Building High-Level Environmental Behavior into HBCU Engineering

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ABSTRACT

This work-in-progress paper explores links between engineering students' environmental awareness and their intended environmental behavior at different levels in a prominent HBCU. Through extensive surveys developed as part of this project, students' higher-level behavior, manifested by their willingness and preparedness to pursue careers in the industries developing sustainable resources, has been explored. To maximize the high-level behavior and sustainability competencies, a pedagogical system with a comprehensive pool of interventions has also been developed and implemented in a senior-level mechanical engineering course. In this paper, we report the initial survey data and details of the intervention strategies, which are intended to develop scalable educational approaches and guidelines for building high-level environmental behavior in the next-generation diverse renewable energy workforce.

I. INTRODUCTION AND BACKGROUND

The US sustainable industry experienced significant expansion in recent years because of increased attention and importance on critical global issues related to energy security and climate change [1]. This renewable energy sector growth should drive engineering education institutions to devise transformative pedagogical techniques to fill the gap in sync with the sustainable industry. Such programs must lay the groundwork for students to become familiar with various green technologies, associated ecological impacts, and fundamental engineering concepts and formulation approaches. However, the mechanisms of how students are informed about environmental challenges during their undergraduate studies in engineering and the link between students' environmental awareness and motivation to join sustainable industries upon graduation are not well-known. Intuitively, the increased environmental awareness among undergraduate engineering students influences their ultimate consumption behavior and empathy toward the environment and inspires them to join green businesses.

A recent study by New York Times projects that climate change will soon drive agricultural and energy shortages in the Southeast region [2]. Developing this workforce via higher education can create new economic opportunities and transform traditional industries in this region. The contribution of curricula to ecological knowledge and promoting students' environmental awareness, presumably the main drivers of environmentally friendly behavior, is also acknowledged and analyzed in the literature [3]. In this context, and based on studies that explored the role of universities as a catalyst for green transformations [4], the present study aims to understand HBCU students' environmental awareness and preparedness to pursue careers in sustainable industries.

Several studies investigated how factors such as gender, major, nationality, years in college, socio-demographics, etc., influence the perceived effectiveness of pro-environmental behavior in students [5]. However, the connection or gap between environmental awareness and pro-environmental behavior is poorly understood. Researchers also pointed out that a change in

environmental knowledge or attitude not necessarily leads to changes in their pro-environmental behaviors [6].

II. OBJECTIVES

To further explore and study the connection between environmental awareness and the environmental behavior of students in an HBCU, the objective of the present study is to test the following two hypotheses:

1. There is no connection between engineering students' *environmental awareness* and their *willingness and preparedness* to pursue careers in industries developing sustainable energy resources, named green energy industries, GEI.

2. There are actions by which rational environmental behavior forms in individuals at various degrees. Specific training and curricula throughout the undergraduate experience might directly impact their anticipated environmental behavior.

While extensive surveys are used for testing the first hypothesis, tailored educational interventions that would create environmental behavior in students are used for testing the second one. The survey developed and used in this study focuses on the following major tasks:

- Evaluate the correlation between student environmental knowledge and attitudes with their high-level intended behavior (i.e., preparedness & willingness) to pursue ecological careers,
- Evaluate the gap between needed capabilities in sustainable industries and those perceived by students,
- Assess changes in students' environmental knowledge, attitudes, willingness, and perceived preparedness for a career in GEI as a result of educational interventions,

The survey developed in this study helps to measure the willingness and preparedness of students to join GEI, and the educational interventions gauge various approaches and implement the ones that fulfill the needs of specified cohorts. The survey and interventional results may provide transformable guidelines to create environmental behavior in engineering students. An amended curriculum and tailored educational program could cultivate requisite skillsets suitable for GEI.

The intervention plans we developed and used for this study align with the United Nations Decade of Education for Sustainable Development framework, which emphasizes the need for high-quality education for sustainable development. This educational approach requires a multi-method approach, a combination of different pedagogical approaches that resonate with students [7].

