Imparting High-Level Environmental Behavior Through Tailored Interventions

Dr. John T Solomon, Tuskegee University

Dr. Solomon is a Tenured Full Professor in the Mechanical Engineering department of Tuskegee University (TU), AL. He received a Ph.D. from Florida State University (FSU) in 2010. Dr. Solomon's research interests include high-speed flow control, actuator development, experimental fluid mechanics, micro-scale flow diagnostics, and engineering education. He holds three US patents on high-frequency microactuator technologies developed for high-speed flow control applications. The National Science Foundation has supported Dr. Solomon's research through grants such as the Research Initiation Award, Excellence in Research (EiR), and Improving Undergraduate STEM Education (IUSE). He was selected as a summer faculty research fellow at NASA Jet Propulsion Laboratory, California Institute of Technology (Caltech), in 2019 and 2020. Dr. Solomon received the Faculty Achievement Award from Tuskegee University in 2023. Dr. Solomon has published and presented 50 technical papers in various journals and AIAA and ASEE conferences.

Mr. Hang Song, Auburn University

Hang Song is currently affiliated with Auburn University, where he plays a pivotal role in the field of environmental research, particularly in the application of data mining and statistical analysis. With a keen focus on developing innovative methodologies, Hang has significantly contributed to the advancement of data-driven environmental studies.

In the paper titled "Imparting High-Level Environmental Behavior Through Tailored Interventions," Hang's expertise is showcased through the design and implementation of a comprehensive survey application. This tool is not only a testament to his technical prowess but also to his deep understanding of environmental behavior patterns.

Hang's proficiency in data mining and statistical analysis is further exemplified by his ability to extract meaningful insights from complex datasets. His work in this area is not just about handling large volumes of data but also about translating these data into actionable knowledge that can drive environmental change.

Throughout his career, Hang has consistently demonstrated a commitment to leveraging technology for environmental research. His innovative approaches to data handling and interpretation have made significant contributions to the understanding of environmental behaviors and interventions.

As a forward-thinking researcher, Hang continues to explore the intersection of technology, data science, and environmental studies, aiming to contribute further to this dynamic and increasingly crucial field.

Dr. Lauren E. Beckingham, Auburn University
Karen McNeal, Auburn University

Dr. McNeal conducts research in geoscience education investigating how people think and learn about the Earth. She conducts quantitative and qualitative methods to assess people's understanding, perceptions, and behavior about complex environmental systems. She has published 65 peer-reviewed articles and secured more than $25M in external funding.

Dr. Kelly Lazar, Clemson University

Kelly Lazar is an Assistant Professor of Engineering and Science Education at Clemson University with a joint appointment in Environmental Engineering and Earth Sciences. Her research largely focuses on recruitment and retention of STEM students through the use of experiential learning opportunities such as virtual reality, field experiences, and undergraduate research opportunities. Her education includes a B.S. in Geology from North Carolina State University, a M.S. in Geological Sciences from East Carolina University, and a Ph.D. in Geological Sciences from The Ohio State University.

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ABSTRACT

This work-in-progress paper presents data from ongoing research that studies engineering students' environmental awareness and pro-environmental behavior at different levels in a prominent HBCU. Through extensive surveys developed as part of this project, students' environmental knowledge and higher-level environmental behavior, manifested by their willingness and preparedness to pursue careers in the industries developing sustainable resources, have been explored. With a focus on imparting these qualities, a pedagogical system with a comprehensive pool of interventions has been designed and implemented in a senior-level mechanical engineering course in the HBCU. The paper summarizes the survey development process and explores the impact of the intervention on students' ecological knowledge, behavior, attitudes, and job decisions, which will help develop strategies for preparing the next-generation, diverse renewable energy workforce.

I. INTRODUCTION AND BACKGROUND

The holistic need for reducing greenhouse emissions is more critical than ever as fossil fuel use continues to rise despite the growth of renewable energy options worldwide [1]. It is a well-accepted scientific fact that global temperature rise and CO2 emission levels are closely correlated, which will significantly impact climate change. Over the past century, the Earth's average surface temperature has steadily increased, primarily due to a rise in greenhouse gases, which is an outcome of human activities such as the increased use of fossil fuels, deforestation, and industrial processes. As an alternative to fossil fuels and to solve the problems of climate change, crucial international agreements on increased renewable energy use and practices that support climate actions are essential for a sustainable future.

To reduce fossil fuel consumption and promote increased use of renewable energy, institutions & socio-economic systems require technological innovations and more substantial and long-term political commitments [2]. One solution to achieve this goal is to develop and implement educational plans that increase awareness of the environment and its protection. We can consider the Environmental Education Act of 1972 a first step toward this goal. This act helped us understand the factors influencing climate change and human activities amplifying it. The IUCN (International Union for Conservation of Nature) defines environmental education as skills and knowledge needed to understand and appreciate the interconnection between humans, culture, and the environment. As environmental education involves recognizing ecological values and understanding the relationship between species and the environment, creating policies and codes of conduct is essential.

