Sustainability Consciousness and Awareness of Sustainable Development Goals among Future Engineers

Salma Shaik and Varun A *

Posted Date: 24 September 2024

doi: 10.20944/preprints202409.1920.v1

Keywords: Engineering education; sustainable development; sustainability consciousness questionnaire; sustainable development goals; mechanical engineering; sustainability knowledge; attitude and behavior

Article

Sustainability Consciousness and Awareness of Sustainable Development Goals among Future Engineers

Salma Shaik [1] and A. Varun [2,*]

[1] Division of Management & Education, University of Pittsburgh, Bradford, PA 16701, USA
[2] Department of Mechanical Engineering, B V Raju Institute of Technology, Narsapur 502 313, Vishnupur, Medak District, Telangana, India
* Correspondence: a.varunphd@gmail.com

Abstract: Since engineering discipline is at the forefront of latest innovations and developments, there is an increasing emphasis on the critical responsibilities of engineers towards sustainability. There are several studies investigating the incorporation of sustainability principles into engineering curriculum but studies analyzing the knowledge, attitude, and behavior of engineering students are lacking. A deeper understanding of the current state of students' knowledge, attitude, and behavior towards sustainability is crucial to determine the type of pro-sustainability trainings, strategies and pedagogical activities needed. Hence, the current study is aimed at assessing the level of sustainability cognizance of Mechanical Engineering students via an online Sustainability Consciousness Questionnaire. The final sample size was 134 students from a Higher Education Institute in India with 90% male responders and 52% from urban areas. Results indicate that 70% of the respondents have heard of the Sustainable Development Goals, only around 32% of the students demonstrate a positive behavior and attitude towards sustainability whereas 30% of the students do not hold any opinion towards sustainability principles. The current exploratory study contributes to the knowledge base about sustainability awareness and consciousness and advocates for measures to insert its principles in engineering courses.

Keywords: engineering education; sustainable development; sustainability consciousness questionnaire; sustainable development goals; mechanical engineering; sustainability knowledge; attitude and behavior

1. Introduction

In 2015, the United Nations members agreed upon a challenging and ambitious but much required roadmap for the next 15 years that will lead us on a path to sustainable future. The core theme lies in devising environmental, societal, and economic frameworks to help us meet our needs without compromising the future generation's ability to meet their own needs [1]. This led to an increased emphasis on ensuring that students, the future stewards of our planet, possess the necessary knowledge of sustainability principles. Given the practical nature of engineering endeavors, sustainability awareness becomes even more critical in engineering education [2,3]. Reports indicate that possessing green skills such as awareness about climate change and sustainable design can increase the chances of getting hired by 29% and more than 300 million additional green jobs are projected to be created by 2050 [4,5]. This can be attributed to the increasing realization among companies that to remain competitive in the global economy, they need employees who are conscious about the environmental and societal impacts of their work while positively influencing the company's bottom line [6,7].

The concept of sustainability is particularly relevant in the field of ME which serves as the backbone of various essential industries such as automotive, construction, energy, production and manufacturing to name a few. Since the field is instrumental in shaping up the latest innovations and developments in diverse industries, it has direct impact on the societal, economic and environmental

 doi:10.20944/preprints202409.1920.v

aspects of SD. By nature of their profession, engineers are considered as unofficial representatives of the public who help 'legislate' technologies that affect human race [8]. In essence, engineers need to be equipped with a comprehensive knowledge of SD so that they are ready to face the "Grand Challenges of 21st Century" (Figure 1) affecting the 5 key pillars of sustainable societies namely people, prosperity, partnership, peace, and planet. Hence, it is essential to assess the level of awareness and knowledge of students regarding SDGs so that proper initiatives and policies geared towards SD can be put in place [8,9].

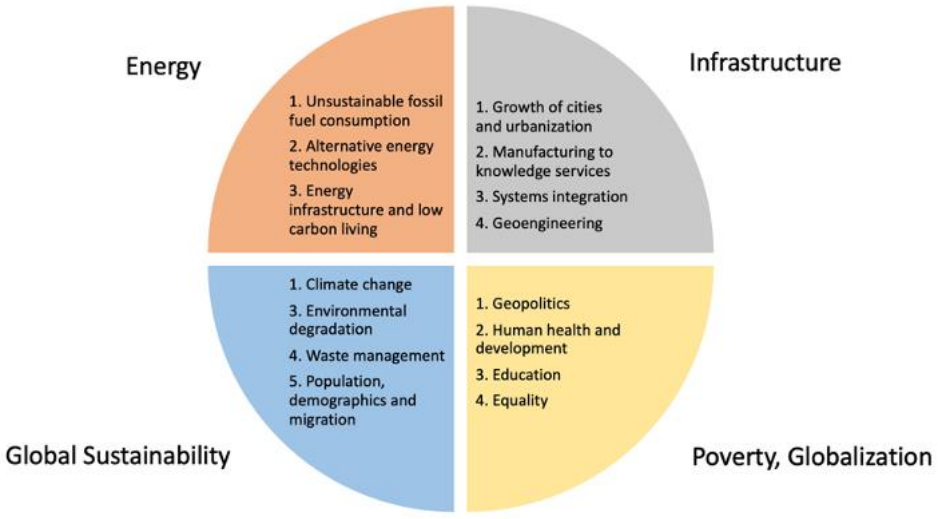

Figure 1. Grand Challenges of 21st Century (Adapted from [10,11]).

