122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #12988

A Cross-institutional Study of the Case Study Teaching in the Sciences Method

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Abstract

Many educators acknowledge that the millennial generation of students learns like no other, yet little has been done to alter laboratory instruction in response to this generational shift. Further, most laboratory courses use a traditional, formal style of "step-by-step" instruction. This "cookbook" instructional pedagogy is based on the lower levels of Blooms Taxonomy and often leaves little to no impact on achieving higher levels of student learning. Data shows that students who participate in "cookbook" instruction are unable to apply lab concepts accurately beyond the original lab and many students do not retain laboratory skills they learned in the long-term. This work involves the use and evaluation of the case study teaching in the sciences method for laboratory instruction. The case study educational pedagogy promotes the use of cases, or interactive "stories," to engage students in STEM courses and it has been successfully used to help reform STEM instruction in traditional lecture courses. Our work is unique because the cases were used to introduce lab concepts and bring relevance to the analytical skills being learned in the lab. This work is funded by NSF IUSE and is a collaborative effort of professors at three distinctly different institutions: a public, historically black co-ed technical university, a private, historically black liberal arts college for women, and a private, predominately white liberal arts university. The proposed poster will report preliminary results from the evaluation of student learning preferences and learning gains for students in environmental engineering, biology, and introductory engineering courses at the three respective institutions. Data collection and analysis is currently underway; however, we anticipate that the data will show clear linkages between learning preferences, learning gains, and demographic data such as gender, ethnicity, classification, and institutional type. This work has the potential for broad impact because there is widespread interest in improving educational practices across STEM fields and in improving laboratory instruction.

Introduction

A shortage of millennial students entering the STEM workforce poses a problem for the United States to retain its stronghold in science and technology. The President Council of Advisors on Science and Technology released a report in 2012 that there is a need to produce one million graduates in the STEM fields for the United States to keep up with the projected demands of the economy. In order to achieve this, the council recommends an overhaul of the old, traditional methods by adopting empirically validated teaching methods and replacing traditional lab courses with discovery based research courses[1]. The current generation of students are millennial learners described as students born between 1982 and 2004[2]. These students belong to the most ethnically diverse and computer literate generation and now represent the students currently enrolled in colleges across the United States. However, they are not pursuing careers in STEM fields, partly because they feel unengaged in their courses and they feel a lack of community amongst STEM learners and faculty[1].

Millennial learners have many unique and positive qualities that pose a challenge for college educators to engage them in learning[3]. They have been attributed with the qualities of being cooperative, team oriented, technology driven, socially aware, and highly optimistic about their futures[4]. Given their unique characteristics, research suggests that various teaching strategies should be implemented in the classroom to engage this generation. Research has shown that students respond better to "pedagogies of engagement" such as case studies, web based assignments and Problem based Learning (PBL) that requires knowledge and critical thinking skills, as well as implementing multimedia (including Facebook, Twitter, YouTube, and podcasts) to help them understand core concepts as well as active teaching methods such as collaborative and service learning approaches[5, 6].

Despite what is known about millennial learners, traditional labs currently being used fall short of incorporating effective teaching methods for millennial student learning[2-4, 6]. In the US, most 21st century laboratory courses use a traditional, formal style of "step-by-step" procedures used since the early era of college laboratory instruction in the 1900's. This instructional pedagogy is based only on the lower levels of Blooms Taxonomy and often leaves little to no impact on the higher levels of student learning and retention of material. Literature suggests that traditional lecturing and laboratories which emphasize rote memorization are relatively ineffective when compared to interactive learning techniques[7-9]. However, instructors tend to teach using the same teaching methods employed by their former teachers which consist of formal lectures and "step-by-step" laboratories[8, 10, 11].