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 [3]. This renewable energy sector growth should drive engineering education institutions to devise transformative pedagogical techniques to train and meet the additional workforce requirement of 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 perception is that the increased environmental awareness among undergraduate engineering students might influence their ultimate consumption behavior, drive empathy toward the environment, and inspire them to join green businesses.

A recent study by the New York Times projects that climate change will soon drive agricultural and energy shortages in the Southeast region, where the focus group of the ongoing research belongs [4]. 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 [5]. 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 [6]. However, the connection or gap between environmental awareness and pro-environmental behavior is poorly understood. Researchers also pointed out that a change in ecological knowledge or attitude does not necessarily change their pro-environmental behaviors [7]. These studies point out that there is still a need for focused training for renewable energy education among college students and to understand their knowledge level and attitude toward a sustainable planet in the future. In this context, and based on studies that explored the role of universities as a catalyst for green transformations, the present study aims to understand the environmental awareness and preparedness of engineering students enrolled at an HBCU to pursue careers in sustainable industries.

Although this project studies students' environmental awareness and pro-environmental behavior at different levels at Auburn University, a predominantly white institution (PWI) with an R1 ranking, and from Tuskegee University, a prominent HBCU (Historically Black Universities and Colleges), this work-in-progress paper presents two years of data (2021-2023) from only from the Tuskegee University. A survey was developed as part of this project to gather information on students' environmental knowledge and higher-level environmental behavior from these universities. Surveys also collected students' willingness and preparedness to pursue careers in the industries developing sustainable resources. A pedagogical system with a comprehensive pool of interventions has been designed and implemented to impart and enhance high-level behavior and sustainability competencies. A detailed description of the survey development is available in Song et al. (2024) [8]. The tailored intervention strategies and the data on their impact on building environmental behavior help develop educational strategies for preparing the next-generation diverse renewable energy workforce.

II. OBJECTIVES

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 developed for this study 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 how educational interventions change students' environmental knowledge, attitudes, willingness to engage with, and perceived preparedness for a career in GEI.

The survey developed in this study helps measure students' environmental knowledge & attitude, and behavior toward sustainability, willingness & preparedness to join GEI, and the impact of the educational interventions on these factors. The survey and interventional results may provide transformable guidelines to create pro-environmental behavior in engineering students. An amended curriculum and tailored educational program could cultivate requisite skillsets suitable for GEI in the future. 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, and strategic action [9], critical thinking & analysis, communication & use of media, assessment & evaluation, tolerance for ambiguity & uncertainty [10]; and interpersonal relations & collaboration [11]. A summary of survey development and its validation are discussed in the next section.

III. METHODS

*A. **Survey development***

A comprehensive and systematic approach has been used to develop the surveys that accurately reflect the research goals of this project. Although a detailed description and approaches used for survey development and its validity assessment are available in Hang [8], we present a summary of the survey development process in this paper for continuity. The primary goal of the surveys is to understand student knowledge levels, attitudes, and factors that affect their career decision in the context of environmental and sustainable engineering. As a first step in the process, a thorough literature survey was conducted to capture the predetermined design scales identified from previous research that evaluate the knowledge levels in renewable energy, understand the attitude and behavior towards energy saving and environmental protection, and factors that affect future job decisions and career skills. An initial inventory of survey questions was prepared and reviewed by the research team, who ensured that they fit the constructs of interest. The pool of survey questions is further refined by adding or eliminating questions based on students' feedback, the details of which are available in Table 1. Finally, a method suggested by Walker and McNeal [12] is used to assess the relevancy of the survey questions selected.

The survey questions developed were validated using several methods. The first is a face validity check with students to confirm understandability and relevance to the project. Experts verified the content validity and its relevance to sustainability and renewable energy. Secondly, an exploratory factor analysis was performed to better understand the factor structure of latent variables related to the project's goals of understanding student knowledge, attitudes, and behavior related to sustainability. Validity check questions provide information on whether students paid attention to the survey questions and responded accurately. In addition to these checks and validation, Cronbach's alpha was calculated to determine the reliability and internal consistency of the survey questions. More details of this survey validation are reported in [8].

The survey is divided into five parts (S1-S5; Table 1), and five separate factor analyses were performed to understand the underlying structures, patterns, or relationships among the variables used [13-15]. This analysis aims to reduce the number of variables into a few factors that explain the maximum variance among the original variables. These factors are then used to interpret the underlying constructs or patterns studied. The omission of certain questions that do not fit well in the factor analysis has improved the interpretability of the results. An eigenvalue threshold (>1) and the shape of the resulting scree plot determined the number of factors to retain in the analysis. A one-factor solution for the first factor is found to be substantially more significant than others. The authors conducted a Principal Component Analysis (PCA) with Varimax rotation to explore the factor structure of the survey items [16]. The Varimax rotated matrix was finally used to obtain the factor structure. More details of this survey development and its statistical reliability analysis are available in Hang [8].