Realizing the need to incorporate sustainability into engineering education and to familiarize students with the new sustainability driven engineering responsibilities, landmark declarations such as Engineering Education for Sustainable Development were drafted [12–14]. This declaration, also known as the Barcelona Declaration, emphasizes that engineers must be equally cognizant of the societal and environmental impacts of their work [15]. Further, Accreditation Board for Engineering and Technology (ABET) has outlined the following two critical sustainability learning outcomes for engineering students [16].

a. the ability to design within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
b. the board education necessary to understand the impact of engineering solution in a global, economic, environmental, and social context.

Researchers agree that it is highly likely for social injustices to perpetuate when there is a lack of social and environmental considerations in engineering endeavors [17,18]. Given the dynamic and complex nature of engineering disciplines, it is challenging to teach sustainability to engineering students, but it is a necessary task [19,20]. But without empirically evaluating the current state of their KAB towards sustainability, it will be difficult to come up with strategies aimed at boosting sustainability consciousness among future engineers. Though there are extensive studies focusing on teaching and promoting SDGs at the university level and especially in the engineering curricula [21–24], there is a lack of studies investigating the KABs of mechanical engineers towards sustainability. Hence, the current study tries to fill this knowledge gap which would help all the stakeholders such as HEIs, companies, government organizations etc. to take necessary actions to equip students with sustainability knowledge.

Following this introduction, the article contains four further sections. Section 2 is dedicated to the literature review about sustainability awareness in students, research questions and main goals of the article. Section 3 describes the methodology used, section 4 presents the results and discussions followed by limitations, future research directions and conclusions in sections 5 and 6 respectively.

 doi:10.20944/preprints202409.1920.v

2. Related Literature

Increasing students' level of sustainability knowledge and helping them improve their attitudes and behaviors toward a more sustainable society should be one of the top priorities of educational institutions [25–34]. Narong and Hallinger [35] carried out a comprehensive review of the literature between 1991-2022 to thoroughly examine sustainability as a distinct knowledge domain within engineering education. They identified a pressing need to reform and continuously improve the engineering curriculum to successfully transform it towards sustainability. Blottnitz et al., [36] presented a novel curriculum reform in chemical engineering by introducing a new course in each of the first 3 years of the program. It is an effective approach to introduce core sustainability principles in the 1st year and then slowly build upon it rather than offering a standalone course at upper levels.

Ramanujan et al., [37] followed a guided discovery instruction approach for integrating ES in undergraduate ME courses. It was concluded that this approach can help students to better understand the complex relationships between domain-specific design parameters. Weber et al., [38] carried out a comparative design-based research study with first-year engineering students by offering a module focused on Life Cycle Assessment. They observed that the intervention module was able to successfully support students to obtain a deeper understanding about ES by addressing certain misconceptions. Though this study gives useful insights on the efficacy of intervention module, it doesn't present a comprehensive picture of how the levels of KAB vary between students at different stages of their undergraduate program [38,39]. For any of the sustainability initiatives, especially those that are aimed at students, to be successful there must be a clear understanding of the current state of students' KAB. Based on that, relevant initiatives and educational strategies can be created to tailor to the specific scenarios. Over the years, researchers have carried out studies evaluating the general understanding and knowledge of SD along with analyzing students' personal attitudes and perceptions towards sustainability [40–45]. A worldwide survey was conducted among engineering students in 2007 to gauge their level of knowledge and understanding of SD [46]. Results show that even though students believed in the importance of SD, there were significant gaps in their SD knowledge. Some of the future studies also corroborated these findings [47–50].

Based on a survey of final year engineering students in three Irish HEIs, Nicolaou and Conlon [51] noticed that majority of the students lacked knowledge and understanding of the complex nature of social and economic aspects of sustainability as was observed by other researchers [52–57]. In addition to this, Rampasso et al. [58] noted that students did not consider the economic and societal effects in their sustainability analysis. These results highlight the need to give equal importance on educating students on all the three dimensions of sustainability. Shealy et al. [59] studied the sustainability related career outcome expectations of civil engineering undergraduate students and noted that there was more interest in addressing environmental issues than contributing to societal needs. Nakad and Kovesi [60] studied the differences in awareness and attitudes towards SDGs among engineering students from developed and developing countries. Results show that students from developing countries demonstrated positive attitude towards sustainability but lacked knowledge of SDGs. Such cross-country comparative studies help in understanding and devising country and culture specific policies that are relevant to the local conditions of different countries.

