Preliminary Study: Assessing the Impact of Remote Pre-College STEM Instruction on the Engineering Identity of Freshmen Students at an HBCU

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Abstract

A cohort of pre-engineering students (chemical, computer, and electrical) was selected to participate in a five-week, remote pre-college engineering program. In conjunction with Introduction to Engineering and Pre-Calculus courses, participants enrolled in a special topics course for exposure to quantum computing, material science/engineering, entrepreneurship/customer discovery, along with hands-on courses with practicing engineers. The subject matters within these courses included potential career pathways, programming quantum circuits, quantum hardware/qubit implementations, business model canvas and customer discovery (based on Lean Launchpad methodology). Students were required to generate a potential product based on their quantum computing or materials/engineering presentations and encouraged to construct a business model canvas. In order to assess the impact of the engineering students' experiences on their engineering identity, semi-structured pre-and post-surveys focused on STEM and entrepreneurship were administered to the students for tracking during their first semester of STEM college courses.

Keywords

Engineering, Entrepreneurship, Education, Innovation

Introduction

National Reports have highlighted concerns about the national and global demands in the scientific workforce[1,2]. There continues to be a disparity in the number of African Americans that graduate from accredited engineering programs as only 4.3% of students who earned a Bachelor's degree in engineering were African American or Black[3]. Both recruitment and retention are critical in increasing the number of Black students who achieve degrees in engineering. Research and problem-based learning activities continue to be deployed to increase interest in engineering and reinforce key principles. Further, there is a continued expansion of entrepreneurship learning in many disciplines among Blacks as it is a vehicle for both economic growth and change as there has never been a greater need for innovations to address social and environmental issues[4]. Thus, the entrepreneur mindset is valuable for HBCU engineering students as HBCU's are historically at the forefront of change. This connection is critical to recruit and retain Black engineers as studies have found an increased interest in engineering and technology among Black students through exposure to innovation and entrepreneurship/customer development training[5,6,7]. All such factors could contribute to the important engineering identity of students.

Engineering Identity has been shown in previous studies to play a critical factor in students' persistence in the engineering majors[8]. Therefore, this study focuses on some of the tenants within engineering identity that have previously been identified as important. These include interest, performance/competence, and recognition.

Background

Engineering Identity

In this study, we define engineering identity as one's feeling like an engineer or seeing themselves as an engineer. We are aware that there are other areas and nuances that affect engineering identity such as self-efficacy, motivation and expectancy value, but due to page limitations, we will focus on those aspects in future studies. Engineering identity is influenced not just by how the students' view themselves, but also by how others within the community view them (recognition). All these factors lead to students' persistence and continued intrigue (interest) in the field and affects other areas such as (performance/competence). Therefore, these elements were included within the instrument/survey that were completed by the students to give a more well-rounded narrative. The students participated in a 5-week course through remote instructions. To monitor student remote engagement and ensure that students were following proper class instructions, frequent assessments through active cameras and chat box discussion aided in fostering active learning.

Course Description

A cohort of incoming engineering students were selected to participate in a new, special topics summer pre-college course entitled, "Introduction to Research Topics Engineering". The course was designed for freshman level undergraduates with emphasis placed on the introduction to areas of engineering research by regular attendance at appropriate seminars, techniques of literature searches, and background study. Three major course topics were discussed at described below.

1) IBM quantum computing. The IBM quantum computing portion of the course was taught by a scientist from IBM. The objectives of the series of presentations included an introduction to quantum computing, potential career pathways in quantum computing, programming quantum circuits, and quantum hardware and qudbit implementations. Jupyter notebook was used to allow the students to create and share documents and code. *2) Materials research (based on NSF PREM research*). During the materials research portion of the course, students were exposed to active Hampton University Partnerships for Research and Education in Materials (PREM) research projects. The four principal investigators of the grant presented their research thrusts with each having the theme of opto-active materials and biomaterials. Each research presentation was 15 minutes and was followed by extensive dialogue and questions. Students were also presented open-ended material case studies during select presentations. *3) Customer discovery (based on Lean Launchpad methodology).* Students were introduced to the business model canvas based on Lean Launchpad methodology, primarily focusing on value propositions, customer segments, and channels. These concepts were presented to them in a similar fashion as they are presented in the NSF I-Corps short course. Students were challenged to construct abbreviated business model canvases (based on categories above) using established products such as popular cell phones and vehicles.

Final Course Project. Students were assigned a final course project to conclude the course. They worked in random groups of three to complete the project. Each group was assigned to develop new products based on either quantum computing or materials (earlier concepts from the course) and develop an abbreviated business model canvas for their product. Each group conducted at least five customer interviews to test their business and technical hypotheses.

Research Questions (RQ)

RQ1: How does participation in this Remote Instruction Pre-College Course impact students' Engineering Identity? **RQ2:** How does participation in this Remote Instruction Pre-College Course impact students' Sense of belonging to the area of entrepreneurship?

Methods

Students were given a pre-validated, adapted engineering identity survey[8] upon enrolling in the course and immediately after completion of the course. The surveys were administered online during 15 minutes increments, pre-and post-course instruction. Results from this survey were coded and reviewed for analysis. All student participants were Black, pre-freshman engineering majors.

Preliminary Results

The completed pre- and post-surveys via remote instruction are based on a likert scale. Students' responses from the different constructs were quantified, analyzed to generate the table below. Each of these constructs was measured using multiple representative items, and response items were given using a 5-point Likert scale of agreement (1=Strongly Disagree to 5=Strongly Agree). All student participants (N=12) responded. Mean (in each category for the pre-and post-surveys) is the average for all 12 students, with the standard deviation being expressed for each one.