B. Intervention group

The sophomore and junior mechanical engineering students at Tuskegee University 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 from sophomore and junior-level engineering classes. The intervention plans designed for building environmental behavior were implemented in Spring 2022 and Spring 2023. In the post and pre-surveys of the intervention semester Spring 2022, 25 and 22 students responded from a senior-level mechanical engineering course. Twenty-one students (21) participated in the Spring 2023 intervention semester.

The survey questions developed were used to understand

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 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 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 these questions 1-3. 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 [17].

Table I: Summary of survey segments. *F21 = Fall 2021; S22 = Spring 2022; F22 = Fall 2022; S23 = Spring 2023.*

Survey Section	Construct	Description of Items	# of Items, F21	# of Items, S22, F22, S23
S1:	Knowledge	Multiple questions about the basic knowledge of global warming/renewable energy. *Only one correct answer (0 or 1). % score indicates the success rate.*	17	8
S2:	Attitude	Students grade their attitude about renewable energy application statements (0-6 Likert-type scale). *The higher the score, the more likely they support the statement.*	19	14
S3	Behavior	Asked if the students would 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*	11	11
S4	Job decision	Students are asked to rate the listed elements that would be important when they apply for a job position in	16	9

		their future careers (1-6 scale). *The higher the score, the more important they consider the job's environmental and life balance aspects.*		
S5.1	Perceived preparedness	Students were asked to rate their agreement in the degree of preparedness for a list of abilities in the workplace (0-6 scale). (Perceived Preparedness*) The higher the score, the higher the perceived preparedness for the workplace.*	21	19
S5.2	Abilities	Students were asked to rate their abilities and whether they considered these abilities to be essential in their future work. They have two choices: *The higher the score (0-2), the higher the agreement.*	21	19

A summary of survey segments S1-S5 with classifications and expected outcomes is given in Table 1. 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 [18]. 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 [19, 20] and reviewed by the Institutional Review Board at the institution where this research takes place to ensure quality and compliance with all human subjects' protocols.

Feedback from a panel of graduate students was considered, 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.

IV. SURVEY DATA AND ANALYSIS

A. Initial survey on junior and sophomore classes

Table I summarizes the descriptions of survey segments S1 to S5 used in this study and the significance of their outcomes. Questions included in the survey are available in Appendix 1-7. Table II summarizes Fall 2021 and Fall 2022 baseline data on students' environmental awareness and behavioral attitudes acquired through the surveys S1-S5 listed in Table I. Note that survey validation occurred between the data collection events for Fall 2021 and Fall 2022; thus, the number of items in each portion of the scale is not necessarily the same for each semester. The basic knowledge of global warming and renewable energy is assessed using questions in the S1 Survey, and 55% of students answered those questions correctly in Fall 2021. The percentage of correct responses was high in Fall 2022 at 74%. The Fall 2021 survey was given to sophomore and junior-level students after the pandemic break. The Fall 2022 survey was given to junior and senior-level students. A higher knowledge level in the second group is anticipated.

Table II: Summary of Fall 21 and Fall 22 Data; <u>Sample without interventions</u>

Semester	Knowledge S1	Attitude S2	Behavior S3	Job Decision S4	Perceived Preparedness S5.1	Abilities S5.2
Fall 21	0.55	4.43	4.65	5.62	5.77	1.36
Fall 22	0.74	5.15	4.79	5.11	4.91	1.44

In the S2 survey using 19 multiple choice questions (Appendix 1), students graded their attitude about some renewable energy application statements (0-6 scale). 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 for the first group and 5.15 for the second group. This score indicates that the senior-level students have a better attitude towards the environment.

The survey S3 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 scores of 4.65 and 4.79 indicate that in both groups, a majority are willing to change their behavior toward greener energy and its increased dependence in the future. In survey S4, students rate the listed elements that would be important when they apply for a job position in their future careers (1-6 scale). The higher the score, the more important they consider the job's environmental and life balance aspects. A higher score of 5.62 and 5.11 indicate that students prioritize their life-work-environmental balance. These data from surveys S1 and S4 support the first hypothesis that no correlation exists between students' environmental knowledge and their *willingness and preparedness* to pursue careers in industries developing sustainable energy resources. However, work yet to be completed will test this hypothesis. In survey S5.1, students were asked to rate their agreement with a list of abilities needed in the workplace (0-6 scale). The score indicates their perceived preparedness for the workplace. The average response score is observed to be high in this survey, with a score of 5.77 for the first group and 4.91 for the second group. The students in the lower level class indicated a more increased perceived preparedness than the senior level students who are about to graduate and ready to work for an industry. The survey S5.2 asked students to rate their skills and whether they consider these abilities to be essential in their future work. This response shows an average score of 1.36 (out of 2) for Fall 21 and 1.44 for Fall 22.