Based on the extensive literature review carried out for this study, we can conclude that there are only a few studies investigating the sustainability KABs of engineering students especially those of ME students. Current paper attempts to fill this gap by focusing on the below research questions.

RQ1: What is the level of awareness of future engineers about SDGs?
RQ2: What is the level of sustainability KAB of future engineers towards sustainability concepts?
RQ3: Are there any differences in the levels of sustainability KAB based on the responder's year of study and place of living?
RQ4: Which actions can be taken from a degree and course perspective to fill the gap in sustainability KAB?

Such a thorough assessment of students' responses will provide us valuable insights to correctly identify the current state of sustainability cognizance in future engineers and to efficiently design necessary and timely actions to teach and promote sustainability. The current study can easily be

 doi:10.20944/preprints202409.1920.v

reproduced or extended with students from other disciplines as the core themes of economic, environmental, and social sustainability and their basic premises are equally relevant and applicable to any field of study.

3. Methodology Procedures

In this section, the methodological procedures employed to carry out this research are presented. A detailed description of the survey instrument, survey procedure and data collection are discussed. This would be useful for other researchers and sustainability practitioners interested in understanding the sustainability KAB of engineering students.

3.1. Research Classification

This study carried out empirical research with descriptive and exploratory analysis focusing on three main research objectives a) a thorough review of existing literature to establish the importance of current research b) a survey with ME students to collect their valuable opinions on sustainability via a KAB assessment questionnaire c) to gain actionable insights out of the data which can inform policy and decision making. The data collection procedure and analysis are discussed in the next subsections. We believe that the results of this research can provide useful information to HEIs and policymakers to tailor sustainability initiatives according to the current levels of KAB of students.

3.2. Survey Questionnaire

The "Sustainability Consciousness Questionnaire - Short version (SCQ-S)" designed by Gericke et al. [61] was used to collect data for this study. This questionnaire was designed to measure individuals' awareness of sustainability by focusing on their KAB towards SD. Researchers have evaluated the reliability of this questionnaire using the Cronbach alpha test and reported separate alphas (for KAB sections) being 0.82, 0.82, and 0.79 [61]. These values were all above 0.7 demonstrating that the items of each construct were from valid questionnaire and indicated sufficient reliability of the instrument [62–64]. The SCQ questionnaire was distributed to the undergraduate students from a public HEI in India. Some questions were rephrased to facilitate easy understanding for the participants (Table S1). Part I of the questionnaire had 7 demographic questions such as the respondent's gender, age, year of study, and place of living. Part II had 28 sustainability related questions with the first question asking the respondents whether they have heard about SDGs or not. Among the remaining questions, 9 were related to ES, 9 for economic sustainability and 9 for social sustainability. Each of the 9 questions in the 3 categories of sustainability were further subdivided into 3 groups to assess the KAB under each sustainability category as shown in Supplementary Table S1. Some of the question statements have been modified to help the responders understand the question better. For each question, students were required to select an option based on 5-point Likert scale ranging from "Strongly Disagree", "Disagree", "Neutral", "Agree" to "Strongly Agree".

3.3. Data Collection

Survey was created using Qualtrics, a web-based software that allows the user to create surveys and to distribute electronically. A survey consent form was shared with all the participants with clear guidelines and requirement that all participants must be 18 or above. Student participation was encouraged among all the survey recipients and the participation was open, free, and anonymous. Data collected via convenience sampling from the survey were managed with full respect of the existing regulations for privacy (in accordance with the protocol approved by the Pitt-IRB, n. STUDY24010085, 31 January 2024) and were used only in aggregated form by the researchers.

3.4. Data Cleaning

A total of 200 students completed the survey depicting a response rate of 11%. Data validation was added to different form fields to ensure that data in the correct format was being captured for each question. This led to a final data set with 0 missing values, but the issue of invalid values

 doi:10.20944/preprints202409.1920.v

remained. Data was normalized accordingly and since all the questions were essential to understand the overall sustainability cognizance of a respondent, any record with at least one missing value was dropped. Extensive data cleaning iterations were carried out to ensure that the final data set was consistent, free of any discrepancies, missing or invalid values and this resulted in a final sample of 134 valid responses.

3.5. Data Analysis

Python programming language was used to clean, analyze, and visualize the collected data. To draw inferences from the obtained data and to test established hypotheses, Statistical Package for Social Science (SPSS) software v.23 for Windows was used. First, descriptive analysis and visualizations were carried out to get a comprehensive overview of the collected data sample. In addition to this, one-way ANOVA was used for testing the established hypotheses after confirming normality by using Levene's test. To identify any significant differences between groups, Tukey's post-hoc test along with Bonferroni and LSD at 0.05 significance level (α = 95% of confidence) were carried out.

