Student Perception of Skill Mastery in a Course Based Undergraduate Research Experience (CUREs)

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Abstract

A key consideration of all engineering educators is, not just the level of student comprehension, taken through conventional assignments, but also the perception of the student of their own level of understanding of the material. Students should be aware of the limitations of their understanding and the limitations of what a course can cover, when compared to the vast amount of information available in their discipline. This is generally considered to be completed through graded assignments and reflective activities, or an alternative “hands on” laboratory experience. In an undergraduate course on composite material fabrication, students are exposed to experimental design and methods, as part of a course project. Assessment of student comprehension and a self-evaluation of experimental design understanding were conducted along three point during the semester; the first, prior to any of the course material, the second, after a conventional lecture format, and the final, after a student project involving experimental design and testing. The intent is to observe any increases in student self-evaluation versus their “true” comprehension, and if the student comprehension and self-evaluation scores consistently grow throughout the semester at the same rate.

Keywords

CUREs, Student Perception, Engineering Technology

Introduction

Recent discussions in the engineering academic community have focused on increasing the amount of experiential learning through experimental labs, design assignments, and projects. Students have the opportunity to use different levels of the Revised Bloom’s Taxonomy that are available in common undergraduate lecture courses, allowing the students to synthesize new designs and evaluate experimental data[1]. The concern with existing undergraduate experimental labs is that a majority of the experiments performed are on basic, fundamental phenomena, discussed in lectures and textbooks. These labs generally do not use modern diagnostic methods, rather using simplified methods, such as measuring head loss from friction inside of pipes through water manometers.

An alternative to design projects or experimental lab courses is through Course Based Undergraduate Research Experiences (CUREs), having the undergraduate students participate in the higher level research conducted at most universities. CUREs have been utilized in the fields of chemistry and biology in order to expose undergraduates to common practices in the research fields [2,3]. The intent is to develop specific skills and experiences for the students in common practices in the field of study, observation of unique, unknown outcomes, operating in relevant and broad research, collaboration and teamwork, and the need to iterate experimental processes to find significant results [2,4].

CURE projects have seen some implementation in engineering curricula, focusing as a method of increasing recruitment of undergraduates for many graduate programs [5,6]. In Kumbhar et. Al, there is a review of different Undergraduate Research Experiences (URE) methods and some of the associated challenges [7]. The key concern discussed in research articles is the authenticity and depth of these research experiences, with students having limited time to participate in these studies (reducing the capability of students to iterate processes), and the amount of understanding and time commitment needed to operate in high-level research [5,7].

A further concern beyond the scope of most university courses is how the student takes the knowledge and experience they receive in courses into context, such as how the students perceive their own skill level after a course in a new topic area. In engineering, it is a central component for students to understand that they have a limited understanding from their coursework and to apply that knowledge in specific situations. From the National Society for Professional Engineers Code of Ethics, it is a key component to only operate in the fields that an engineer has a competency [8].

In academic fields, it has been observed that there can been a distinct discrepancy between how learners perceive their knowledge or skill mastery and their true level of mastery, which has been termed the “Dunning-Kruger” effect [9]. In the “Dunning-Kruger” effect, there is a large increase in perceived mastery of a skill in the early phases of learning, as the learner is exposed to a significant amount of information in the new topic area, but this perceived mastery outpaces the learner’s true (or assessed) understanding of the topic area [10].

