Adapting an Experiment-centric Teaching Approach to Increase Student Achievement in Multiple STEM Disciplines

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Abstract

According to National Science Foundation data, the percentage of college-aged Blacks in the United States population is five to seven times the African American B.S. degree recipients in the geosciences, physics and engineering disciplines. Since Historical Black Colleges and Universities produce a disproportionate number of African American STEM graduates, there is an urgent need for them to increase their focus on broadening STEM participation among these students.. Hence, hands-on learning pedagogy should be an excellent precursor to increase participation and understanding of STEM-related concepts since the pedagogy incorporates real life experience in the delivery. This paper describes how a hands-on learning pedagogy called Experimental Centric Pedagogy (ECP) has been used to teach these concepts to undergraduate students at a historically black university. The research questions are: 1) Can ECP lead to an improvement of STEM undergraduates' understanding of foundational STEM concepts, 2) Can ECP cause a significant difference between the motivation of STEM undergraduates pre- and post-implementation of module? and (3) Does self-identified gender mediate STEM undergraduates' motivation pre- and post-implementation of experiment-centric pedagogy? To answer these research questions, ECP was implemented and assessed when used to teach concepts across 7 STEM disciplines. Assessment results from about 222 undergraduates revealed an increase in students' motivation and cognitive understanding of the relevant concepts as well as learning gains and improved success rate compared to the traditional method of teaching.

Background

According to National Science Foundation data, African American students comprise 2% of the B.S. degree recipients in the geosciences, 2.6% in physics and 3.9% in engineering, while Blacks comprise 14.9% of the college-aged population. Traditional methods of teaching and learning STEM concepts, rely on lectures and memorization, rather than developing critical thinking, problem-solving, and technical skills. ECP is currently being implemented at our HBCUs to allow students of varying learning styles the opportunity to learn at their own pace and in their environments by providing them with an alternative way to acquire technical skills and knowledge both in the classroom and outside.

The use of instrumentations in other STEM fields facilitates the adoption of ECP in these fields. Although ECP has been successfully implemented in electrical engineering, it had never been implemented in the field of transportation infrastructure engineering.

Soil Compaction (Source: Conquest Equipment)

Steel Bridges (Source: Steel Fabrication Services)

Noise Barriers (Source: The Bluebeam Blog)

Highway Culvert (Source: The Engineering Community)

Theoretical Framework

The 5E Model of the Constructivist Learning Theory

Methods

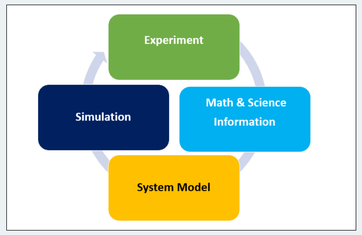


Figure 1: The Fundamentals of Experiment-Centric Pedagogy

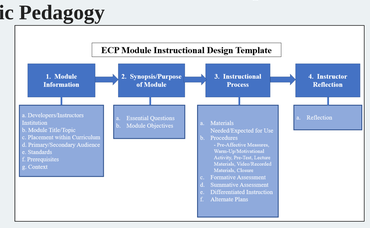


Figure 2: ECP Module Instructional Design

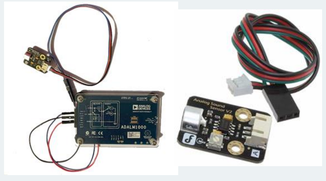


Figure 3: ADLM M1K

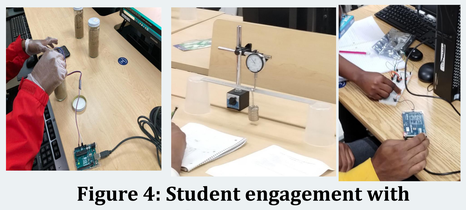


Figure 4: Student engagement with instruments

Other Tools:

The Motivated Strategies for Learning Questionnaire (MSLQ), Classroom Observation Protocol for Undergraduate STEM (COPUS), and the signature assignment