4. Results and Discussion

4.1. Descriptive Statistics

The questionnaire was administered to ME students at a HEI in India from January 2024 to April 2024 and students' participation in the study was voluntary. Of the final sample of 134 students, 90% (121) of the students were male and 10% (13) were female. This low percentage of female participation can be attributed to the fact that there is a very low enrollment of women in engineering programs in India. Recent studies have highlighted that only 19.2% of engineering students in India are women and, on an average, only 6% of women are in the core ME program [65,66]. The age of respondents varies between 19 and 23 with the highest response from 21-year-olds (28%) while the 23-year age group had the lowest response at 6%. Response rate from other ages were 20%, 19%, 14%, 12% for 20-year, 18-year, 22-year, 19-year age groups respectively. As shown in Figure 2, most respondents were seniors (44%) followed by freshman (30%), junior (19%) and sophomore (7%). Further, 52% of the respondents live in a city and 40% in a village while only 8% live on-campus since majority of the students in Indian universities are local commuter population.

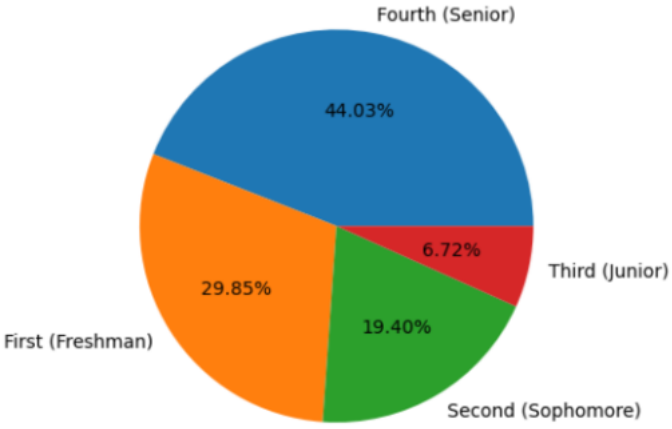

Figure 2. Response% by Year of Study.

The following sub-sections provide the findings and discussions on students' SDG awareness and KAB towards sustainability.

RQ1: What is the level of awareness of future engineers about SDGs?

Question 5 on the survey asked whether the respondent has heard about SDG or not. Based on this question, researchers sought to understand to what extent do future engineers know about the

 doi:10.20944/preprints202409.1920.v

existence of SDGs. This is important to investigate because if the future generation is not aware of this initiative, then any policies or programs designed by concerned organizations towards attaining SDGs would be moot. The current survey results indicate that around 65% of the respondents have heard about SDGs and 70% of the respondents who are 19 or above have heard about the SDGs. From the year of study dimension, most of the seniors (86%) have heard about SDGs whereas the awareness about the SDGs is the lowest (32%) among freshmen students.

The level of SDG awareness is also high among sophomores and juniors at 78% and 62% respectively. It can be observed that as the student progresses through the undergraduate program, the level of SDG awareness is also increasing (freshman – 32%, senior – 86%). This could be due the increased exposure to sustainability themes that a student gets via courses, hands-on projects, internships etc. as he/she progresses through the program. On the other hand, SDG awareness is at the same level among students living in the city and village indicating that in this sample, the place of living has no influence on SDG knowledge. This could also indicate that irrespective of place of living, students have the required resources and media exposure giving them access to information. But as a future study, it would be insightful to further investigate the contributing factors to this increase in SDG awareness and devise strategies to further strengthen and enhance those factors. Though the good awareness of SDGs among the respondents is a good indication, the researchers plan to carry out further studies to evaluate the level of understanding of students about SDGs with respect to their purpose, importance, relevance, challenges, and limitations.

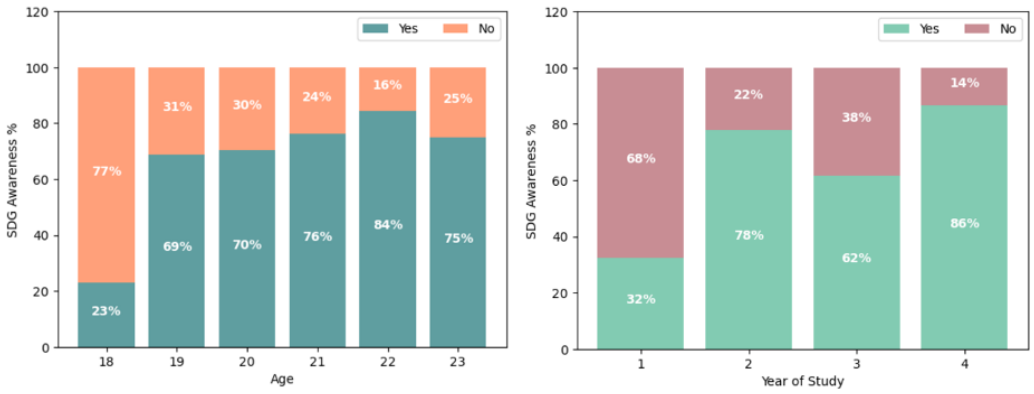

Figure 3. SDG Awareness by Age and Year of Study.