The surveys developed for this study used a synthesis of twelve sustainability competencies available in the literature, namely: systems thinking, empathy & change of perspective, personal involvement, interdisciplinary work, anticipatory thinking, justice, responsibility & ethics, strategic action [8], critical thinking & analysis, communication & use of media, assessment & evaluation, tolerance for ambiguity & uncertainty [9]; and interpersonal relations & collaboration [10]. Each of these competencies has implications in formal and informal learning settings. For example, other learning manifestations include system thinking, which entails understanding connectivity and cause-effect relationships, attention to systemic features such as feedback, inertia, stocks, and flows, and stemming impacts [8].

III. METHODS

*A. **Surveys***

The students in a sophomore and junior-level mechanical engineering course in an HBCU participated in this study. The surveys developed as part of this project are used to acquire baseline data on students' environmental behavior in the Fall semester of 2021. Apart from survey data collection, intervention plans were developed during this period. Twenty-two (22) students participated in the initial baseline survey. The intervention plans designed for building environmental behavior were implemented in Spring 2022. In the post and pre-surveys of the intervention semester, 25 and 22 students responded from a senior-level mechanical engineering course.

A pool of survey questions was developed to understand the following:

a) Knowledge of sustainability,
b) Attitudes and intended behavior towards sustainability,
c) Willingness to pursue a sustainability career, and
d) Perceived preparedness for a sustainability career.

The essential goal of the intervention is to understand the role that the instructional approach plays in changing undergraduate students' knowledge, attitudes, willingness and perceived preparedness to pursue professional careers in GEIs. The relationship between student demographic factors such as race/ethnicity, gender, parental education, and socioeconomic status on these outcome variables will also be assessed in this study.

The following research questions guided both the surveys and intervention strategies:

1) What are students' knowledge and attitudes about sustainability, and their willingness and perceptions to pursue a career in GEIs?
2) How do employed educational tools impact student sustainability knowledge, attitudes, willingness, and perceptions about their preparedness to enter the target fields?
3) What is the relationship between student demographic information and outcome variables?

4) What are the gaps in perceptions of preparedness between undergraduate students and professionals working in the field?

This work-in-progress paper presents the data to address questions 1 and 2. The mixed methods research study employed in this project will follow an Explanatory Design wherein quantitative survey results will be explained and clarified through subsequent qualitative data collection [11]. Surveys and data analysis to address questions 3 and 4 are ongoing and will be reported in the future.

Pre and post-surveys contain multiple-choice, Likert-type, and open-ended questions that relate to the four outcome variables (sustainability knowledge, attitude/intended behavior, willingness to pursue a career, and perceived preparedness for a sustainability career). We modified a validated instrument for the first two variables based on surveys developed by NEETF [12]. However, due to the unavailability of a research-grade assessment that targets student willingness and perceptions of preparedness for careers in the GEIs, a research-grade instrument has been developed separately and validated for this purpose. These preliminary instruments are developed using expert-derived questionnaire design principles [13, 14] reviewed by Auburn University's and Tuskegee University's Offices of Assessment and Institutional Review Board (OAIRB) to ensure quality and compliance with all human subjects' protocols.

Feedback from a panel of graduate students and appropriate modifications were incorporated to establish the survey questions' content validity. As an instrument for measuring preparedness, two questionnaires, one for students to gauge perceived preparedness and one for industry representatives to gauge required preparedness, have been developed based on principles of sustainability competencies.

Each competence that possibly connects to a corresponding pedagogical approach was classified into three groups- one that addresses it, one that may address it, or one that does not address it. The adopted instruments are either derived from standard NEETF or literature surveys for similar diverse groups of students in Southeast regions. The devised instruments are examined throughout the project and modified and validated throughout the study. A summary of survey segments S1-S5 with classifications and expected outcomes are given in Table 1 below.

Table 1: Summary of survey segments.