Case studies have been proven to increase student motivation, their ability to apply critical thinking skills, and can help students integrate concepts learned in the course for problem-solving skills long-term[11-15]. Case-Based instruction has been used extensively in medical and law schools to prepare students for the real world practices[8,15-17]. With the success of case-based instruction seen in medical and law curriculums, an increasing number of science, technology, engineering and math (STEM) instructors have begun to integrate cases into their courses. A new champion for the use of cases in the sciences emerged in 1994 with the work of Herried and funding from the National Science Foundation to form the National Center for Case Study Teaching in the Sciences (NCCSTS). This educational pedagogy promotes the use of cases, or interactive "stories", to engage students in STEM courses and to help reform STEM instruction[14, 18-20]. These "stories" are designed using role play cases or interrupted narratives with characters that may be real or fictional experiencing the case and "telling" the content the teacher wishes to deliver to their students using the characters in the story. It engages the students because they can relate to the characters or story and encourages discussion of the case through the use of guided questions.

Using Case Studies to Improve Laboratory Instruction

Given the recommendations to replace traditional teaching methods with more empirically validated teaching methods that uses inquiry based methods and active learning, for our educational research study, we investigated two main questions: 1) To what extent does the use of the case studies method address all learning styles despite differences in students' discipline? 2) To what extent does the use of case studies in the sciences method increase learning gains, critical thinking skills or self-efficacy in laboratory skills? Using published cases from the NCCSTS database, we evaluate the intervention impact based on STEM disciplines, student learning, gender, ethnicity and institutional type. We also evaluate the impact on student learning, critical thinking and student impression of the Case Study Teaching in the Sciences method amongst three inter-related, STEM courses (engineering, environmental engineering and biology orientation /biotechnology) offered at three very different types of universities.

Methodology

This educational research study is being conducted in engineering and biology laboratory and seminar-based courses at three unique universities. Elon University is a selective, independent, liberal arts university. Elon engineering students typically spend three years at Elon and another two at a traditional engineering school. Upon completion, students earn a liberal arts degree in a complimentary math or science from Elon and an engineering degree in their discipline of choice from the engineering school. Bennett College is one of only two historically black colleges for women in the country. It is a small private liberal arts college. NC A&T State University is a public, historically black institution located in Greensboro.

For year 1 of our project, each course used two published cases from the NCCSTS. The case entitled "A Case in Point: From Active Learning to the Job Market" served as the common case used by all faculty to acquaint students to the NCCSTS pedagogy. Each faculty member then selected a second published case from NCCSTS that matched a lab or interactive hands-on module traditionally taught in their course. During year 2, the two NCCSTS published cases along with a case written by the professor will be used. Table 1 summarizes the cases selected by the faculty for their courses.