RQ2: What is the level of KAB of future engineers towards sustainability?

The second research question addresses the major goal of the research which is to thoroughly evaluate and quantify the level of knowledge (K), attitude (A), and behavior (B) of the future engineers towards sustainability. Questions 6-32 on the survey address the constructs for KAB consisting of 9 questions each. Among these 9 questions, 3 questions each address the environmental, economic, and social aspects of sustainability. For brevity, questions related to KAB are coded as shown in Supplementary Table S2 and would be referred to using these codes going forward.

From Figure 4 and Table S3, we can observe that with respect to the sustainability knowledge dimension, majority of the respondents agree with all the statements (K1-K9). More than 50% of the students agree that conserving natural resources (52%), Education for Sustainable Development (ESD-54%), respecting human rights (54%), responsible business practices (54%) along with fair distribution of goods and services among people in the world (55%) are essential for SD. But almost 28% of the students expressed neutral opinion on the knowledge statements indicating either a lack of awareness or indifference towards sustainability.

 doi:10.20944/preprints202409.1920.v

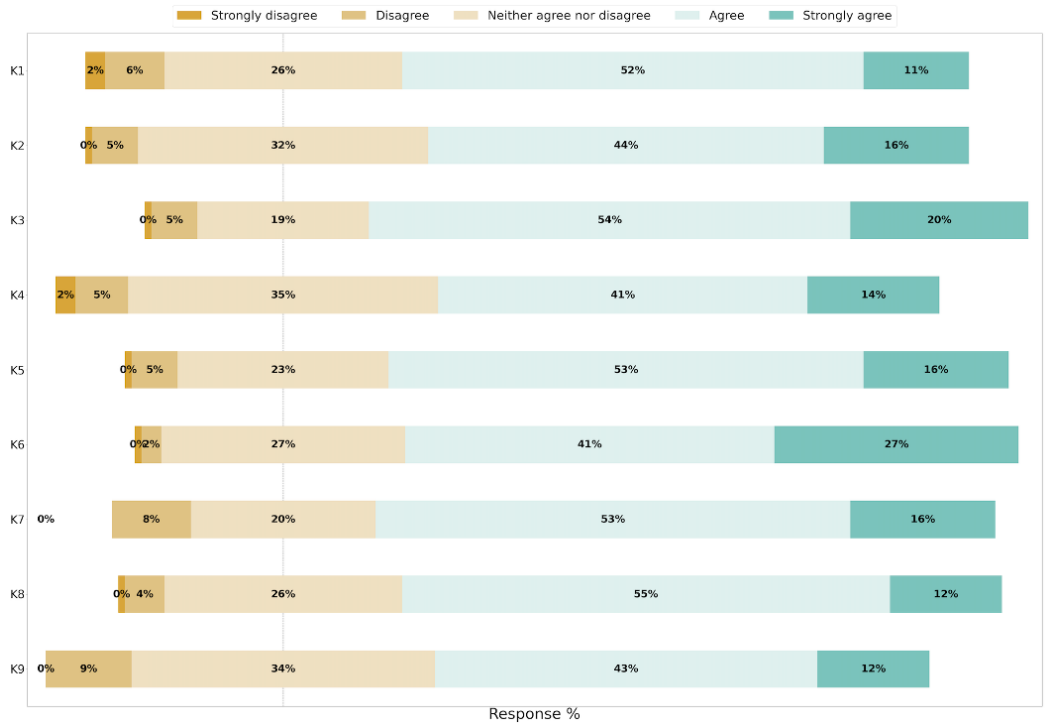

Figure 4. Distribution of Knowledge Statement Responses.