S1:	17 Multiple questions about the basic knowledge of global warming/renewable energy. *Only one correct answer (0 or 1). % score indicates the success rate.*
S2:	Students grade their attitude about some renewable energy application statements (0-6 scale). *The higher the score, it is highly likely that they support the statement*
S3.1	Ask if the students want to change their behaviors to use renewable energy or save energy (0-6 scale). *The higher the score, the higher the possibility they would like to change*
S3.2	Ask if the students would like to change their habits in the future to save energy (0-6 scale). *The higher the score, the higher the possibility they would like to change*
S4.1	Students grade the listed elements that would be important when they apply for a job position in their future careers (0-6 scale). *The higher the score, the more important they consider environmental and life balance aspects of the job*

S4.2	Students were asked how much they would like to sacrifice for a job position in renewable energy compared to a traditional company (0-6 scale). *The higher the score, the more they can accept the sacrifice.*
S5.1	Students were asked to grade the agreement about the list of abilities in the workplace (0-6 scale). *The higher the score higher the agreement.*
S5.2	Students were asked to grade their abilities and whether they considered these abilities could be essential in their future work. They have two choices: *The higher the score (0-2), the higher the agreement.*

IV. SURVEY DATA AND ANALYSIS

A. Initial survey on junior and sophomore classes

Table 1 summarizes the descriptions of survey segments S1 to S5 used in this study and the significance of their outcomes. Table 2 summarizes Fall 2021 baseline data on students' environmental awareness and behavioral attitudes acquired through the surveys S1-S5 listed in Table 1. The basic knowledge of global warming and renewable energy is assessed using questions in S1 Survey, and 55% of students answered those questions correctly.

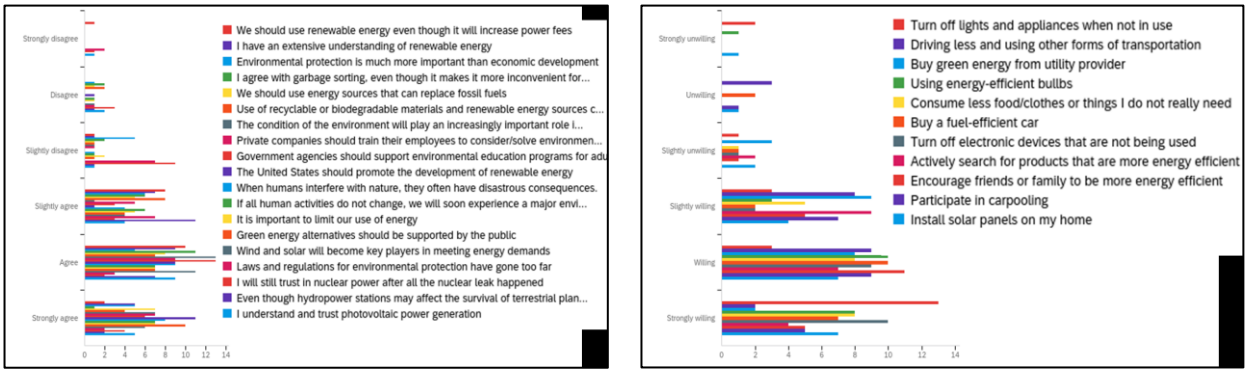
Table 2: Summary of Fall 21 Data Sample

	S1	S2	S3.1	S3.2	S4.1	S4.2	S5.1	S5.2
Fall 21	0.55	4.43	4.65	3.46	5.62	3.67	4.77	1.36

Figures 1-7 summarize responses to survey S2-S5 that targeted students' attitudes, behavior, changes in attitude, career decisions, sacrifice, and abilities assessed based on several statements related to renewable energy and its usage. Students' response rates and renewable energy application statements used in the survey are also indicated in each figure. Fig. 1*a* shows responses to 19 statements in survey S2 related to general information on renewable energy and environmental behavior. Responses were rated 0-6 based on their agreement with the statement from 'strongly disagree' (0) to 'strongly agree' (6). If the rating is high, they will likely support the statement. The average score for the S2 Survey is 4.43. This score indicates that most students who participated in the survey agreed about the significance of renewable energy use, its importance in their life, and the need for public support for this sector.

