Case Studies in Sustainability Used in an Introductory Laboratory Course to Enhance Laboratory Instruction

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Abstract

This educational research seeks to develop novel laboratory modules by using the case studies in the sciences teaching method in order to introduce sustainability and environmental engineering laboratory concepts to 21st century learners. The increased interest in "going green" has led to a surge in the number of engineering students studying sustainable engineering concepts in their courses. The goal is to improve laboratory instruction and the transfer of laboratory concepts to tangible real world applications for students by utilizing student learning preferences. Research methods were implemented in a junior level environmental engineering laboratory course. The case modules focused on providing (1) the contextual case-study or problem based learning modules that link engineering topics to real world sustainable engineering issues and (2) hands-on experiences for students that are designed to address new areas in sustainable engineering. The case studies engaged students in a "short case story" with real or fictional characters experiencing a real world event. Following the "short case story," students conducted independent research related to the case and the laboratory exercise. This paper investigates the improvements to laboratory instruction as a result of the gains in student learning, self-efficacy and engagement observed when the case studies in the sciences teaching method is used. Student assessment data shows that students felt the case study methods used in the course were more engaging, more interesting, and made connections between laboratory exercises and real world applications clearer when compared to their traditional laboratory classes they had taken during their education. Results also show that the case studies teaching method should be paired with more traditional instructional methods because students prefer learning facts, solving problems by well-established methods, seeing pictures and demonstrations, and learn best when a linear stepwise approach is used.

Introduction

This educational research study was initiated to evaluate a method to enhance student learning, critical thinking, and analytical skills in an Environmental Engineering Laboratory course. Research has shown that use of interactive, inquiry-based instructional methods in classes are more effective for increasing students' critical thinking skills, retention of material, and learning concepts (Abraham, 2011; Abraham et al., 1997; Benbasat, Goldstein, & Mead, 1987a; Herreid, 1994, 2004; A. Yadav et al., 2007). The Case Studies in the Sciences Teaching (CSST) technique is an inherently interactive and inquiry-based method which uses short stories to present a topic to teach science and engineering concepts (Herreid, 1994, 1997a, 2004). Business and medical schools have used the case study teaching technique for decades to provide simulated and real stories to help educate their students and prepare them for their future careers (Domin, 1999; Hofstein & Lunetta, 2004; A. Yadav et al., 2007; Aman Yadav et al., 2007).

This work evaluates the utility of the CSST method to improve instruction in an engineering laboratory course. Our research questions for this work were:

1) What learning styles and instructional preferences are represented in this student population?

2) Will students' instructional preferences change after experiencing the CSST laboratory method of instruction?

3) How do students compare the CSST laboratory instruction method to traditional laboratory instruction?

Traditional Laboratories: Follow the cookbook steps

A STEM education includes college level chemistry, biology, physics and/or engineering laboratory courses. Laboratory instruction has consistently followed a "cookbook" approach for decades. This usually means students are given a set of procedures with perhaps a few pre-laboratory questions to answer. They then complete the steps during the laboratory exercise, record the data, and fill-in the answers on the laboratory worksheet. To conclude the laboratory, students may be asked to analyze the data collected and summarize findings in a report or presentation.

Educators can insist that this traditional laboratory format provides hands-on experience unlike a lecture; however, many traditional laboratories only address the lower levels of Bloom's Taxonomy (Felder & Brent, 2004; Luckie et al., 2012; Momsen, Long, Wyse, & Ebert-May, 2010). To reach the upper levels of Bloom's Taxonomy (analysis, synthesis, and evaluation) a paradigm shift in laboratory instruction is necessary. Laboratory instruction can evolve to include methods that present relevant and current societal issues that can be applied for modern applications. It is possible to enhance laboratory instruction by teaching laboratory concepts and analytical principles through stories, cases, and applications that highlight real world issues.

The CSST Technique for Laboratory Instruction

The case studies method is ideal for active learning. CSST allows instructors to diverge from a formal lecture format to one which allows students to learn topical content by reading cases, researching concepts, and actively discussing the issues with the guidance of their professor (Abraham, 2011; Abraham et al., 1997; Pavelich & Abraham, 1979; A. Yadav et al., 2007). The National Center for Case Study Teaching in Science (NCCSTS) model recommends several key factors for developing a good case (Herreid, 1997b). These are: 1) the case tells a story; 2) it focuses on an interesting, arousing issue; 3) the case is set in the past five years.; 4) it creates empathy with the central characters; 5) the case must have pedagogic utility; and 6) the case is short. For a traditional lecture course using the CSST method, students are provided with background information about the case and data shown in graphs and tables. Students then analyze and discuss the pertinent information with each other and the professor as they solve the case. A laboratory course using CSST would provide a case story related to the laboratory topic and learning goals. Students then generate their own data during the laboratory class to help them understand the case as they complete the experimental procedures. Data are intended to bring more relevance as students analyze, synthesize and evaluate their results in the context of the case. Laboratory reports then feature this authentic student data and analysis. This method shifts the laboratory instruction from a traditional "cookbook" laboratory model of instruction to one that is more active in and outside of the laboratory classroom setting (Benbasat, Goldstein, & Mead, 1987b; Herreid, 1994, 1997a, 1997b, 2004; Lee, 1989; A. Yadav et al., 2007).