Assessing the responses for attitudes towards sustainability, we notice that around 32% of students demonstrate a positive attitude with respect to sustainability actions (Figure 5 and Table S4). Majority agree that stricter measures, laws and regulations are needed to protect the environment (52%) and placed equal importance on reducing poverty (50%) and ensuring that future generations enjoy the same quality of life as we do today (50%). 28% of students took a neutral stance on avoiding over-exploitation of natural resources, providing equitable and fair working conditions for employees irrespective of their working location, corporate responsibility towards mitigating environmental damages. Further, around 30% of students expressed neutral opinions on gender equality in education and employment. The dearth of women in engineering programs could be a contributing factor to this as less than 20% of women in India are enrolled in engineering programs and much less (5%) specifically in ME programs. Thorough knowledge of these issues is critical for the SD of societies and to attain the UN SDGs and hence educational institutions and specifically engineering programs should look for ways to incorporate Diversity, Equity, and Inclusion aspects into the curriculum.

 doi:10.20944/preprints202409.1920.v

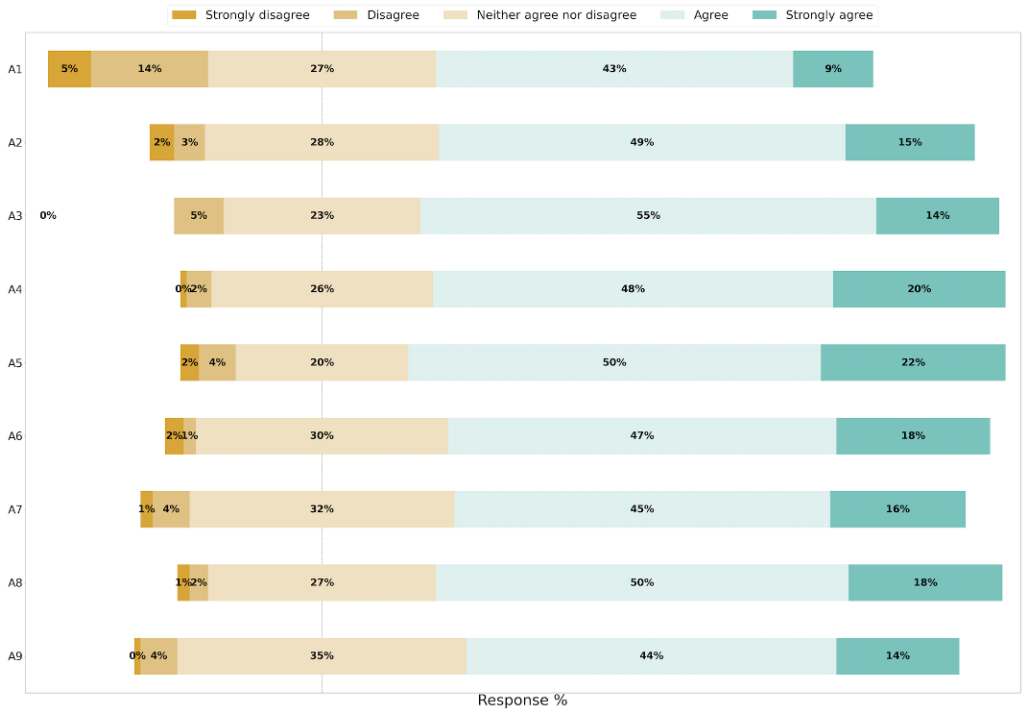

Figure 5. Distribution of Attitude Statement Responses.

Analyzing the results of behavior dimension towards sustainability from figure 6 and Table S5, we observe that 33% of students engage in sustainability-oriented behavior. 35% of the students recycle as much as they can and follow good recycling practices such as separating food waste from other types of wastes. Almost 35% of the students agreed that they changed their lifestyle to reduce waste. On the economic and social aspects, 49% of the students treat everyone with respect irrespective of their age, race, gender etc. during both physical and digital interactions on social media platforms. Though 50% of students agreed that they try to do things which directly or indirectly help the people, many respondents took a neutral stand on supporting aid organizations (31%), purchasing second-hand goods (34%), buying goods from companies with a bad reputation for looking after their employees and the environment (38%). These observations need to be studied upon further because being cognizant of the business practices and corporate social responsibility initiatives is essential to make informed decisions regarding future purchases, investments, choosing an employer and positively supporting organizations that are working towards a sustainable future.