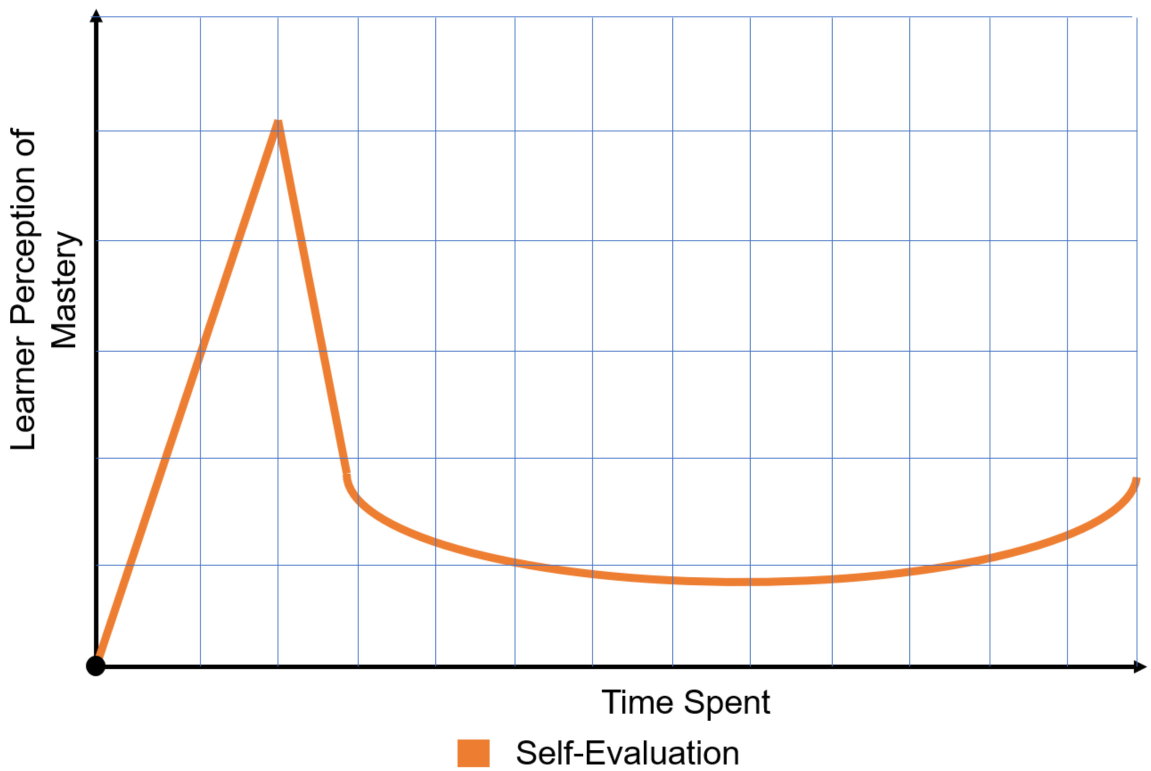

Figure 1-A Graphical Depiction of the Perception v. Mastery from the Dunning-Kruger Effect

This effect has been observed in technical and non-technical fields, where it was observed that underperforming students would overestimate their grades, whereas overperforming students would underestimate their grades [10,11]. The concern comes into play with students participating in high-level research would assume a level of understanding in both the course topic area and in experimental methods beyond their competency.

Methodology

This Course Based Undergraduate Research Experience was formed an undergraduate, senior level course in Engineering Technology, at an Historically Black College or University (HBCU), focusing on composite material fabrication in the 2019-2020 school year. During the initial iteration of the course, students (in groups of 3-4 students) were asked to propose an experiment on the course material focusing on current trends in composite material research, then conduct this research, present their findings, and write a detailed report. During the first year of the course, students proposed experiments in passively varying pitch of composite aerodynamic structures, galvanization of aluminum-carbon fiber structures in salt-water environments, effects of voids in impact absorption for carbon fiber structures, and UV radiation effects on carbon fiber samples. In order to determine the effectiveness of the CURE implementation, a set of assessments were added to the second year. For the assessment semester, students proposed experiments in high speed imaging of carbon fiber under impact loading, rapid tensile loading of composites, and drop testing of computational equipment.

In the 2020-2021 academic year, a similar approach was utilized with the addition of a series of assessments on experimental methods. Students were given a pretest at the beginning of the semester to create a benchmark of student knowledge, with 8 assessment questions and 1 self-evaluation question, shown in Table 1, which was distributed through the University's Learning Management System (LMS). Students were then given an online lecture covering vary aspects of experimental methods during the scheduled class time, though due to the Regional University's COVID guidelines, many students preferred to observe the lecture through the LMS. Students were given a second assessment between the lecture and the CURE project.