The average scores of the data samples shown in Table II from Fall 2021 and Fall 2022 serve as a baseline for the data analysis for the intervention semesters in Spring 2022 and Spring 2023. The same surveys were given at the beginning and end of the semester to understand the impact of tailored interventions intended to change these qualities positively.

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 in Spring 2022, while 21 students participated in Spring 2023.

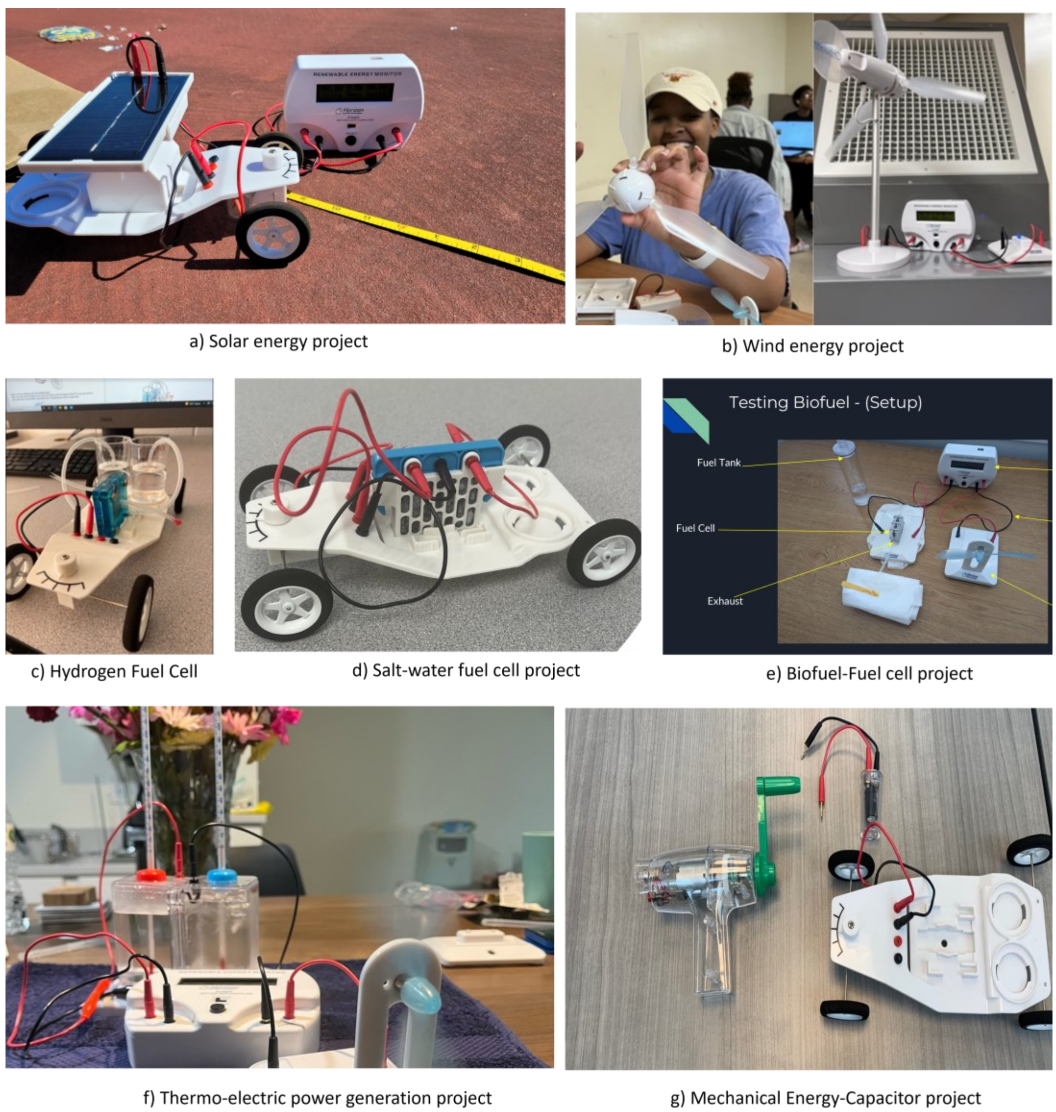

Fig. 1 Photographs of seven student projects used as part of the interventions intended for creating high-level environmental behavior in students

Pre- and post-surveys are conducted at the beginning and end of this intervention semester. This course traditionally uses lectures, tests, and quizzes on renewable energy topics for instruction. Two intervention strategies were added to this course as part of the project. 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 are used for the project experiments, as shown in Fig. 1. Finally, they collected data, analyzed it, and presented their projects.

Five to seven student groups, each having four student members, performed experiments on the following renewable energy sources:

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.

Tables III and IV compare survey response scores of Spring 2022 and Spring 2023 pre- and post-intervention with the baseline data acquired in Fall 2021. Figs. 2 and 3 show a graphical representation of this comparison.