Method

Implementation in the Course

The cases for this educational study followed the NCCSTS model for the development of cases (Herreid, 1997a). For each case, students were encouraged to research the topic online and find videos, or articles to gain additional insight. The case studies selected for the environmental laboratory focused on sustainability topics to update the course content to include content consistent with 21st century ideas for considering economic, social, and environmental responsibility in design. For example, the new interest in "going green" makes alternative energy, e-waste, global warming, and water sustainability appropriate and relevant topics.

The study was implemented in a junior level environmental engineering laboratory course. The case studies introduced the laboratory topic and linked the laboratory skills students should learn during the course to real world sustainability applications engineers may encounter. The cases were either based on a real world event, location, person, or a fictional character experiencing a real world event or occurrence.

Blackboard, an online course management package, was used as the software interface to provide the students with the case, laboratory experimental procedure, and additional resources from the faculty member one week prior to the laboratory. Each case included a short story overview and You Tube video clips. Students were asked to research the topic using the recommended video clips, on-line references, and their own sources. Along with each case scenario, students were assigned pre-laboratory questions related to the case and were provided with the laboratory procedure. As is customary in traditional laboratories, students were expected to report to laboratory knowledgeable about the experiment and with laboratory notebooks prepared.

The laboratory was two hours in duration. The first five minutes of the class were used to address any pre-laboratory questions related to the case. The subsequent five to twenty minutes in class were used to discuss the case and how it related to the laboratory experiment. Unique to this case study approach, this time allowed students to discuss background information about the experiment topic attained outside of class using the video clips and on-line references provided in Blackboard and/or their own information sources. This was also the time for answering questions related to the laboratory procedure or clarifying the procedure steps. As needed, the faculty provided students with guidance or discussed the case with the students informally for the remaining laboratory class period. Students were required to develop hypotheses for the laboratory experiment and to complete the laboratory exercise. The students were assigned to groups of 3 – 4 students for the laboratory and worked together to complete the laboratory report. As part of the laboratory report's introduction and conclusions they were required to discuss how the case related to the experiment or incorporate the case into their discussion of the laboratory results. Group laboratory reports were due one week after completing the laboratory.

The cases were designed to scaffold student learning beyond the simple "cookbook" laboratory instructions. Because this was an environmental engineering course, the topics selected for the case related to human exposure to hazardous waste, statistical analysis of data, water quality and treatment, solar power, environmental sampling, and quantification of coliform concentrations in natural water. Overviews of the cases are provided in Table 1.

Description of the Case Studies used for Laboratory Instruction

E-waste

Case Background/Setting: Students assume the roles of engineers and scientists sent to investigate illnesses in workers exposed to hazardous e-waste. Using

Fictional Case Studies (fictional characters experiencing an event based upon actual events)				
Case Study	**Learning and Skills Goals**	**Videos**	**Lab Activity**	**Published at NCCSTS**
E-waste	Evaluate an environmental site assessment, statistical analysis of data, understand chemical hazardous waste, public health, and risk assessment.	yes (3)	yes	no
No Longer Fond of the Local Pond	Field sampling protocols, biological, chemical, and physical analysis for water quality.	no	yes	yes
Real World Case Studies (actual events)				
Case Study	**Learning and Skills Goals**	**Videos**	**Lab Activity**	**Published at NCCSTS**
Duke Energy Coal Ash Spill	Distinguish dissolved solids, suspended solids, filterable solids, and settable solids.	yes	yes	no
Point-of-Use Water Treatment	Understanding limited access to safe potable water in third world countries.	no	yes	no
Farmville Future	Environmental justice and ethics, discerning fact and bias, nitrate and phosphate contamination of soil and water, applying EPA regulations for fecal coliform contamination in drinking water and recreational water, and quantitative measurement of bacteria.	no	yes	yes
Tours for Real World Case Studies (tour of actual site)				
Case Study	**Learning and Skills Goals**	**Videos**	**Lab Activity**	**Published at NCCSTS**
Green Building Practices	Explore solar panels, xeriscaping, water recycling, use of local and recycle materials, and sustainable practices that could be incorporated into a building.	no	yes	no

Table 1. Summary of the case studies used during the course

a method to randomly generate data for the occurrence of illnesses in workers who wore protective equipment versus workers who do not wear protective equipment, the students perform statistical analysis on the data and must predict the probability of illnesses occurring in the workers.

Learning Objective Goals: Students learn about hazardous chemicals contained in electronic waste. They will learn about disposal practices in the US versus third world countries and discuss environmental ethics and justice. They will learn about the types of hazardous waste present in e-waste and how people in China and Ghana live where unsafe and illegal recycling practices occur.

Lab Activity: Students generate data representing exposure of the workers to heavy metals or lead at 3 fictional e-waste factories using decks of cards. Decks of cards are prearranged by the instructor to produce high and low probabilities of infection as a function of the workers' safety gear. Students use the decks to randomly generate the raw data and must use the data to determine which fictional factories have workers with high exposure rates for their employees.

Laboratory Skills: Practice statistical analysis calculations and use of a statistical analysis software package; understanding chemical hazardous waste, public health, and risk assessment; environmental ethics and justice.

Type of Case: Fictional character experiencing a real world event or environmental concern.

Resources Provided: Videos explaining E-waste recycling in the US, showing e-waste disposal in Ghana, and showing e-waste handling in China (Journeyman Pictures, 2007, 2011; Mambo & Kochnower, 2012). Student teams were also provided with two technical journal articles related to heavy metal contamination in Guiyu (Huo et al., 2007; Leung, Duzgoren-Aydin, Cheung, & Wong, 2008; Wong, Wu, Duzgoren-Aydin, Aydin, & Wong, 2007).