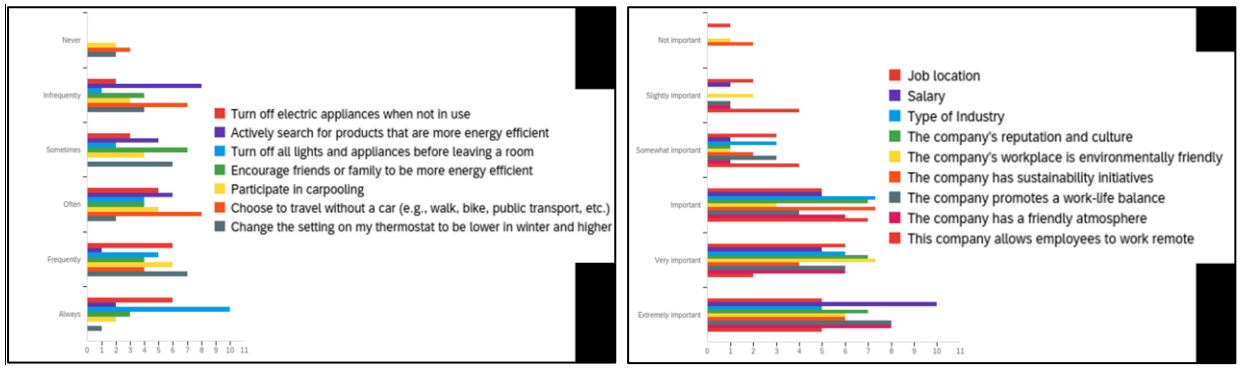
Fig. 1*b* shows responses to survey S3.1 with 11 statements framed to understand possible *behavioral changes* students will agree to accept for a general need for energy saving and increased use of renewable energy in their daily lives. The average score of 4.65 indicates that a majority are willing to change their behavior toward greener energy and its increased dependence in the future. Fig. 2*a* shows responses to survey S3.2 (7 statements) that assess students' responses toward immediate changes in their behavior in favor of renewable energy use and energy saving. The average score in this pool of statements is 3.46, less than the S3.1 survey. The interesting outcome of surveys S3.1 and S3.2 is that although students agree that there is a need for energy saving and increased use of renewable energy in their daily lives, they are less intended to this change in the

near future.



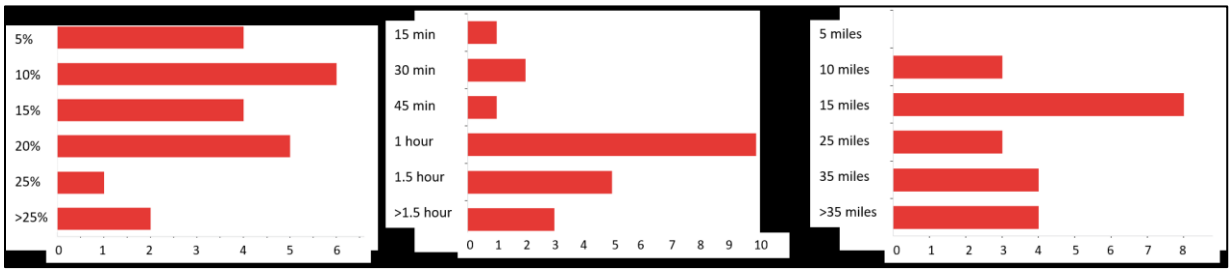
a) *b)*

Fig. 1 Survey response S2 targeting students' a) ***attitudes*** about 19 renewable energy application statements listed in figure b) Survey response S3.1 assessing students' ***possible behavioral changes*** for renewable energy use or energy saving, using 9 general statements.