Table III: Summary of Spring 22 Data in Pre and Post-Interventions

	Knowledge S1	Attitude S2	Behavior S3	Job Decision S4	Perceived Preparedness S5.1	Abilities S5.2
Fall 2021 Baseline	0.55	4.43	4.65	5.62	5.77	1.36
Spring 22 Pre	**0.51**	**4.3**	**4.89**	**5.8**	**5.28**	**1.23**
Spring 22 Post	**0.54**	**4.67**	**4.79**	**5.57**	**4.86**	**1.52**
Change Δ (%)	**+5.9%**	**+8.6%**	**-2%**	**-4%**	**-8%**	**+23.6%**

Table IV: Summary of Spring 23 Data in Pre and Post-Interventions

	Knowledge S1	Attitude S2	Behavior S3	Job Decision S4	Perceived Preparedness S5.1	Abilities S5.2
Fall 2021 Baseline	0.55	4.43	4.65	5.62	5.77	1.36
Spring 23 Pre	**0.71**	**5.09**	**4.97**	**5.36**	**4.65**	**1.43**
Spring 23 Post	**0.77**	**5.39**	**5.01**	**5.16**	**5.11**	**1.16**
Change (%)	**+8.5%**	**+5.9%**	**+0.8%**	**-3.7%**	**+9.9%**	**-18.9%**

For pre-and post-intervention (Spring 2022 semester), the correct response rates for the S1 Survey are 51% and 54%, respectively, indicating a slight increase (+5.9%) in the knowledge level of students after the intervention. Survey S2, which has statements that reflect the *attitude towards sustainability*, shows a higher score of 4.67 (+8.6%) in post-intervention compared to its pre-intervention score of 4.3. 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, 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, are 5.28 and 4.86 in pre-and post-intervention. The data point out that students are generally willing to change their behavior toward sustainability, and the current intervention has not impacted it (-2%)

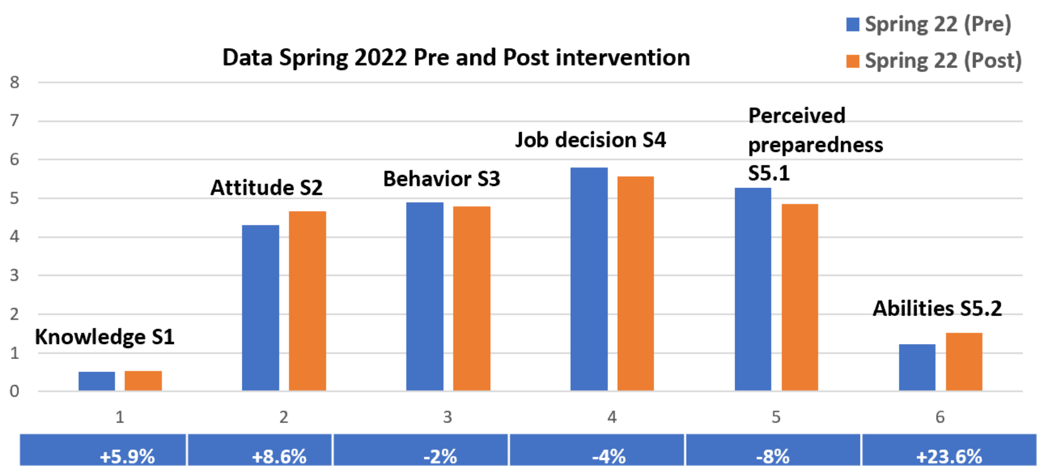

Fig. 2 Comparison of survey data in the pre-and post Intervention period Spring 2022

In Survey S4, students graded the listed elements that would be important when they apply for a job position in their future careers (1-6 scale). The higher the score, the more important they consider the job's environmental and life balance aspects. S4 shows a higher score of 5.28 and 4.86 in pre and post-intervention (-4%), indicating that their future decisions for a job will consider the element of life-work-environmental balances. The survey data 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.

In survey S5.1, students were asked to rate their agreement about how confident they were with performing a list of abilities in the workplace (0-6 scale; Perceived Preparedness). The higher the score, the higher the agreement on the list of abilities in the workplace. In contrast to Spring 2022 S5.1 data (+9.9%), the perceived preparedness indicated 5.28 and 4.86 (-8%) for pre and post-interventions in Spring 2023. Finally, the survey S5.2, which assesses how important the student views each of the listed abilities for a sustainable career (essential skills they think they have for the renewable energy industry), shows a +23.6% change after the intervention in comparison to -18.9% in Spring 2022. This data needs to be probed further to understand the two distinct trends.

Figure 3 shows the pre- and post-survey data from the Spring 2023 intervention. The S1 survey on knowledge level, S2 survey on attitudes, S3 data on behavioral change, and S5 data on perceived preparedness improved after the intervention in Spring 2023. In summary, the survey indicates that the intervention had measurable changes in *students' knowledge of* *sustainability (+8.5%), their attitude and intended behavior toward sustainability (+5.9),* and *their perceived preparedness for a sustainable career(+* 9.9%).