Table 1. Educational Research team, Institution, and Proposed Case Studies

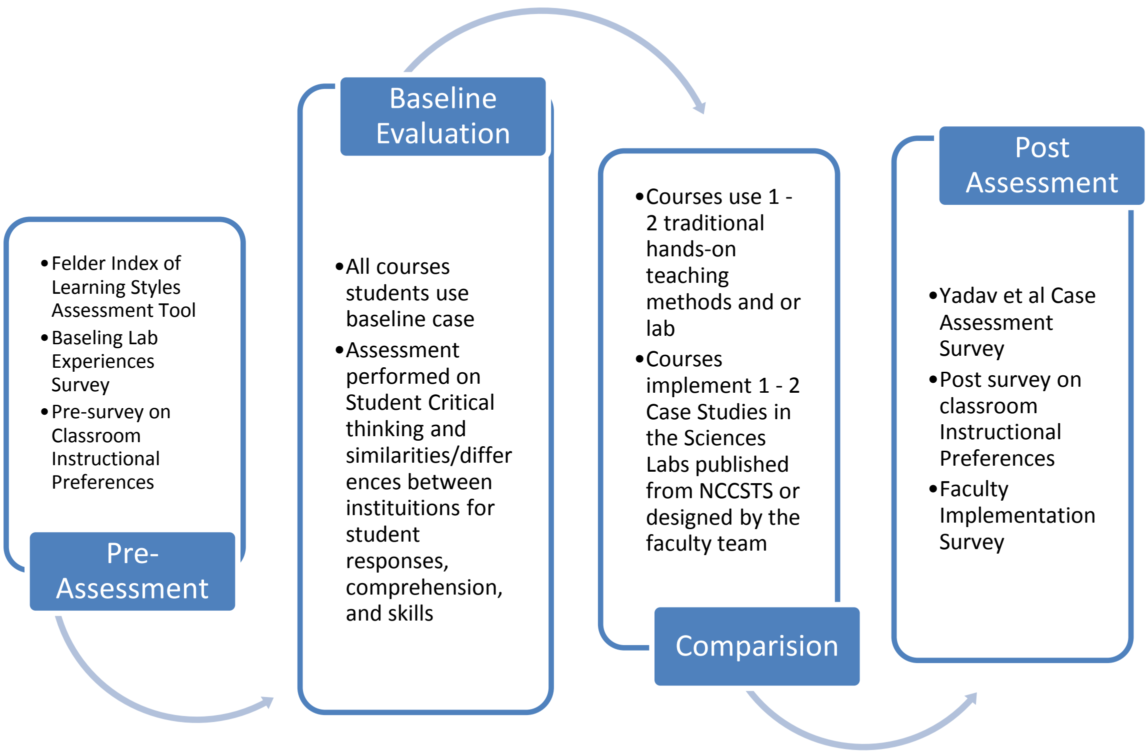
College/University	Discipline	Proposed Case Studies
NC A&T	Environmental Engineering	1. Case In Point (NCCSTS case) 2. Farmville Future (NCCSTS case) 3. E-waste (Yr2)
Bennett	Biology	1. Case In Point (NCCSTS case) 2. From Cow Juice to a Billion Dollar Drug, With Some Breakthroughs in Between (NCCSTS case) 3. Case written for course (Yr2)
Elon	Engineering (all disciplines)	1. Case In Point (NCCSTS case) 2. So what is it that engineers do, anyway? (NCCSTS case) 3. Case written for course (Yr2)

Blackboard and Moodle software platforms were used to provide the cases and videos related to the cases to students before class to aid in the discussion and laboratory activities. Students were asked to conduct research on-line to learn more about the cases, find videos or other multi-media, and encouraged to discuss the cases prior to the laboratory activities.

Assessment

Figure 1 summarizes the logic model for assessing our work. Pre-assessment data included a Felder Index of Learning Styles (ILS) assessment to identify learning trend differences, if any, between engineering students and biology students. Felder's assessment is popular among engineering education studies[21-23]. Students were also given a pre-laboratory quiz and instructional preferences survey. Post-assessments included a Case Studies Impression survey by Yadav et al[15], post survey on classroom preconference, and a post faculty course assessment (i.e. exam, exam questions, quiz, or report).

Figure 1. Overview of Educational Study Steps



Student Deliverables

Students were responsible for individual and group homework, laboratory reports and presentations which will be evaluated for assessment of student gains using the case method. At the end of the academic semester, students participated in post-survey assessments and focus group interviews conducted by the co-PIs from a different university so the students felt free to discuss their case experience. The alternate co-PIs also used a rubric to evaluate the performance of students from the test university on the post-faculty course assessment (i.e. exam, exam questions, quiz, or report).

Results and Discussion

To evaluate this project in its early stages, a mixed method concurrent design, giving equal priority to both quantitative and qualitative methods[24], was used. A mixed methods approach to conducting evaluation is different from using multiple methods or a combination of methods, in that data from one type of method (quantitative or qualitative) is merged, connected, or embedded with data from the other type of method[25]. Use of mixed methods provides both formative and summative information useful for continuous improvement by providing information that allows project leadership and primary stakeholders to determine the project's progress toward achieving annual benchmarks and meeting stated goals and objectives, as well as for accountability. The experimental design is concurrent in that the study's quantitative and qualitative data collections occur simultaneously[26]. It has equal priority in that both the quantitative and qualitative methods are assigned equal weighting in the interpretation of findings[27].

The Felder Index of Learning Styles Assessment (ILSA) is a 44-item questionnaire which assesses students' learning style preferences which are evaluated on four continua. Felder ILSA results categorize all respondents' learning styles in terms of being active/reflective (ACT_REF), sensing/intuitive (SEN_INT), visual/verbal (VIS_VRB), and sequential/global (SEQ_GLO). Each anchor of the continua is assigned a quantitative value of -11 or 11, respectively, and all respondents are assigned individual values between these extremes. Respondents' ratings on the various Felder ILSA continua served as the independent variables in this research.

