. The senior-level hydrology course at VT typically consists of one section of roughly ten female and twenty male students with about 10% graduate students. The LEWAS was integrated into this course during the fall 2012 semester using three learning modules as part of a TUES grant. The first module entailed characterizing the water quantity relationships between rainfall and runoff for rain events in the LEWAS watershed. The second module related water quantity and quality during rain events to landcover within the watershed. For the third module, students assessed the watershed on a rotating weekly basis by visiting the field site, analyzing data and writing on a course wiki about their observations. Overall, student assessment results indicated that students believed exposure to the LEWAS was beneficial for learning hydrologic concepts.[24]

Table 1 outlines the details of the longitudinal true experimental research design[52-53] in the senior-level Hydrology course. Since this course has only a single section, random assignment will be used to break students into groups A and B of roughly five subgroups each with each subgroup consisting of roughly three students each. Following the pre-test, one subgroup from each group will complete treatment 1 (see Table 1) for one week, post-test 1 at the end of the first week, treatment 2 for one week, post-test 2 at the end of the second week and the post-test 3 during the third week. A new subgroup from each group will begin treatment 1 every two weeks until all students have completed the process. For the pre-test and each post-test, the students will write narrative descriptions in response to the same set of prompts. Using the same prompts for the pre-test and each post-test allows for direct comparison of the students' results. Prompts and scoring rubrics will be developed using Figure 6 as a guide. Sample prompts are shown in Table 1.

Several factors have been taken into consideration in the development of this research design. It was originally considered to use students from a previous year as a control group. However, this was considered to be a poor choice since this would likely introduce several confounding variables.[52] One significant threat to the internal validity of this research is imitation of treatments, which will occur if students in group B visit the field site prior to the completion of post-test 1. In order to minimize the impact of this threat, students in both groups will be given access to the PIRMS only when they first need it for their assignments. A design where all students visited the field in treatment 1 and added the PIRMS in treatment 2 was considered. However, this was rejected over concerns of the maturation threat to internal validity and the absence of a comparison group. Finally, the students will not be given access to the blog/wiki until after post-test 2 so that the sociocognitive aspect of situated learning, i.e. the PIRMS, can be tested before the sociocultural aspect of situated learning is implemented. As for reliability, care will be taken to minimize the threat of inter-rater reliability issues. The test-retest threat to reliability[52, 54] is minimal in this research because the increasing cognitive levels, rather than the memorization of facts, are sought. That is, although the prompts are identical for each assessment, the expected responses are not.

It was originally planned to implement this research design in the spring 2014 semester. In this plan, the first two learning modules from the 2012 course would be retained and the third learning module would be replaced by this research design. However, due to delays in the technical development of the PIRMS, the full implementation could not be implemented in the spring 2014 semester. Rather, a pilot test of the PIRMS will be implemented in week 13 of the semester. In this pilot test, the students will be given access to the PIRMS and asked to write about the parameter relationships that they see during a summer rain event. They will also inform the technical development of the PIRMS by discussing the strengths and weaknesses of the interface.

Table 1: Research Methods - Senior Undergraduate Level

<table>
<tr><td colspan="8">Research Question 1 – Senior Level: Hydrology class at VT</td></tr>
<tr><td colspan="8"><u>Instrument Used in Data Collection - Pre-test and post-test prompts:</u>
1) What value, if any, do you see in real-time monitoring of water quantity and quality?
2) How can the LEWAS system help you learn hydrologic concepts?
3) What types of unusual water quality events might this system detect?
4) Describe three limitations of the LEWAS system.
5) How can this system be used for advancing research questions relevant to hydrology?
6) Describe the relationship between water quantity and pH during and after a rain event.
7) What are the typical and extreme values of water flow at the LEWAS site in cfs?
8) What would be the added value of a product that delivers live and/or historical remote system data (visual, environmental, geographical, etc.) to end users regardless of the hardware (desktop, laptop, tablet, smartphone, etc.) and software (Windows, Linux, iOS, Android, etc.) platforms of their choice?
9) What difficulties can you anticipate in your one week assignment to monitor the water quantity, quality and weather parameters?
A rubric will be developed and applied to narrative responses to questions 3, 4, 6 & 7 in order to convert qualitative data to quantitative data for analysis.</td></tr>
<tr><td colspan="8">Timeline: Student recruitment: Spring 2015; Data collection: Spring 2015; Data analysis and interpretation: Summer 2015.</td></tr>
<tr><td colspan="8">Experimental Procedure: Pre-tests, post-tests 1, 2 & 3</td></tr>
<tr><td>Student Population</td><td>Random Assignment</td><td rowspan="3">Pre-test</td><td>Treatment 1</td><td rowspan="3">Post-test 1</td><td>Treatment 2</td><td rowspan="3">Post-test 2</td><td rowspan="3">Post-test 3: Blog/wiki</td></tr>
<tr><td rowspan="2">Students from single section Hydrology course</td><td>Group A</td><td>Exposure to field site and the LEWAS meas. data and imagery</td><td>Exposure to the PIRMS and field site and the LEWAS meas. data and imagery</td></tr>
<tr><td>Group B</td><td>Exposure to the PIRMS and the LEWAS meas. data and imagery</td><td>Exposure to the PIRMS and field site and the LEWAS meas. data and imagery</td></tr>
<tr><td colspan="4">Variables</td><td colspan="4">Statistical Test and Inferential Hypothesis</td></tr>
<tr><td colspan="4"><u>Dependent:</u>
Student scores from rubric.
<u>Independent:</u>
Gender, Race, group assignment.</td><td colspan="4">One-way and multi-way ANOVA, ANCOVA, non-parametric and post-hoc tests to assess differences in response and interactions among independent variables.[45, 55, 56]</td></tr>
</table>