No Longer Fond of the Local Pond

Case Background/Setting: Students read a fictional story about an elementary teacher and students who participated in a field trip to a local park and became ill. While at the park, the story characters visited locations where they potentially could have been exposed to bacteria contaminated water.

Learning Objective Goal: Students learn how to collect samples in the field and perform field measurements such as pH, turbidity, and temperature using portable equipment. In the laboratory, they learn how to perform microbial analysis using Membrane Filtration and IDEXX.

Lab Activity: The laboraotry students are given maps depicting the sites where the fictional class visited in the park. The students have a field experience where they go to the park described in the case and perform field measurements such as turbidity, temperature, and pH. The students collect water samples from the locations described in the story and learn how to perform bacteria analysis.

Laboratory Skills: Environmental justice and ethics, discerning fact and bias, nitrate and phosphate contamination of soil and water, applying EPA regulations for fecal coliform contamination in drinking water and recreational water, and quantitative measurement of bacteria.

Type of Case: Fictional character experiencing a real world event or environmental concern.
This case was peer reviewed and published as part of the NCCSTS database (Luster-Teasley, Locklear, & King, 2015).

Farmville Future

Case Background/Setting: This case presented concepts for confined animal feeding operations and their impact to water quality using a town hall meeting format and testimonies from characters impacted by agricultural waste from the concentrated animal feeding operations (CAFOs). They read an article about a community that has observed adverse health effects they suspect are caused by the large number of CAFO farms located nearby.

Learning Objective Goals: Students learn about environmental justice and ethics, discerning fact and bias, nitrate and phosphate contamination of soil and water, applying EPA regulations for fecal coliform contamination in drinking water and recreational water, and quantitative measurement of bacteria using Membrane Filtration and IDEXX.

Lab Activity: Students are provided water samples containing fecal coliform and learn how to perform bacteria analysis. They also use assay kits to measure for nitrate, phosphate, alkalinity, turbidity, hardness, ammonia, and chemical oxygen demand.

Type of case: Fictional character experiencing a real world event or environmental concern. This case was peer reviewed and published as part of the NCCSTS database (Luster-Teasley & Ives, 2013).

Duke Energy Coal Ash Spill

Case Background/Setting: This case study discussed the accidental release of coal ash from a regional energy company into a local river used for drinking water in Virginia and North Carolina in February 2014 due to improper disposal and maintenance practices at the energy plant (Catawba Riverkeeper Foundation, 2015; CBS Associated Press, 2015; U.S. Environmental Protection Agency, 2015).

Learning Objective Goals: Students learn about environmental policies, environmental ethics and justice, and physical and chemical water quality.

Laboratory Activity: Students are given simulated water samples and asked to perform total suspended solids, total dissolved solids, fixed suspended solids, and settleable solids analyses. Students also build a water filtration system to improve color, odor, and turbidity in the simulated water samples.

Laboratory Skills: Distinguish dissolved solids, suspended solids, filterable solids, and settable solids; environmental policy, regulations, EPA reporting requirements, and public impact.

Type of Case: Real world case study (based on actual events)

Resources Provided: Students watch news report video about the coal ash spill and videos demonstrating the procedures to measure total suspended solids, total dissolved solids, fixed suspended solids, settleable solids using simulated water samples.

Point-of-Use Water Treatment

Case Background/Setting: Students read real testimonies published by the World Health Organization to learn about the lack of access to ample supplies of drinking water in countries such as India and Africa. They then design a point-of-use water treatment system, scale-up the system, present their designs, and perform a cost analysis of their system.

Learning Objective Goal: Students learn about physical treatment methods to remove color, odor, dissolved solids, settleable solids and suspended solids from their water samples. They measure pH, turbidity, color, and odor changes before treatment and compare to after treatment and water for a simulated water sample and discuss the observed water quality parameters.

Lab Activity: Students are given a 1-L water sample simulated with color, odor, dissolved solids, solids that settle and suspended solids. They are then asked to design and test a water filtration system using their sample. Finally, students are challenged to scale up their design to treat 10,000 gallons of water.