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 and interpretation, including data from the ongoing studies, which will reported in the final paper. A set of paired sample t-tests for each intervention semester is given in Table V for Spring 2022 and Table VI for Spring 2023, respectively. 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. Initial statistical analysis indicates a significant increase in attitudes about sustainability from the pre- to the post-intervention in Spring 2022 (t=(11)=-2.328, p=.040) and Spring 2023 (t=(8)=-2.498, p=.037). Additionally, the perceived importance of abilities for a career in sustainability significantly increased from the pre- to post-interventions in Spring 2023 (t=(8)=-3.157, p=.013). These relationships will be further investigated and aggregated across semesters as we complete our data-collection phase.

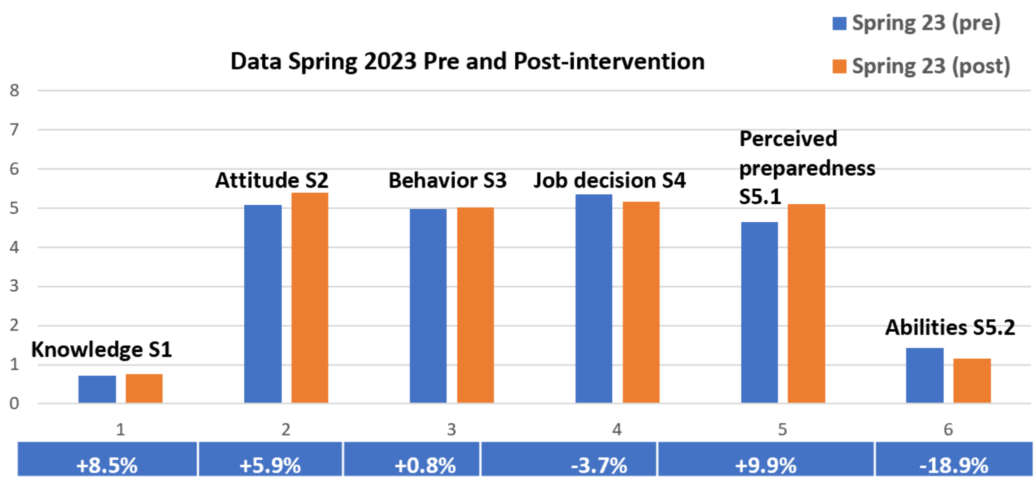

Fig. 3 Comparison of survey data in the pre-and post Intervention period Spring 2023

Table V t-test analysis for statistical significance of intervention

Paired Samples Test Spring 2022									
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	PreS1 - PostS1	-0.02	0.20	0.06	-0.14	0.11	-0.27	11.00	0.79
Pair 2	PreS2 - PostS2	-0.34	0.50	0.14	-0.65	-0.02	-2.33	11.00	0.04
Pair 3	PreS3.1 - PostS3.1	-0.05	0.49	0.14	-0.37	0.26	-0.38	11.00	0.71
Pair 4	PreS3.2 - PpstS3.2	0.17	0.80	0.23	-0.34	0.67	0.72	11.00	0.49
Pair 5	PreS4.1 - PostS4.1	0.03	0.69	0.20	-0.40	0.47	0.18	11.00	0.86

Pair 6	PreS4.2 - PostS4.2	0.33	1.22	0.35	-0.44	1.10	0.95	11.00	0.36
Pair 7	PreS5.1 - PostS5.1	0.24	0.50	0.14	-0.08	0.55	1.64	11.00	0.13
Pair 8	PreS5.2 - PostS5.2	-0.02	0.17	0.05	-0.13	0.09	-0.40	11.00	0.69

Paired Samples Test Spring 2023

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	PreS1 - PostS1	-0.05	0.12	0.04	-0.14	0.04	-1.37	8.00	0.21
Pair 2	PreS2 - PostS2	-0.34	0.41	0.14	-0.66	-0.03	-2.50	8.00	0.04
Pair 3	PreS3 - PostS3	-0.25	0.43	0.14	-0.57	0.08	-1.75	8.00	0.12
Pair 4	PreS4 - PostS4	-0.13	0.82	0.27	-0.76	0.50	-0.47	8.00	0.65
Pair 5	PreS5.1 - PostS5.1	-0.29	0.28	0.09	-0.50	-0.08	-3.16	8.00	0.01
Pair 6	PreS5.2 - PostS5.2	-0.07	0.18	0.06	-0.21	0.06	-1.26	8.00	0.24

VI. CONCLUSIONS:

This work-in-progress paper discusses initial data from Tuskegee University, a prominent HBCU, and studies the links between engineering students' environmental awareness and its connection to their environmental behavior. The goal is to test two initial hypotheses: *1. 'there is no correlation between students' environmental knowledge and pro-environmental behavior' and 2. 'targeted academic interventions may positively change their attitude towards the environment*.' The study developed six survey segments to capture preliminary data to evaluate these hypotheses and 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 designed 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, are presented and compared to each other to understand the effectiveness. Although the initial survey provides valuable information on students' attitudes, behavior towards sustainability, willingness, sacrifice, perceived abilities for a career in renewable energy, and efficacy of interventions, the ongoing comprehensive analysis with additional data will provide a conclusive evaluation of the hypothesis, which will be reported in the final paper.