a) *b)*

Fig. 2 Survey response a) S3.2 assess students' possible **behavior changes** for renewable energy use or ***saving of energy in their daily life*** b) S4.1 on factors deciding ***career decision***



a) Salary difference *b) Driving time* *c) Driving distance*

Fig. 3 Survey response 4.2 on ***sacrifice for a job position in renewable energy*** when compared with a traditional company

Fig. 2*b* shows responses to survey S4.1 that explored vital factors influencing students' career decisions. In this survey, students choose a company's reputation, culture, and salary as extremely and equally important aspects as its environmental and life-balancing commitments. A high average

score of 5.62 indicates that a job's ecological and life-balancing factors also play a significant role in their career decisions.

In Survey S4.2, students were asked how much they would like to sacrifice for a job position in the renewable energy industry compared to a traditional company. Sacrifices on salary difference, driving distance, and driving time were given as response options with varying acceptance levels. The sacrifice levels are mapped to a 0-6 scale so that a maximum average score might reflect their intention to sacrifice more for a renewable job option. The average score for this response is 3.67, indicating that they are willing to sacrifice their salary/driving distance/time to a reasonable extent for a job in the renewable industry.

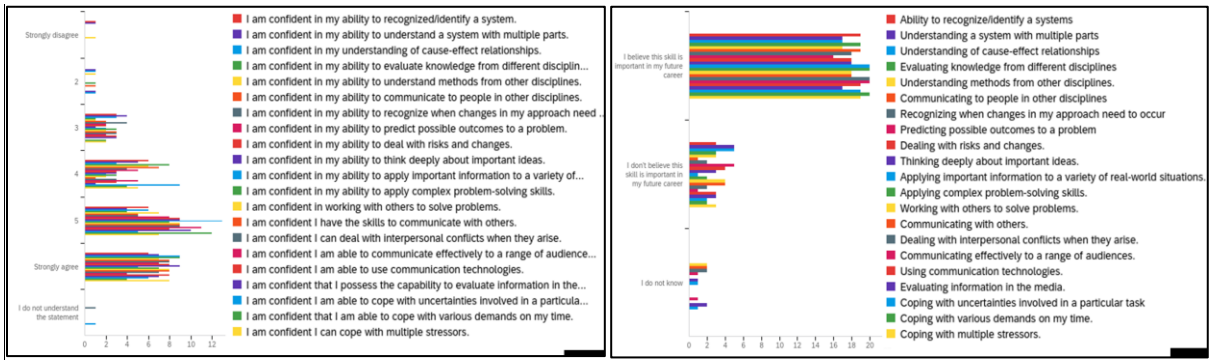


Fig. 4 Survey response *a)* S5.1 **on sacrifice** for a job position in renewable energy when ***compared with a traditional company*** *b)* Survey response 5.2 ***abilities could be critical in their future work***

In survey S5.1, students were asked to grade the agreement about the list of abilities needed in the workplace (0-6 scale). The average response score is observed to be high in this survey, with a score of 4.77. Students were also asked to grade their skills and whether they consider these abilities could be essential in their future work. This response shows an average score of 1.36 (out of 2) for this survey segment.

The average scores of the data samples shown in Table II from Fall 2021 serve as a baseline for the data analysis for the intervention in Spring 2022. The same surveys were given before and after tailored interventions to create environmental behavior in a selected senior-level course in Mechanical Engineering, which will be discussed next.