Dependent variables were a product of the 22 questions in the Case Studies Impression Survey (CSIS), which probed the utility of the case study approach for student learning. For all questions, students responded using a five-point Likert scale (1 = "strongly agree"; 5 = "strongly disagree"). We had 65 students respond to this preliminary round of data collection. In order to reduce the 22 questions of the CSIS into usable indexes we employed an exploratory factor analysis which groups questions based on the correlations of individual respondents' answers. From this analysis, the 22 initial questions were shown to be summarized in three categories or indices: learning, negatives, and applicability. Learning includes student perceptions of engagement, mastery, depth of thought, and synthesis of information; negatives includes student perceptions of frustration, inefficiency of the technique, increased difficulty, and dislike of the technique; and applicability includes student perceptions of real world application, connection to prior knowledge and experiences, and transferability of material. As these three themes emerge from the 22 questions, individuals' responses can be grouped (i.e., the responses to the questions that fall in each of the categories can be averaged to form an index for that category). Reliability analysis (evaluating the Chronbach's alpha for each index) confirmed the appropriate groupings of the questions.

Three separate regressions were run, each individually regressing one of the three CSIS indexes on the Felder ILSA continua. Using stepwise regression, only the Felder items that significantly predicted one of the CSIS indexes remained in the model. Statistical significance is indicated by a p-value less than or equal to 0.05.

The statistical data show, VIS_VRB predicts negatives with statistical significance ($p = .019$/Beta (slope) = .104). This means as individuals report being more verbal learners, they also report a more negative case experience. Verbal learners prefer spoken and written modes of teaching, such as lectures, notes on a board, and reading textbooks and handouts. This description fits what occurs in most classrooms, so it is expected that the use of the case study technique may disrupt the verbal learner. ACT_REF significantly predicts applicability ($p = .032$/Beta (slope) = .07), where as individuals report being more reflective, they see more applicability of the cases. Reflective learners prefer to have an opportunity to think quietly about information before doing something with it. They also thrive when given a chance to pause periodically during a reading to review, ask questions, or think of potential applications. Case studies are designed to have students to think and reflect as they explore content; therefore, it is reasonable that reflective learners appreciate the usefulness of this approach in connecting learning with practice. VIS_VRB is marginally predictive of applicability ($p = .056$/Beta (slope) = -.286). It will be interesting to observe how this p-value changes as the data set grows. If the p-value falls below 0.05, it will indicate that as students are more visual learners, they self-report a belief that the case content is transferable. Visual learners benefit from having some visual representation of material. The case study approach inherently helps students connect content to a real world story, thus we suspect that visual learners benefit from this technique because they paint a mental picture. Similarly, ACT_REF predicts learning with marginal statistical significance ($p = .069$/Beta (slope) = .041). If the p-value falls below 0.05, it will indicate that as individuals are more reflective learners, they self-report learning more from the case experience. As noted earlier, the intentional moments to think and reflect built into the case study teaching approach is beneficial for reflective learners.

Conclusions

These preliminary results confirm that linkages between student learning preferences and learning gains do exist and are statistically significant. This supports the broader notion that the case study teaching approach is an effective tool for engaging students in STEM disciplines beyond lectures and "cookbook" laboratory exercises. These results also support our continued work to explore linkages of student learning preferences and learning gains to demographic data such as gender, ethnicity, classification, and institutional type.

Acknowledgement

The authors are grateful for financial support for this collaborative project from the National Science Foundation (Award #1431302, #1431410, and #1431446), the Department of Biology at Bennett College, the Department of Civil Engineering at NC A&T State University, and the Dual Degree Engineering Program at Elon University. We also wish to acknowledge a previous National Science Foundation Award (#1140109) to NC A&T State University professors Drs. Stephanie Luster-Teasley and Cindy Waters for preliminary work which inspired this collaborative project.

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