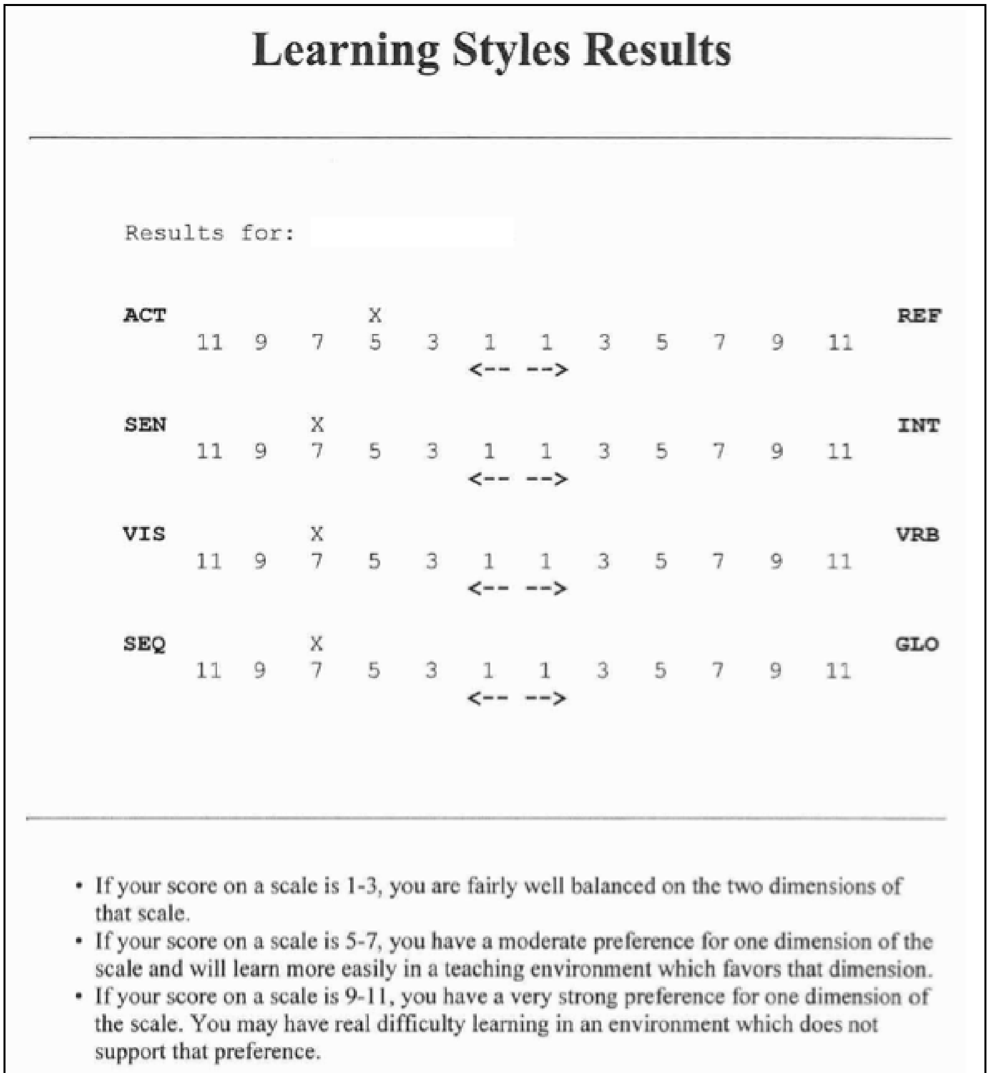
Type of Case: Real world case study (based on actual events)

Green Building Practices

Case Background/Setting: This is a tour of an eco-friendly, LEED Platinum hotel located in Greensboro, NC. The Proximity Hotel was built to use 40% less energy and 30% less water than traditional hotels. During the tour, students see the sustainable design and engineering practices at the hotel. Some of these features include solar panels, xeriscaping, recycled materials for building and decorating the hotel, use of local suppliers to reduce the carbon footprint, a geothermic kitchen, and water recycling.

Learning Objective Goal: Students learn about green designs and sustainable practices in a commercial building.

Laboratory Activity: Students tour a LEED Platinum hotel. Back on campus, students conduct an experiment using solar panels to determine the energy generated by



Learning Styles Results

Results for:

ACT				X									REF
	11	9	7	5	3	1	1	3	5	7	9	11	
						<--	-->						
SEN			X										INT
	11	9	7	5	3	1	1	3	5	7	9	11	
						<--	-->						
VIS			X										VRB
	11	9	7	5	3	1	1	3	5	7	9	11	
						<--	-->						
SEQ			X										GLO
	11	9	7	5	3	1	1	3	5	7	9	11	
						<--	-->						

- If your score on a scale is 1-3, you are fairly well balanced on the two dimensions of that scale.
- If your score on a scale is 5-7, you have a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favors that dimension.
- If your score on a scale is 9-11, you have a very strong preference for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference.

Figure 1. Example of the Index of Learning Styles (ILSS) results

the panel based on location and solar panel angle or conduct an experiment on the cooling effect of a green roof.

Laboratory Skills: Data collection and statistical analysis of the data collected.

Optional Laboratory Activity: After the tour, students are asked to choose a building on-campus and redesign the building with sustainable and green concepts. They present their designs to the class and instructor. Students might also build two identical buildings out of foam core board to test a green rooftop versus a black rooftop to better understand green roofs and xeriscaping.

Optional Resources Provided: Video tour of the hotel explaining the sustainable practices and green design concepts in the hotel.

Assessment

Qualitative and quantitative measures were used to determine whether the case studies can increase student learning and address the various learning styles represented in the laboratory course. Surveys were used to identify student learning styles and to query their impression of the case studies method used for a laboratory course. Focus group interviews were conducted to capture student qualitative responses.

Learning Styles Assessment

Students in this study participated in the Richard Felder Index of Learning Styles Assessment (Felder & Spurlin, 2005). This assessment is widely used in engineering education research (Felder & Spurlin, 2005) and was selected in an effort to determine if there are trends in the learning styles for engineering students. The learning styles identified by Felder are: Active Learners versus Reflective Learners, Sensing Learners versus Intuitive Learners, Visual Learners versus Verbal Learners, and Sequential Learners versus Global Learners (Felder & Spurlin, 2005). The Index of Learning Styles Survey (ILSS) is a free 40 question assessment tool developed by Richard Felder and Barbara Soloman [http://www.ncsu.edu/felder-public/ILSpage.html]. During the assessment, participants are scored with odd numbered values in the range of 1 – 11 on their propensity to prefer one form of learning over another based on the Active vs Reflective, Sensing vs Intuitive, Visual vs Verbal, or Sequential vs Global categories. An example of the ILSS results generated is shown in Figure 1. The ILSS was conducted once early in the semester. A total of 90 students enrolled in the environmental engineering laboratory course have completed the ILSS surveys over the last five years.