V. INTERVENTION

A. Approach

A senior-level mechanical engineering course (MENG 425 Renewable Energy) has been chosen for tailored interventions intended to create environmental behavior in students. Twenty-five (25 final-year Mechanical Engineering students participated in the intervention studies and associated pre-and post-surveys at Tuskegee University. This course traditionally uses lectures, tests, and quizzes on renewable energy topics for instruction. As part of the project, two intervention strategies were added to this course. In addition to lectures, students were grouped

and assigned seminars and experimental projects related to renewable energy during the intervention period. Scaled models from Horizon Energy Box^{TM} that demonstrate various renewable energy generation is used for the project experiments. Finally, they collected data, analyzed it, and presented their projects. Seven students groups, each having four students members, performed experiments on the following renewable energy sources:

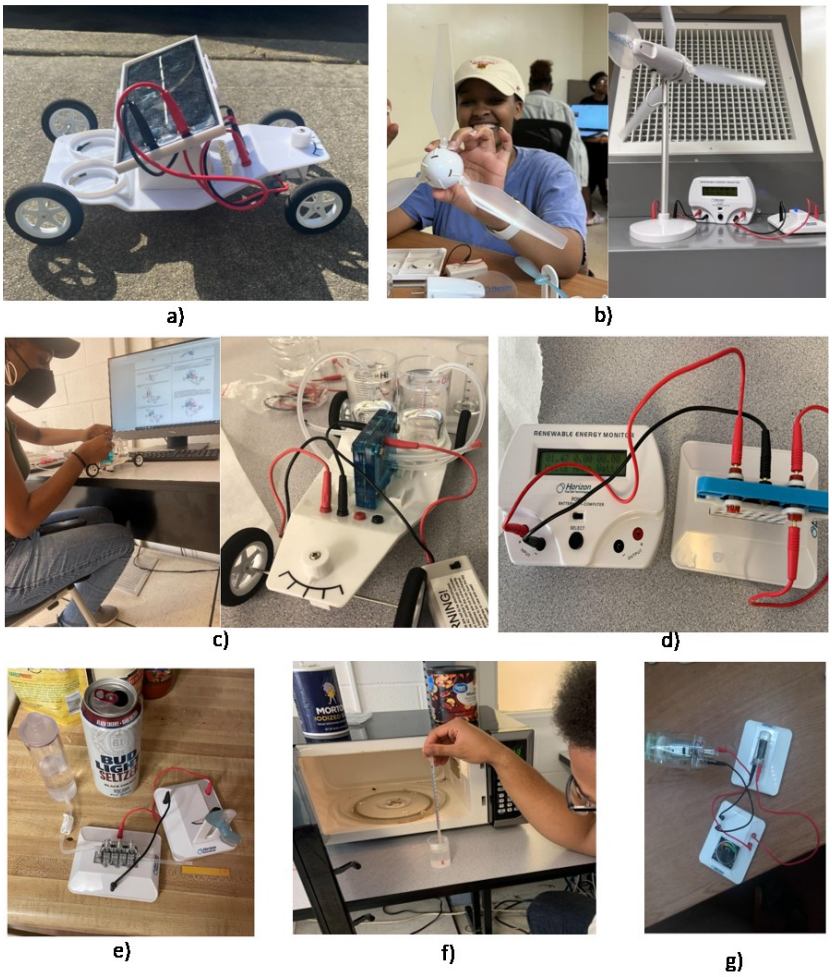


Fig. 5 Photographs of seven student projects used as part of the interventions intended for creating high-level environmental behavior in students

a) Solar Energy Project

In this project, students assembled an electric model car from Horizon Energy Box powered by a solar PV panel. The power from solar radiation was measured using a multimeter, and students conducted experiments at various insolation rates and evaluated the car's performance.

b) Wind Energy Project

In the wind energy project, students assembled a wind turbine model and studied its performance by measuring wind speed and energy output. Different blades were used to study the optimum power output from the wind turbine.

c) Hydrogen fuel cell

Another student group assembled a hydrogen-powered car. Electricity stored in a battery generates hydrogen and oxygen from the water through electrolysis. These gases are further used in a hydrogen fuel cell to produce electricity and drive the electric motor of a model car. Students conducted a few parametric variations and studied the performance of this car.

d) Saltwater fuel cell

A Saltwater fuel cell that produces electricity directly using salt water is another demonstrative experiment used in the intervention. Students assembled this model and conducted experiments by varying concentrations of saline water and its temperature. The power output from the fuel cell is measured using a digital multimeter.