Results

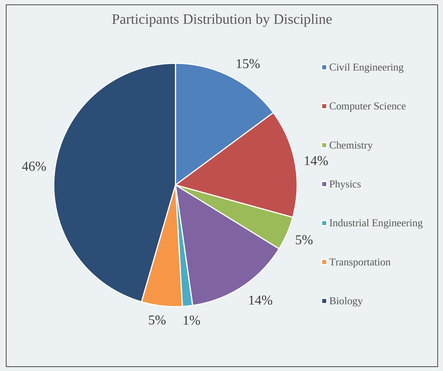


Figure 5a: Gender Distribution

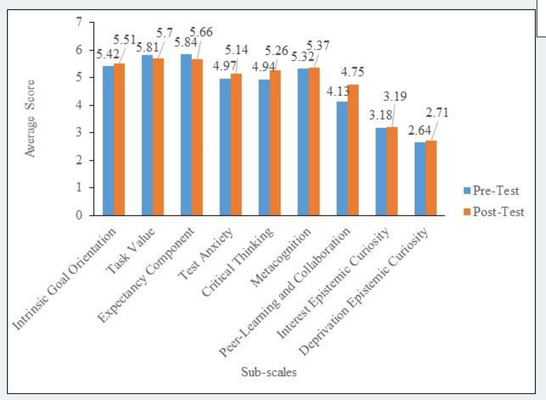
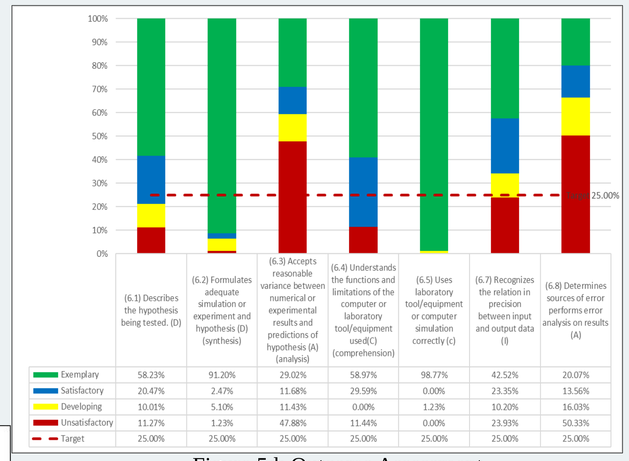


Figure 5b: Motivated Strategies for Learning Strategies



	(6.1) Describes the hypothesis being tested. (D)	(6.2) Formulates adequate simulation or experiment and hypothesis (D) (synthesis)	(6.3) Accepts reasonable variance between numerical or experimental results and predictions of hypothesis (A) (analysis)	(6.4) Understands the functions and limitations of the computer or laboratory tool/equipment used(C) (comprehension)	(6.5) Uses laboratory tool/equipment or computer simulation correctly (c)	(6.7) Recognizes the relation in precision between input and output data (I)	(6.8) Determines sources of error performs error analysis on results (A)
Exemplary	58.23%	91.20%	29.02%	58.97%	98.77%	42.52%	20.07%
Satisfactory	20.47%	2.47%	11.68%	29.59%	0.00%	23.35%	13.56%
Developing	10.01%	5.10%	11.43%	0.00%	1.23%	10.20%	16.03%
Unsatisfactory	11.27%	1.23%	47.88%	11.44%	0.00%	23.93%	50.33%
Target	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%

Figure 5d: Outcome Assessment

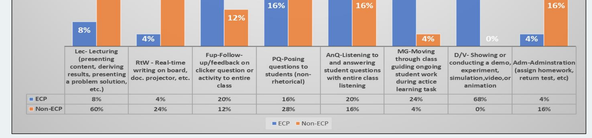


Figure 5e: Classroom Engagement

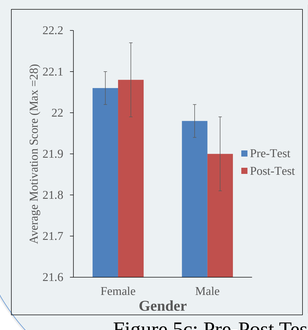


Figure 5c: Pre-Post Test Motivation Average Score by Gender

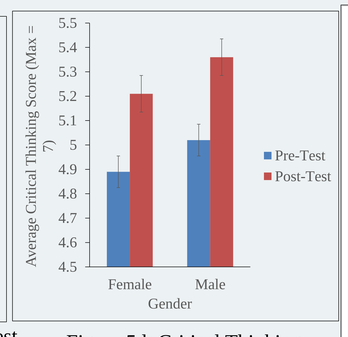


Figure 5d: Critical Thinking Score Pre-Post Test by Gender

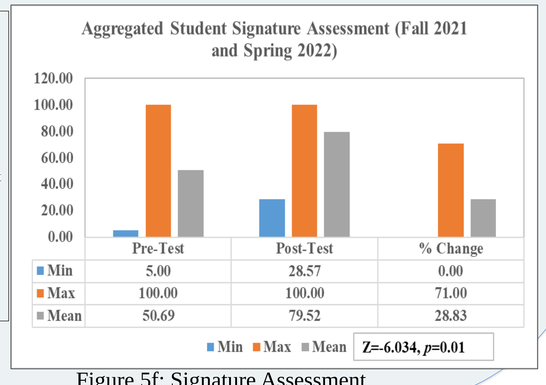


Figure 5f: Signature Assessment

Conclusion/Future Directions

ECP has been demonstrated to improve student's motivation and achievement of the stated learning objectives of transportation infrastructure systems concepts.

ECP facilitates students' demonstration of better mastery of the expected competencies in the modules. ECP will be implemented in other departments in Engineering

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