Instructional Preferences

As the study progressed, the instructional preferences survey (INST) was added to determine students' preferences for instructional methods in the classroom. Students in the spring 2013 and 2014 cohorts (n = 55) completed the INST assessment.

Open-ended Survey Responses

While the INST survey helped to provide more information, it did not provide detailed information about students' interests and motivation. Therefore, a post-course survey where an open-ended question asked students to compare their traditional laboratory experience to the case studies method used in the environmental engineering laboratory course was also added. The open-ended survey question was: *"You have experienced traditional laboratories in other courses and case study based laboratories in this course. In your opinion is one method better than the other? Does it matter which method is used in a laboratory course?* Do you prefer traditional or case-based laboratories? Why?" The responses were coded to identify common themes. A total of n = 28 students completed this assessment in spring 2014.

Case Study Survey

As with the INST, this survey was added to learn more detailed information about the students' impressions of the case study teaching method. The case study survey was modified from the survey instrument used in Yadav et al (2010) to change the wording from mechanical engineering to environmental engineering. This survey consisted of 22 questions related to use of cases and student impression of the case study method. This assessment used a 5-point Likert scale ranging from Strongly disagree (1) to Strongly Agree (5) (Yadav, Shaver, & Meckl, 2010). Surveys were administered and collected by faculty not involved in the teaching of the case studies at the end of the semester. Twenty-eight students in the spring 2014 cohort completed this survey.

Analysis

The distribution of learning style preferences for the students involved in this study was analyzed for normality using the Shapiro-Wilk test. The four learning style categories of the ILSS represent four continuous variables, which are expected to yield four normal distributions for a random sampling of a population. The graphs shown in Figure 2 visually suggest that this population of engineering students tend toward one side of the continuum

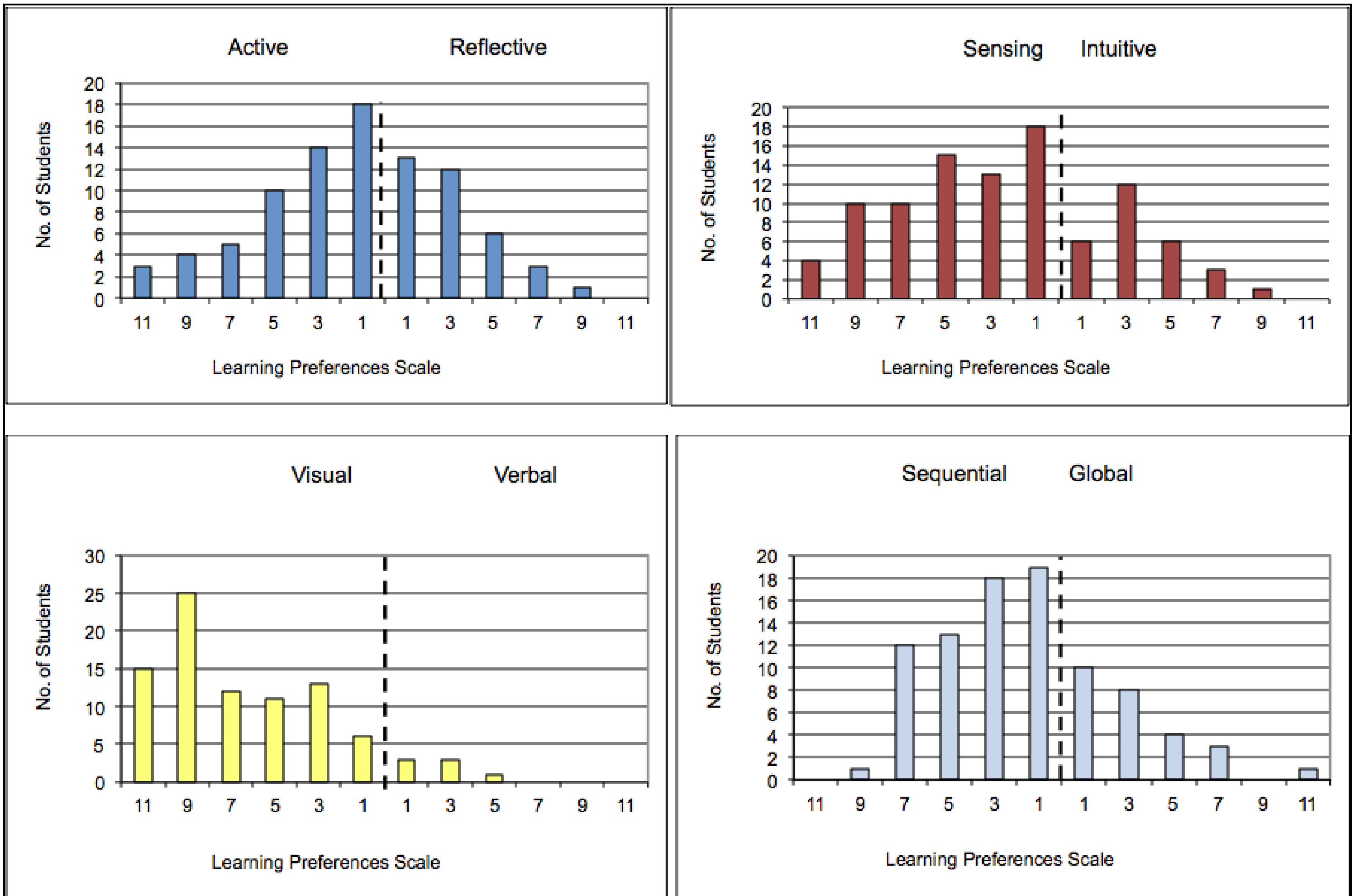


Figure 2. Graphs of the distributions of student learning style rankings (n= 90).

in three out of the four learning style categories. In the Shapiro-Wilk test, deviations from a normal distribution are considered significant if the test yields a value of $p <= 0.05$ and not significant if $p > 0.05$.