Table 1- Questions for Student Assessments

Question	Topic
1	Scientific Method
2	Correlation v. Causation
3	Number of Data Points for Statistical Significance and P-Hacking
4	Reporting Instrumentation Accuracy
5	Following Industry Testing Protocols
6	Choosing Lines of Best Fit for Datasets
7	Types of Instrument Errors
8	Error Types that Should Be Reported
9	Self-Evaluation of Experimental Methods Mastery (Likert Scale)

After the lecture, students participated in the CURE project, discussed above, which lasted 6 weeks in total. At the end of the CURE project, a final assessment was given. The overall project was reviewed by the University's Internal Review Board (IRB) and was rated as exempt.

Data and Analysis

For the data collection, the students were asked to complete the pretest, post-lecture test, and the post-CURE test, which resulted in the numbers below.

Table 2-Number of Respondants in Each Assessment

Assessment	Pretest	Post-Lecture Test	Post-CURE Test
Number of Students that Completed the assessment	9	6	6

With the low number of participants, there were concerns about achieving statistically significant results from the assessment data. For the purposes of this study, ANOVA (Analysis of Variance) tests were conducted on the data from the assessments to observe any statistical significance between the three assessments.

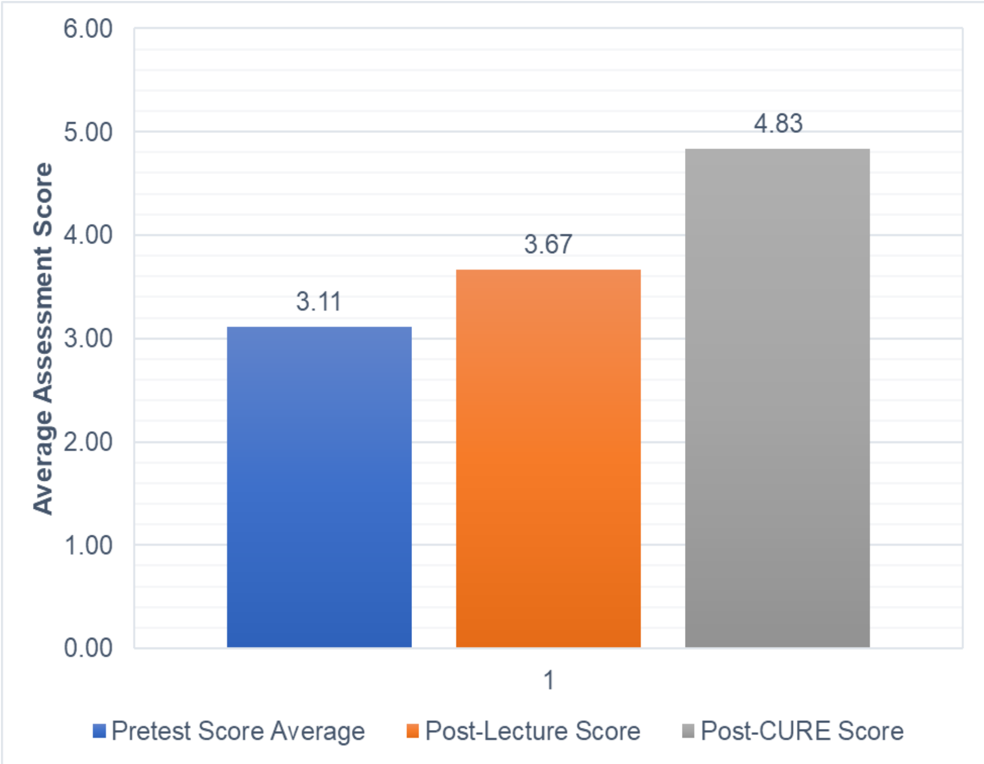

Figure 2- Average Assessment Scores for Each Assessments

As seen in Figure 2, the averages of the scores for the factual portions of the assessments increased throughout the semester, starting at an average of 3.11 for the pretest, increasing to an average of 3.66 in the post-lecture assessment, with a final average of 4.83 in the Post-CURE assessment. With these averages, the resulting ANOVA provided a p-value of 0.0178 between the three assessments, showing that there was a significant increase in the student understanding of experimental methods along the course, with the largest gains occurring between the post-lecture and post-CURE assessments. This would indicate that the CURE method was the most beneficial for student learning of experimental methods.

Beyond improving the understanding of experimental methods, the purpose of this study was to observe any changes in student self-perception of skill mastery.