 doi:10.20944/preprints202409.1920.v

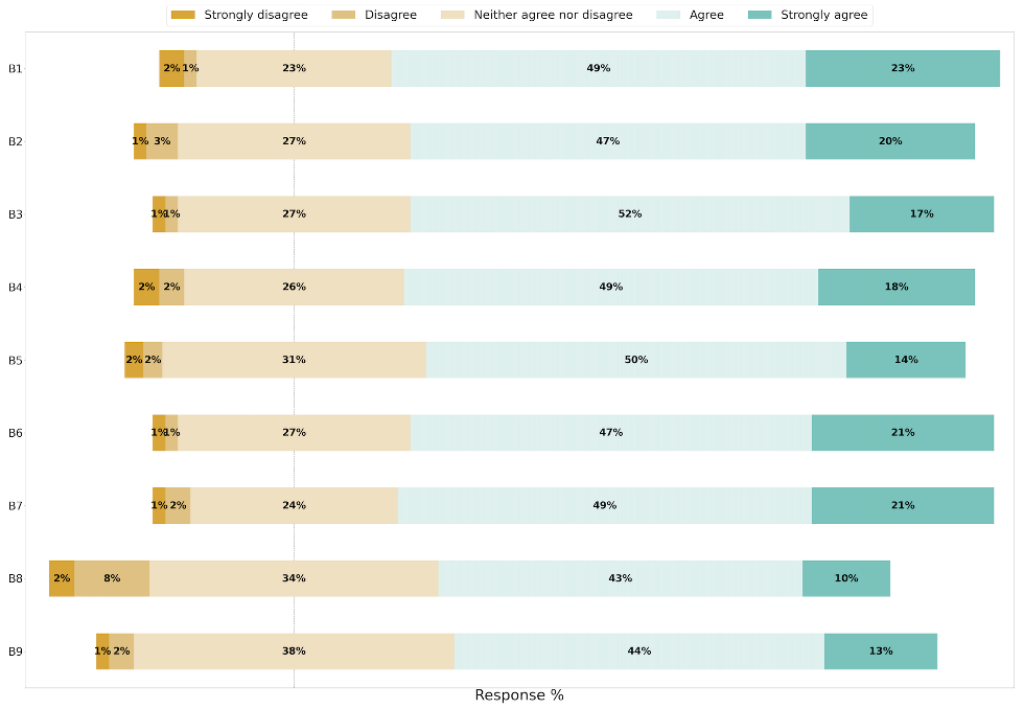

Figure 6. Distribution of Behavior Statement Responses.

Since each of these 27 questions could be answered on a standard 5-point agree Likert scale, responses were converted to numerical form and a mean was calculated for each respondent as explained in Table S6. Figure 7 shows the distribution of mean of Likert response scores for each of the sustainability KAB question. It can be observed that for each of the 9 questions regarding sustainability knowledge, the mean score was between 3.5 and 4.2. This indicates that the average response for questions K1-K9 was in the "Agree" category. Questions regarding education for sustainable living, respecting human rights, global access to good education and responsible and accountable business practices received the highest consent from the students. Analyzing the responses for attitude questions, we observe that almost all the questions except the first one received an "Agree" rating. It is noticeable that students demonstrated neutral attitude towards first question which asks whether over-exploiting natural resources threatens the health and well-being future generations. Finally, the distribution of mean scores of Likert responses for behavior questions also follows a similar trend to that of knowledge and attitude questions. Student responses to all of the behavior questions falls in the range of 3.5 to 3.9 "Agree" category.