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Appendix: 1 Multiple Choice Questions- S1
Appendix: 2 Surve on attitude on - S2
Appendix: 3 Surve on the possible change in behaviors S3
Appendix :5 Surve on Factors important in career decision S4
Appendix :6 Surve Perceived Preparedness- S5.1
Appendix :7 Survey Abilities essential in future work- S5.2

Appendix 1 Multiple Choice Questions asked- S1

Understanding fundamentals of environmental protection and renewal energy knowledge

1.	Which is the sustainable (renewable) energy source: Solar energy (1) Natural Gas (2) Petroleum (3) Carbon (4) I do not know (5)
2.	Which is **not** the sustainable (renewable) energy source: Oil (1) Wind (2) Biomass (3) Hydropower (4) I do not know (5)
3.	Which source generates the most electricity in the U.S. By burning oil, coal, and wood (1)
	With nuclear power (2) Through solar energy (3) hydro-electric power plants (4) I do not know (5)
4.	Wind flows from (low/high) pressure area to (low/high) pressure area. high, high (1)high, low (2) low, high (3) low, low (4) I do not know (5)
5.	Of the following, which would be considered the **most** environmentally sustainable? Recycling all recyclable packaging (1)Reducing consumption of all products (2) Buying products labeled "eco" or "green" (3) Buying the newest products available (4) I do not know (5)
6.	Which of the following is the **most** commonly used definition of sustainable development? Creating a government welfare system that ensures universal access to education, health care, and social services (1) Setting aside resources for preservation, never to be used (2) Meeting the needs of the present without compromising the ability of future generations to meet their own needs (3)Building a neighborhood that is both socio-demographically and economically diverse (4) I do not know (5)
7.	Which is the **most** common cause of pollution of streams, rivers, and oceans? Dumping of garbage by cities (1) Surface water running off yards, city streets, paved lots, and farm fields (2) Trash washed into the ocean from beaches (3) Waste dumped by factories (4) I do not know (5)
8.	Humans can be exposed to environmental contamination through which of the following pathways: Bioaccumulation in food chains (1) Atmospheric aerosols (2) Aqueous transport (3) All of the above (4) I do not know (5)
9.	Which of the following is the largest contributor to world pollution? Commercial resources (1) Non-Commercial Resources (2) Renewable Resources (3) Nuclear Energy (4) I do not know (5)
10.	What percent of global electricity generation is considered renewable? 45% (2) 30% (3) 25% (4) 20% (5) I do not know (1)
11.	What is solar radiation? Energy radiated from the sun (1) Energy radiated from Earth (2) Radiation traveling in space (3) All the 3 definitions are correct (4) I do not know (5)
12.	Compared to people in many developing countries, North Americans use about 5 times as much energy (1) 15 times as much energy (2) 30 times as much energy (3) 50 times as much energy (4) I do not know (5)
13.	Which of the following **primarily** affects the amount of solar radiation a location on Earth receives? The shape of the landscape (1) The time of day (2) The location's altitude and latitude (3) The speed of Earth's rotation (4) I do not know (5)
14.	Which is the **most** widely used energy resource in the US? Oil (1) Natural Gas (2)Coal (3) Solar (4) I do not know (5)
15.	Which of the following statements about solar energy is **most** accurate? It is a renewable and conventional source of energy (1) It is a non-renewable and non-conventional source of energy (2) It is a renewable and non-conventional source of energy (3) It is a non-renewable source of energy (4) I do not know (5)
16.	Which of the following is the most likely effect of global climate change? Loss of habitats (1) Less severe weather (2) Loss of ozone layer (3) Decrease in sea level (4) I do not know (5)
17.	Which of the following is the main cause of global climate change? More carbon emissions (1) Sunlight radiating more strongly through the ozone hole (2) Increased volcanic activity (3) increase in oxygen in the atmosphere (4) I do not know (5)

Appendix 2 Survey on Attitudes - S2 Your beliefs about renewable energy statements.					
Strongly disagree (1)	Disagree (2)	Slightly disagree (3)	Slightly agree (4)	Agree (5)	Strongly agree (6)
We should use renewable energy even though it will increase power fees.					
I have an extensive understanding of renewable energy.					
Environmental protection is much more important than economic development.					
I agree with garbage sorting, even though it makes it more inconvenient for me.					
We should use energy sources that can replace fossil fuels.					
The use of recyclable or biodegradable materials and renewable energy sources can solve environmental challenges.					
The condition of the environment will play an increasingly important role in the nation's economic future.					
Private companies should train their employees to consider/solve environmental problems and integrate sustainability into their day-to-day tasks.					
Government agencies should support environmental education programs for adults.					
The United States should promote the development of renewable energy.					
When humans interfere with Nature, they often have disastrous consequences.					
If all human activities do not change, we will soon experience a major environmental disaster.					
It is important to limit our use of energy.					
Green energy alternatives should be supported by the public.					
Wind and solar will become key players in meeting energy demands.					
Laws and regulations for environmental protection have gone too far.					
I will still trust in nuclear power after all the nuclear leaks happen.					
Even though hydropower stations may affect the survival of terrestrial plants and impact their living environment, I still think the government should build more hydropower stations (27)					
I understand and trust photovoltaic power generation.					