Table 1. Engineering and Entrepreneurship Constructs Survey Results.

		Engineering Constructs		*Entrepreneurship Constructs*	
		Pre-Survey	**Post-Survey**	**Pre-Survey**	**Post-Survey**
		Mean ± STD	Mean ± STD	Mean ± STD	Mean ± STD
Recognition	My parents see me as an engineer.	3.83 ± 1.11	3.75 ± 1.06*	3.17 ± 1.19	3.08 ± 1.08*
	My instructors see me as an engineer.	3.75 ± 0.62	3.58 ± 0.67*	N/A	N/A
	My peers see me as an engineer.	3.83 ± 0.72	4.00 ± 0.60	2.83 ± 0.94	3.0 ± 0.85
	I have had experiences in which I was recognized as an engineer.	4.00 ± .095	3.67 ± 0.89*	3.25 ± 1.14	3.50 ± 1.00
Interest	I am interested in learning more about engineering.	4.75 ± 0.45	4.83 ± 0.58	3.25 ± 1.14	3.17 ± 1.40*
	I enjoy learning engineering.	4.67 ± 0.49	4.75 ± 0.45	4.00 ± 1.04	4.0 ± 0.74
	I find fulfillment in doing engineering.	4.42 ± 0.67	4.50 ± 0.52	3.50 ± 1.24	3.75 ± 0.87
Performance and Competence	I am confident that I can understand engineering in class.	4.00 ± 0.85	4.17 ± 0.58	3.58 ± 1.24	3.5 ± 1.00*
	I am confident that I can understand engineering outside of class	3.83 ± 0.72	3.83 ± 0.72*	3.83 ± 0.72	3.92 ± 0.67
	I can do well on exams in engineering.	3.67 ± 0.65	3.83 ± 0.58	3.83 ± 0.83	3.75 ± 0.97
	Others ask me for help in this subject.	3.17 ± 0.39	3.92 ± 0.79	2.50 ± 0.80	2.42 ± 1.16
	I can overcome setbacks in engineering.	4.17 ± 0.39	4.17 ± 0.39	3.75 ± 0.62	3.58 ± 0.67
	I feel confident that I will perform well in my engineering studies.	4.42 ± 0.51	4.17 ± 0.58	N/A	N/A

**Asterisk denotes a decrease or lack of mean change after instruction.*

For the Engineering constructs, the items that focuses on “My peers see me as an engineer “had an increase (mean of overall response of 3.83 ± 0.72 to 4.00 ± 0.60, with a standard deviation of after completing the remote instruction. The other items within the construct of recognition did not show an increase in student response. The other items shown above (with asterisk) decreased or remained the same after instruction. The survey items under “interest” all showed an increase from pre-remote instruction to post -remote instruction. For the entrepreneurship constructs, showed half increase and half decrease with the survey questions. The survey items, “my peers see me as an entrepreneur “ and “ I see myself as an entrepreneur” increased from 2.83 ± 0.94 to 3.0 ± 0.85 and 3.25 ± 1.14 to 3.50 ± 1.00. On the “interest” survey item, student responses show an increase from 3.50 ± 1.24 to 3.75 ± 0.87 with the other two survey items having the results stay the same or decrease slightly. For the “performance/competence” survey item, there was only an increase for one of the four survey items, which was “I am confident that I can understand entrepreneurship in class”, which had a slight increase from 3.83 ± 0.72 to 3.92 ± 0.67.

Discussion and Future Directions

For our preliminary results, the trends from this study are complicated. There were no significant differences between the pre-survey and post-survey constructs as the number of participants were low and lack of filter questions could have limited more concrete findings (n = 12). In reviewing the means for the engineering constructs, the mean values all decreased with the exception of peer recognition. Despite being challenged in the course, the mean student interest increased among all surveyed items, showing that they students were interested in engineering and they paid attention to how their peers saw them as it came to being an engineer (engineering identity). Among the entrepreneurship constructs, the pre-survey recognition mean values were all lower than the engineering pre-survey values. However, two of the entrepreneurship recognition post-survey values increased. Mean values for the interest and performance/competence constructs were mixed as pre-survey and post-survey mean value changes oscillated. Further analysis needs to be done in order to properly assess these findings.

Some of these decreases could possibly suggest a slight mismatch between the student’s perception of the engineering field prior to enrolling in the special topics course and their changed perceptions after the course. Although it seems as if there is no significant change between the means, pre-and post- remote instruction, it may be that students’ actually learned the true nature of engineering and entrepreneurship. Therefore, they re-adjusted in their minds their previous ratings within the survey without opportunity to adjust their pre-survey responses. The students were challenged with many new concepts (e.g., quantum computing), and such challenges could have initiated an new self-assessment of both engineering and entrepreneurship constructs.

In extended future studies, in order to further analyze student perception of entrepreneurship and engineering identity, measures will be taken to fully understand students’ definition of engineering identity before and after instruction. Our next study will have students define the terms pre- and post- instruction to see if there is a shift in their definition that may account for the ratings for the individual constructs. We will also attain a focus group from the participants that we can further probe about their responses to gain a better understanding of student thought processes and how they reach their ideas that they use towards persistence and their identities that lead towards engineering and entrepreneurship career-making decisions.

Limitations: Due to the preliminary nature of this study, we cannot formulate any conclusions at this time. One limitation of this study is the lack of pre-evaluation of students' pre-existing content knowledge of the delivered course material. A second limitation of this preliminary study is the survey questions are broad (subjective and objective metrics). To address this limitation, future studies we will include surveys metrics as described in Liu and Baker[9,10].

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