The freshman-level research design will be implemented in first semester engineering courses at VWCC and JTCC in the fall of 2014. Both of these courses typically have three sections of 15-20 students each. The LEWAS was previously used in the spring and fall 2013 semesters in a freshman engineering course at VWCC as part of the NSF TUES grant. In these courses, four 50 minute lecture periods and multiple assignments were used to introduce students to the general water sustainability concepts and the LEWAS, complete data collection from a local waterway, and complete computational exercises. Overall, assessment results indicated that students in the course believed that exposure to the LEWAS was beneficial for increasing public awareness of human impacts on water quantity and quality. For example, one student believed that the LEWAS could be used to "Show [the public] the effects of humans on the environment in simple terms." While another believed that the LEWAS can "Show negative side effects of Runoff/uncontrolled urbanization."

Table 2 outlines the details of the pre-test-post-test quasi experimental design.[52-53] This design is considerably simpler than that of the senior-level course, and it is constrained to two fifty-minute class periods for each of three successive weeks. In these courses, the students will self-select into the course sections of their choice. Students in all three sections will be given a common pre-test and common post-tests. In these courses, the students will write narrative descriptions that are assessed using rubrics, and the prompts will be the same for the pre-test and both post-tests as in the senior-level course. However, the prompts and rubrics will be appropriate to the level of the course based on Figure 6. Sample prompts are included in Table 2. Since there is not a natural sequential structure as in the senior-level course, no blog/wiki is included for this group. Rather, focus groups will be used to assess the sociocultural aspect of situated learning. Focus group prompts will be similar to those used in the pre-test and first post-test.

Table 2: Research Methods - Freshman Undergraduate Level

<table>
<tr><td colspan="7">Research Question 1 – Freshman Level: EGR 124 Intro to Engineering and Engineering Methods at VWCC and EGR 120 Introduction to Engineering at JTCC (same for each school)</td></tr>
<tr><td colspan="7"><u>Instrument Used in Data Collection - Pre-test and post-test sample prompts:</u>
1) Describe the sources of water arriving at the field site and where the water goes afterward.
2) How do the actions of people impact the watershed? Provide examples.
3) What are five water quantity/quality parameters, and what do they tell us?
A rubric will be developed and applied to narrative responses to questions in order to convert qualitative data to quantitative data for analysis.</td></tr>
<tr><td colspan="7">Timeline: Student recruitment: Fall 2014; Data collection: Fall 2014; Data analysis and interpretation: Fall 2014/Spring 2015.</td></tr>
<tr><td colspan="7">Experimental Procedure: Pre-test, post-tests and focus groups.</td></tr>
<tr><td>Student Population</td><td>Self-selection</td><td rowspan="4">Pre-test</td><td colspan="2">Treatment</td><td rowspan="4">Post-test 1</td><td rowspan="4">Post-test 2: Focus Groups</td></tr>
<tr><td rowspan="3">Students from 3 sections of EGR 120</td><td>Course Section A</td><td colspan="2">Exposure to the LEWAS measurement data and imagery (control)</td></tr>
<tr><td>Course Section B</td><td colspan="2">Exposure to the PIRMS; Exposure to the LEWAS measurement data and imagery</td></tr>
<tr><td>Course Section C</td><td colspan="2">Exposure to video about the LEWAS field site; Exposure to the LEWAS measurement data and imagery</td></tr>
<tr><td colspan="3">Variables</td><td colspan="4">Statistical Test and Inferential Hypothesis</td></tr>
<tr><td colspan="4"><u>Dependent:</u>
Student scores from rubric.
<u>Independent:</u>
Gender, Race, group assignment</td><td colspan="3">One-way and multi-way ANOVA, ANCOVA, non-parametric and post-hoc tests to assess differences in response and interactions among independent variables.[45, 54, 55]</td></tr>
</table>

Several factors help to minimize the imitation of treatment threat to internal validity for this course. These include that treatments are applied to different course sections of first semester freshmen who are primarily commuting students, not living in close proximity to each other and that the duration of the exposure is relatively short. However, the inter-rater threat to reliability still exists for this course.[54]

Conclusion

The PIRMS has been developed in response to the need for increased water sustainability education. Within the framework of situated learning, the PIRMS interactively delivers live and/or historical remote system data (visual, environmental, geographical, etc.) to end users regardless of the hardware (desktop, laptop, tablet, smartphone, etc.) and software (Windows, Linux, iOS, Android, etc.) platforms of their choice to virtually situate users at the LEWAS field site. As part of this Work-in-Progress, the PIRMS is being applied to water sustainability education at multiple undergraduate levels. Initial results and a demonstration of the PIRMS will be given in the presentation.

Acknowledgement

This work has been supported by NSF/TUES type I grant (award# 1140467). Any opinions, finding, and conclusion or recommendations expressed in this paper are those of the author (s) and do not necessarily reflect the views of the National Science Foundation.

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