Comparison analyses were performed using unpaired t-test for the INST assessment. This approach explores whether the mean difference (post mean response minus pre mean response) is statistically significant. Any deviation from zero indicates a shift in student confidence over the course of the term. Positive deviations denote increases in student confidence, negative deviations denote decreases in student confidence, and zero deviations denote no change in student confidence. Mean differences are considered significant if the corresponding p-value is $<= 0.05$.

Statistical analysis was performed using the software PRISM to calculate mean, standard deviation, and standard error. Student participation was voluntary for all surveys and interviews. Survey data collected from spring 2013 and spring 2014 participants (n=55) are provided for the INST assessment. Spring 2013 students (n=27) completed informal interviews. Based on results from the spring 2013 students, the spring 2014 students (n=28) participated in informal interviews and completed a case study impression survey in an attempt to learn specific details from the students about the best-practices and their impression about the method.

Results

Learning Styles Assessment

Felder's ILSS learning style preferences is a good way to assess learning styles because the style categories are grouped into Active Learners versus Reflective Learners, Sensing Learners versus Intuitive Learners, Visual Learners versus Verbal Learners, and Sequential Learners versus Global Learners. The ILSS assessment represented as a frequency plot for each individual student is provided in Figure 2 for the learning style pairings. Of the 90 students who participated in the ILSS surveys, 60.0% of the students preferred active learning and 40.0% preferred reflective learning. Active Learners tend to understand and learn information best by doing something active such as discussing or applying the material. While traditional laboratories do involve hands-on activities well suited for these learners, case-based laboratories offer the additional opportunities to apply the techniques in real-world scenarios and discuss the results. Reflective Learners are learners who prefer to think about material before applying the material learned in a course. These learners can use the case studies to think deeply about the problem or the story associated with the case study activities prior to class. Case studies can complement both of these learning styles.

Sensing Learners represented 78.9% of the study population while intuitive represented 21.1% of the students. Sensing learners prefer to learn facts and solve problems by well-established methods. This finding is consistent with the problem solving, logical and math-driven nature of engineering students. The research or fact gathering opportunities built into the case studies facilitate learning for students who are sensing learners. Intuitive Learners prefer to investigate possibilities and relationships. These learners are more comfortable with abstractions and mathematical formulations. Intuitive Learners can use the case studies to investigate "what if" scenarios in their projects. Guided-inquiry cases would be a better teaching style for Sensing Learners as opposed to open-inquiry cases where students work with little guidance from the professor or without well-established direction.

An impressive 92.2% of the students were Visual Learners compared to 7.8% representing Verbal Learners. Visual Learners learn best by seeing pictures, diagrams, flow charts, films, and demonstrations. Hence the use of

	Active versus Reflective	Sensing vs Intuitive	Visual vs Verbal	Sequential vs Global
p-value	0.083	0.008	<0.001	0.002
Statistically significant? (p <= 0.05)	No	Yes	Yes	Yes
Preference?	Neither; evenly split	Sensing	Visual	Sequential

Table 2. Shapiro-Wilk Analysis Results for Student Learning Style Preferences (n = 90)

You Tube and other visual media on-line that the students have access to, can enable their learning. Verbal Learners learn more by written and spoken explanations. The finding that students were more visual than verbal suggests the case studies combined with the hands-on experiment would have the most impact on students for learning, as opposed to reading the lab report and hearing the professor talk about the laboratory.

Sequential Learners tend to learn using linear steps in a logical order or pattern. Global learners learn by understanding the "big picture" and then linking concepts. Sequential Learners have the structure of the laboratory procedure and logically can use the time before class with the "flipped" method see how the case relates to the laboratory experiment. Sequential Learners represented 71.1% and 20.9% were Global Learners. This result is consistent with the logical, math-driven, and sequential pathways for learning typically displayed by engineering students.

The Shapiro-Wilk analysis of the four learning style pairings indicated that one is normally distributed around the center of the scale, meaning the population was equally divided across the two learning styles in the pairing with most people in the middle. The analysis of the remaining three learning style pairings revealed that this student population tended toward one learning style. Table 2 shows the specific Shapiro-Wilk results.