e) Biofuel – Energy from a fuel cell that uses ethanol

Another student group has used a fuel cell that converts ethanol (biofuel) directly into electricity as part of their project. The electric power output from the fuel cell is measured by varying the ethanol percentage.

f) Energy from thermos electric effect

The thermos electric emf generated by two fluids maintained at a hot and cold temperature is used for driving a model turbine. The power output and its correlations to the temperature difference were investigated in this project.

g) Mechanical Energy- Super-capacitor

In this experimental model, a hand-driven mechanical system connected to an electromagnet converts mechanical energy to electrical energy. This energy is further stored in a super-capacitor for later use. Students conducted experiments to measure the stored energy from a given mechanical action for a given period.

Table III compares survey response scores of Spring 2022 pre-and post-intervention with the baseline data acquired in Fall 2021. Fig. 6 shows a graphical representation of this comparison.

Table III: Data Summary of Baseline in Fall 2021 and Pre and Post-Intervention in Spring 2022

	S1	S2	S3.1	S3.2	S4.1	S4.2	S5.1	S5.2
Fall 21	0.55	4.43	4.65	3.46	5.62	3.67	4.77	1.36
pre-Spring 21	0.51	4.30	4.89	3.71	5.80	3.47	5.28	1.23
post-Spring 21	0.54	4.67	4.79	3.83	5.57	3.46	4.86	1.52

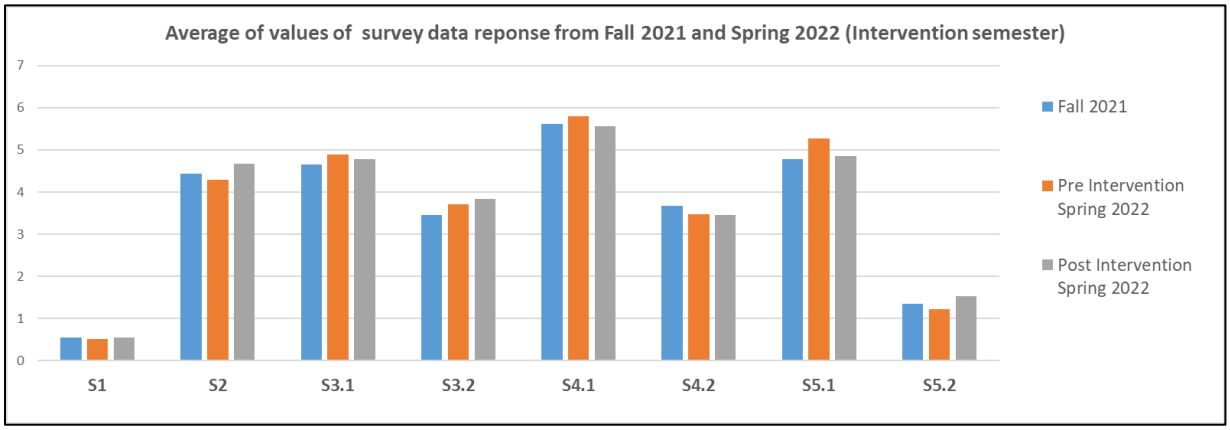


Fig. 6 Comparison of survey data from Fall 2021 and Pre and post Intervention period Spring 2022

For pre-and post-intervention (Spring 2022 semester), the correct response rates for the S1 Survey are 50.4% and 54.3%, respectively, and this is not far from the Fall 2021 baseline data of 55%. This indicates that in all three samples, the knowledge level of students shows very similar levels, and the intervention has slightly changed this. Survey S2, which has statements that reflect the *attitude* and *intended behavior towards sustainability*, indicates a score of 4.67 in post-intervention compared to its pre-intervention score of 4.30 and baseline score of 4.43. The higher score after intervention indicates some effectiveness intervention for tailoring this behavior and supports our second hypothesis in section II.