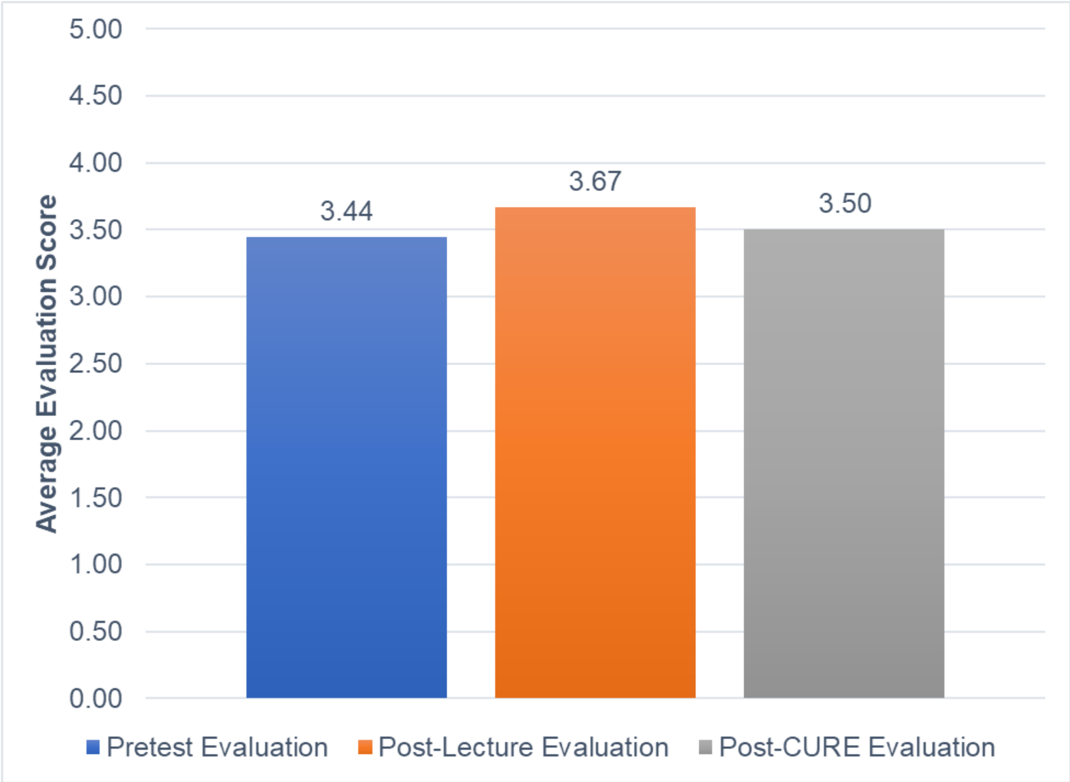

Figure 3- Average Self-Evaluation of Experimental Methods

As seen in Figure 3, there was a slight increase in the self-evaluation scores between the first and second assessments, from 3.44 to 3.67, with a small decrease in the self-evaluation scores between the second and final assessments. An ANOVA test showed that there was not a significant difference between the three assessments, with a p-value of 0.836, well above the 0.05 or below to show significance.

One other data point of note was a comment from a student course evaluation from the previous year, where a student stated, "This class was fun and interactive, so you don't mind going the extra mile on the work that was required". The student involvement in the project did lead to some students asking about graduate research, even beyond topics covered in the course, in other fields of study.

From this data, it was observed that the students did not see a significant increase in self-evaluation scores, with an increase in actual understanding, especially through the application of CURE interventions. Further research will be conducted expand the overall number of participants to see if the self-evaluation results reach significance in a larger cohort. With the small number of participants, no definitive conclusions could be established with regards the development or prevention of the Dunning-Kruger effect.

Conclusions

In a series of assessments on experimental methods were conducted as part of an undergraduate course with an embedded Course-Based Undergraduate Research Experience (CURE), after a series a lectures on experimental methods and after the CURE intervention. Students proposed a unique experiment in composite material phenomena and conducted the experiment as part of the course. The assessments showed a significant increase in understanding of experimental methods, with an increase between a pretest and the post-lecture assessments, and a larger increase between the post-lecture assessment to the post-CURE assessment. Students did not see a significant increase in the self-evaluation of their skills in experimental methods.

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