The ILSS data for the Active-Reflective learning style pairing was normally distributed ($p = 0.083$). Therefore, this student population was fairly evenly split across Active and Reflective learning styles. The Sensing-Intuitive ($p = 0.008$), Visual-Verbal ($p < 0.001$), and Sequential-Global ($p = 0.002$) pairings were all skewed toward

	MEAN Pre	MEAN Post	Mean Difference (Post - Pre)	p value	t, df
Q1: I learn more when we perform calculations in class	4.212 ± 0.108	4.418 ± 0.106	0.206	0.1743	t=1.368 df=105
Q2: I enjoy working in groups	3.712 ± 0.111	3.818 ± 0.142	0.107	0.5589	t=0.5863 df=105
Q3: I can currently communicate about environmental engineering and sustainability with classmates	3.846 ±0.097	4.463± 0.098	0.617	0.0001	t=4.481 df=104
Q4: I enjoy having my peers as teachers	3.725 ± 0.126	3.982 ± 0.112	0.256	0.1288	t=1.531 df=104
Q5: I prefer working individually on assignments	3.231 ± 0.122	3.564 ± 0.134	0.333	0.0699	t=1.831 df=105
Q6: I learn better when the class discussions led by the professor (not formal lectures)	4.077 ± 0.098	4.218 ± 0.109	0.141	0.3405	t=0.9576 df=105
Q7: I learn better when the class discussions are led by classmates	3.096 ± 0.138	3.109± 0.132	0.013	0.946	t=0.06791 df=105
Q8: I learn better when there are structured lectures given by the professor	3.88 5± 0.128	4.255 ± 0.111	0.370	0.0304	t=2.195 df=105
Q9: I learn well from independently reading course reading materials	2.942 ± 0.141	3.218 ± 0.157	0.276	0.1961	t=1.301 df=105
Q10: I learn well through the use of electronic resources, primarily the Internet, to find information	3.846 ± 0.136	4.018± 0.118	0.172	0.3383	t=0.9620 df=105
Q11: I use library resources more than electronic, on-line resources	2.269 ± 0.148	2.364 ± 0.173	0.094	0.6808	t=0.4126 df=105
Q12: I prefer to use computers to research topics	4.058 ± 0.121	4.296 ± 0.101	0.239	0.1321	t=1.518 df=104
Likert Scale: (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, and (5) Strongly Agree					

Table 3. Instructional Preferences Survey Results (n = 55)

one learning style in the pairing. Sensing-Intuitive was skewed toward Sensing. Visual-Verbal was skewed toward Visual. Sequential-Global was skewed toward Sequential. Therefore, the students in this study were Sensing, Visual and Sequential Learners.

Instructional Preferences

The goal for the instructional preferences survey was to determine if students' preferences for instructional methods in the classroom can potentially change during a CSST laboratory course. The questions may be categorized as active learning (Q1), team/peer interaction (Q2, Q4, Q5), presence of an authority figure (Q6, Q7, Q9), variety in the classroom (Q10), and use of multimedia (Q10, Q11, Q12). Mean pre- and post-instructional preferences survey student responses were analyzed using a one-sample t-test (Table 3). Ten of the twelve means comparing the pre- and post-means were statistically similar. This indicates that these instructional preferences remained fixed for the students surveyed.

Notably, Q3, which asked about the ability to communicate about environmental engineering and sustainability, did show a significant change (mean difference = +0.617, $p < 0.001$). This question is also specific to an environmental engineering course; therefore, it will be included with the student efficacy data in the next section. The question asking if the responder learns better when the professor gives structured lectures, Q8, also showed a significant change (mean difference = +0.370, $p = 0.0304$). This suggests that the surveyed students realized they prefer traditional structured lecture instruction over the CSST method of instruction, a point further discussed in the Conclusion section. Faculty should consider implementing instructional styles that complement these fixed preferences of the millennial students.

Questions	Percentage					Mean (S.D.)
	SA	A	N	D	SD	
I felt the use of case studies was relevant in learning about the course concepts	92.86	7.14	0.00	0.00	0.00	4.93 (0.05)
The case studies helped me analyze the basic elements of the course concepts	85.71	14.29	0.00	0.00	0.00	4.86 (0.07)
I felt that what we were learning in using the case studies was applicable to my field of study	92.86	7.14	0.00	0.00	0.00	4.93 (0.05)
The case studies were helpful in helping me synthesize ideas and information presented in the course	85.71	14.29	0.00	0.00	0.00	4.86 (0.07)
The case study allowed me to retain more from the class.	71.43	25.00	3.57	0.00	0.00	4.68 (0.10)
I felt that we covered more content by using the case study in class	67.86	25.00	3.57	0.00	0.00	4.57 (0.13)
I thought the use of the case studies in the class was thought provoking.	82.14	10.71	0.00	3.57	3.57	4.64 (0.18)
The use of case studies allowed for more discussion of course ideas in the class	82.14	14.29	3.57	0.00	0.00	4.79 (0.09)
The case study allowed me to view an issue from multiple perspectives	78.26	21.74	0.00	0.00	0.00	4.78 (0.09)
The case study brought together material I had learning in several other courses	64.00	24.00	8.00	0.00	4.00	4.44 (0.19)
The case study added a lot of realism to the class	82.14	14.29	0.00	0.00	3.57	4.71 (0.15)
I was more engaged in class when using the case study	75.00	25.00	0.00	0.00	0.00	4.75 (0.08)
The case studies was more entertaining than it was educational	32.14	10.71	39.29	14.29	3.57	3.54 (0.23)
I felt immersed in the activity that involved the use of case studies	74.07	14.81	11.11	0.00	0.00	4.63 (0.13)
I took a more active part in the learning process when we used the case studies in class	67.86	28.57	0.00	3.57	0.00	4.61 (0.13)
I was frustrated by ambiguity that followed when using the case study	17.86	7.14	21.43	42.86	10.71	2.79 (0.24)
I felt that the use of case studies in the course was inefficient	21.43	7.14	10.71	32.14	28.57	2.61 (0.29)
I found the use of case studies format challenging in the class	39.29	7.14	14.29	28.57	10.71	3.36 (0.29)
Most of the students I know liked the case studies	60.71	32.14	7.14	0.00	0.00	4.54 (0.12)
I needed more guidance from the instructor about the use of the case studies in the class	21.43	3.57	21.43	32.14	21.43	2.71 (0.27)
The case studies took more time than it was worth	17.86	7.14	17.86	35.71	21.43	2.64 (0.26)