The average survey scores for S3.1, which has 11 statements framed to understand possible *behavioral changes* students will agree to accept for a general need for energy saving and increased use of renewable energy in their daily lives, show scores of 4.89 and 4.79 in pre-and post-intervention. The baseline data also recorded a value of 4.65 for this survey. This data points out that students are generally willing to change their behavior towards sustainability, and the current intervention has not impacted it.

The survey S3.2 (7 statements) that assesses students' responses toward immediate changes in their behavior in favor of renewable energy use and energy saving received a score is 3.71 and 3.83, respectively, for pre and post-interventions. The baseline score was 3.46 for this survey. This data suggest that although they have a positive attitude towards sustainability, as reflected in S3.1, they are less intended to practice those in real life soon. In this case, the intervention has slightly improved this score.

Survey S4.1 explored vital factors influencing students' career decisions, such as a company's reputation, culture, and salary, as extremely and equally important as its environmental and life-

balancing commitments. Survey S4.1 intends to reflect students' willingness to pursue a sustainability career, showing average scores of 5.80 and 5.57 in pre and post-intervention. The baseline score was 5.62 for this survey. This indicates that students are generally willing to pursue a sustainability career. In this case, the intervention does not show any impact. The survey suggests that a job's ecological and life-balancing factors significantly influence their career decisions. The intervention does not affect this aspect of willingness to pursue a sustainability career.

The survey S4.2 was about sacrifice for renewable energy jobs; the score is almost the same for pre-and post-interventions (3.47 and 3.46). The baseline was 3.67. The intervention shows no change in their intention to sacrifice for a renewable energy job. In survey S5.1, students were asked to grade the agreement about the list of abilities in the workplace. Indicates scores of 5.28 and 4.86 for pre and post-interventions. The baseline score was 4.77. This suggests that students generally agree on abilities essential in a workplace. Finally, the survey S5.2, which assesses perceived preparedness for a sustainable career (essential skills they think they have for the renewable energy industry), shows a 24% change after the intervention. (score 1.23 and 1.52, 1.36 respectively for pre and post-interventions and baseline data). This data suggests the intervention strongly impacts their perceived preparedness for a sustainable career.

In summary, the increased mean scores for surveys S1, S2, and S5.2 suggest the intervention had measurable changes in *students' knowledge of sustainability*, *their attitude and intended behavior toward sustainability,* and *their perceived preparedness for a sustainable career*. Surveys S3.1, S3.2, S4.1, S4.2, and S5.1 revealed students' attitudes, behavior, willingness, sacrifice, and abilities for renewable-related workplaces. Intervention does not show any effect on these characteristics.

Although this comparison provides only a preliminary insight into the possible effects of the intervention from the initial data, we are currently working on a more rigorous statistical analysis, including data from the ongoing studies, which will reported in the future. A paired sample t-test for each section will be conducted in the next step for data from previous and ongoing interventions. This will help ascertain the statistical significance of the differences between pre- and post-intervention scores while accounting for the paired nature of the data.

VI. CONCLUSIONS:

This work-in-progress paper discusses initial data from a prominent HBCU to study the links between engineering students' environmental awareness and environmental behavior. This study developed eight survey segments to capture preliminary data on students' willingness and preparedness to pursue careers in industries developing sustainable resources. To maximize the high-level behavior and sustainability competencies, a pedagogical system with a comprehensive pool of interventions has been developed and implemented in a senior-level mechanical engineering course. The intervention strategies aim to develop scalable educational approaches and guidelines for building high-level environmental awareness among students. Data acquired from two semesters, with and without intervention, is presented and compared to each other to understand the effectiveness. The survey developed and implemented in this project provides

valuable information on students' attitudes, behavior towards sustainability; willingness, sacrifice, and perceived abilities for a career in renewable energy. Detailed statistical analysis of survey data from this study and from the ongoing intervention in Spring 2023 will be reported in the future.

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