Appendix 3 Survey on possible change in behaviors S3 Habits and willingness in regard to the renewal energy usage.					
Strongly unwilling (1)	Unwilling (2)	Slightly unwilling (3)	Slightly willing (4)	Willing (5)	Strongly willing (6)
Turn off lights and appliances when not in use.					
Driving less and using other forms of transportation					
Buy green energy from the utility provider.					
Using energy-efficient bulbs					

Consume less food/clothes or things I do not really need
Buy a fuel-efficient car.
Turn off electronic devices that are not being used.
Actively search for products that are more energy efficient.
Encourage friends or family to be more energy efficient.
Participate in carpooling
Install solar panels on my home.
Turn off lights and appliances when not in use.
Driving less and using other forms of transportation
Buy green energy from the utility provider.
Using energy-efficient bulbs
Consume less food/clothes or things I do not really need
Buy a fuel-efficient car.
Turn off electronic devices that are not being used.
Actively search for products that are more energy efficient.
Encourage friends or family to be more energy efficient.
Participate in carpooling
Install solar panels on my home.

Appendix 4 Survey on willingness to change habits in real S3

Please take a moment to think about your typical energy usage habits, how often in **one week** period do you do each of the following?

Never (1)	Infrequently (2)	Sometimes (3)	Often (4)	Frequently (5)	Always (6)
Turn off electric appliances when not in use.					
Actively search for products that are more energy efficient.					
Turn off all lights and appliances before leaving a room.					
Encourage friends or family to be more energy efficient.					
Participate in carpooling					
Choose to travel without a car (e.g., walk, bike, public transport, etc.)					
Change the setting on my thermostat to be lower in winter and higher in summer.					

Appendix 5 Survey on Factors important in career decision S4

Not important (2)	Slightly important (3)	Somewhat important (4)	Important (5)	Very important (6)	Extremely important (7)
Job location					
Salary					

Type of Industry
The company's reputation and culture
The company's workplace is environmentally friendly.
The company has sustainability initiatives.
The company promotes a work-life balance.
The company has a friendly atmosphere.
This company allows employees to work remotely.

Appendix 6 Survey Perceived Preparedness- S5.1

Strongly disagree (1)	Disagree (2)	Slightly disagree (3)	Slightly agree (4)	Agree (5)	Strongly agree (6)
I am confident in my ability to recognize/identify a system.					
I am confident in my ability to understand a system with multiple parts.					
I am confident in my understanding of cause-effect relationships.					
I am confident in my ability to evaluate knowledge from different disciplines.					
I am confident in my ability to understand methods from other disciplines.					
I am confident in my ability to communicate to people in other disciplines.					
I am confident in my ability to recognize when changes in my approach need to occur.					
I am confident in my ability to predict possible outcomes to a problem.					
I am confident in my ability to deal with risks and changes.					
I am confident in my ability to think deeply about important ideas.					
I am confident in my ability to apply important information to a variety of real-world situations.					
I am confident in my ability to apply complex problem-solving skills.					
I am confident in working with others to solve problems.					
I am confident I have the skills to communicate with others.					
I am confident I can deal with interpersonal conflicts when they arise.					
I am confident I am able to communicate effectively to a range of audiences.					
I am confident I am able to use communication technologies.					
I am confident that I possess the capability to evaluate information in the media.					
I am confident I am able to cope with uncertainties involved in a particular task					
I am confident that I am able to cope with various demands on my time.					
I am confident I can cope with multiple stressors.					

Appendix 7 Survey Abilities essential in future work- S5.2

Whether they considered these abilities could be essential in their future work.

I believe this skill is important in my future career (1)	I don't believe this skill is important in my future career (4)	I do not know (5)
Ability to recognize/identify a systems		
Understanding a system with multiple parts		
Understanding of cause-effect relationships		
Evaluating knowledge from different disciplines		
Understanding methods from other disciplines		
Communicating with people in other disciplines		
Recognizing when changes in my approach need to occur		
Predicting possible outcomes of a problem		
Dealing with risks and changes		
Thinking deeply about important ideas		
Applying important information to a variety of real-world situations		
Applying complex problem-solving skills		
Working with others to solve problems		
Communicating with others		
Dealing with interpersonal conflicts when they arise		
Communicating effectively to a range of audiences		
Using communication technologies		
Evaluating information in the media		
Coping with uncertainties involved in a particular task		
Coping with various demands on my time		
Coping with multiple stressors		