Table 4. Student attitudes towards the use of case studies

Student Attitudes towards the Use of Case Studies

Overall, the student mean values for the Case Study Survey indicated agreement that the cases positively impacted their learning experience (Table 4). The highest responses (mean of 4.93) were reported for relevance in learning course concepts and for the case studies being applicable to their field. Second highest mean responses (4.86) were obtained for perceived value of the case studies in analyzing the basic elements of the course concepts and in synthesizing ideas and information presented in the course. The mean response values suggest that there is tendency for the students to believe that the case study approach was frustrating, made the course inefficient, and takes more time than it is worth (mean responses of 2.79, 2.61 and 2.64, respectively). However, a close look at the actual percentages reveals that a significant percentage of students agree that they experienced these negative feelings, but also a significant percentage of students who disagree that they experienced the negative feelings. These results indicate that the case study method may not suit all students.

The open-ended survey questions and focus group interviews provided qualitative feedback about student attitudes. Eight major themes that emerged from the student responses were identified: relatability, ability to apply learning outside of classroom, interactive and interesting, understanding more/increased knowledge and perspective, rationale for what we are learning, interest/personal investment, and ability to research topic of problem-based learning. The students indicated that when comparing the CSST laboratory instruction to their traditional laboratory courses, they were more engaged. The open-ended responses ranged from "best lab class experience" to "the case studies were more work but interesting." However, the students reported from the focus group interview that cases are not essential for all courses and laboratory activities, the selection of the case study needs to complement the course, and they would like to see a mixture of teaching styles.

Conclusion

Our goal for this education research was to evaluate the use of the CSST method to improve "cookbook" laboratory instruction. Using real world and simulated stories based on real world scenarios in conjunction with a hands-on laboratory course, we hypothesized, the case studies teaching method can enhance laboratory instruction as compared to traditional laboratory course formats (Elam, Stratton, & Gibson, 2007; Howe & Strauss, 2000; Novotney, 2010; Strange, 2004). We wanted to research if the CSST method improved instruction in an engineering laboratory course and addressed the following research questions:

1) What learning styles and instructional preferences are represented in this student population?

2) Will students' instructional preferences change after experiencing the CSST laboratory method of instruction?

3) How do students compare the CSST laboratory instruction method to traditional laboratory instruction?

In this research study, junior level students in an environmental engineering laboratory course were introduced to five cases that provided the real world events or activities that helped them to link the laboratory theory to how the analytical skill relates to an application they will see when they enter their careers. Students positively responded to the use of the case studies and indicated the use of the cases made the laboratory course more engaging than a traditional "cookbook" laboratory experience. They indicated the use of the cases to introduce the laboratory concepts helped aid in their understanding of the laboratory purpose, theory and transfer from theory to practice. The student interest in discussing the cases outside of class, with peers, and sending additional resources for the faculty member to share with the class additionally supported the finding that student interest and engagement increased compared to traditional laboratories. Student focus group responses suggest the students felt that the cases provided the real world approaches and provided clarity about how course laboratory skills may be applied outside of the classroom environment. Students clearly indicated they were more willing to engage in the laboratory experience because their interest had been piqued by the cases.

Yadav et al (2010) similarly observed that case study teaching provided a positive and engaging experience for the students but did not necessarily increase student's conceptual understanding the mechanical engineering courses. Yadav et al. also noted that previous psychology research in learning suggests that higher engagement does not necessarily translate or transfer over to increased student knowledge and understanding (K. K. Gallucci, 2007; K. Gallucci, 2006; McDaniel, Waddill, Finstad, & Bourg, 2000; Yadav et al., 2010). Overall, students did not indicate strong feelings about the cases taking too long or not being beneficial to their learning.

Several students noted that some of the activities were strikingly similar to the traditional laboratory format but required more work. They recommended that use of cases depended on the topic being taught, therefore, case studies would not be appropriate for all courses but could be used in the context of a course to offer a change from normal lecture only instruction. The ILSS data supports these findings. Learning styles of the students involved in this study were equally balanced between Active and Reflective, but tended toward Sensing, Visual, and Sequential. In other words, they prefer learning facts, solving problems by well-established methods, seeing pictures and demonstrations, and learn best when a linear stepwise approach is used. This was supported by the instructional preference data indicating that the students learn better when the professor gives structured lectures, which are typically laden with facts and linear explanations. Overall, we agree that the CSST laboratory instruction method is beneficial for improving student interest and engagement, which has the potential to improve student learning, but that it should be paired with more traditional instructional methods.

Key factors to consider for effective implementation of cases in courses are student buy-in and fit. Students need to understand the teaching approach, its purpose, and its potential for improving student learning. The type of case and how it is used is vitally important for appropriate fit in a course. From a faculty perspective, implementation of the CSST method requires extra time to develop the case scenarios based on the laboratory skills being covered and current real world events.

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