 doi:10.20944/preprints202409.1920.v

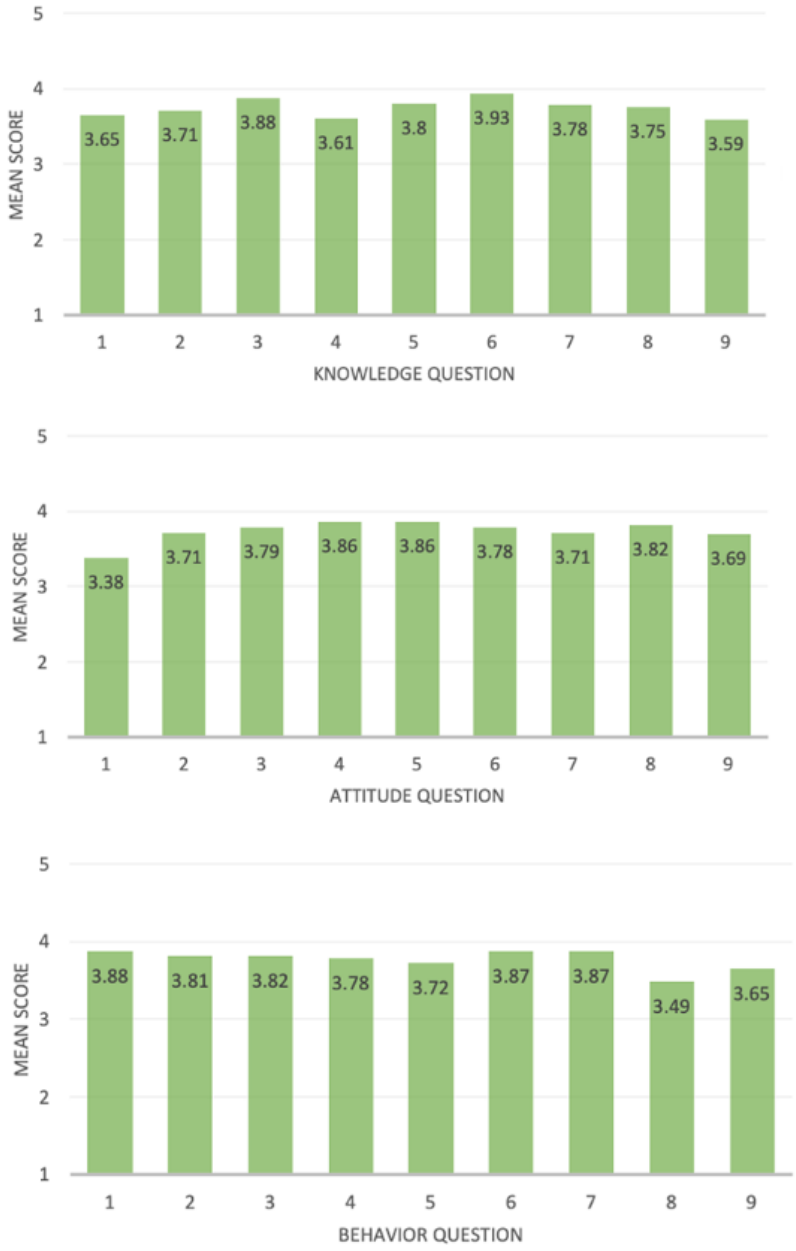

Figure 7. Mean Scores of Sustainability KAB Questions.

RQ3: Are there any differences in the levels of sustainability KAB based on the responder's year of study and place of living?

To determine whether there is any influence of a student's year of study or place of living on the sustainability KAB, the mean score for each of the questions by different groups (Freshman/ Sophomore/ Junior/ Senior and City/ On-Campus/ Village) are calculated. Tables S7 and S8 shows that the mean scores for each of the KAB questions remain pretty much consistent above 3.5 ("Agree" category) irrespective of the students' year of study or place of living. There are considerable responses in the "Neutral" category but there doesn't seem to be any direct relationship between year of study or place of living on the students' level of sustainability KAB. To further determine this statistically, parametric tests are carried out as explained in the next sections.

 doi:10.20944/preprints202409.1920.v

4.2. Inferential Analysis

As explained in the previous section, since each of these 27 questions could be answered on a standard 5-point agree Likert scale responses were converted to numerical form and a mean was calculated for each respondent by utilizing the numerical Likert score for responses to each of the KAB questions (Supplementary Table S1). This helped to carry out further descriptive and inferential analysis to identify any significant differences between variables such as year of study, place of living, or the score reached by each dimension of sustainability KAB. To achieve this, a systematic approach with ANOVA comparison between groups (Freshman/ Sophomore/ Junior/ Senior and City/ On-Campus/ Village) was carried out after parametric confirmation using Levene's Test. A significance level of 0.05 is considered for all the tests. If the ANOVA test doesn't yield any significant results, none of the post-hoc tests are carried out since a post hoc test is used only in case of a statistically significant result which would help us to identify the true source of differences.

4.2.1. Year of Study and Sustainability KAB

The first inferential test that was carried out was to investigate if there are any statistically significant differences in the levels of KAB among ME students from different years of study. Hence, the null hypothesis for this test is H1: There is no difference in the levels of sustainability KAB between students from different years of study. Tables 1 and 2 show the corresponding results.

Table 1. Levene's Test for Year of Study vs Sustainability KAB.

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
kab_mean	Based on Mean	1.166	3	130	.325
	Based on Median	.992	3	130	.399
	Based on Median and with adjusted df	.992	3	104.275	.400
	Based on trimmed mean	1.143	3	130	.334

Table 2. One-Way ANOVA for Year of Study vs Sustainability KAB.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.523	3	.174	.765	.516
Within Groups	29.609	130	.228		
Total	30.132	133			

As Table 1 shows that the Levene's test statistic is not significant, parametric analysis using One-Way ANOVA is carried out. Since the p-value is > 0.05, we conclude that the null hypotheses which states "There is no difference in the levels of sustainability KAB between students from different years of study" cannot be rejected. Hence no post hoc tests for inter-group comparisons are carried out as no significant differences are revealed between the groups (years of study) by ANOVA. Hence, no differences due to year of study in sustainability KAB could be established.

4.2.2. Place of Living and Sustainability KAB

The second inferential test focused on investigating whether the place of living has any effect on the level of sustainability KAB of ME students. Hence, the null hypothesis for this test is H1: There is no difference in the levels of sustainability KAB between students from different places of living. Tables 3 and 4 show the results of this test.

 doi:10.20944/preprints202409.1920.v

Table 3. Levene's Test for Place of Living vs Sustainability KAB.

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
kab_mean	Based on Mean	.639	2	131	.529
	Based on Median	.695	2	131	.501
	Based on Median and with adjusted df	.695	2	129.148	.501
	Based on trimmed mean	.599	2	131	.551

Table 4. One-Way ANOVA for Place of Living vs Sustainability KAB.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.073	2	.036	.159	.853
Within Groups	30.059	131	.229		
Total	30.132	133			

Like the previous test, Table 8 shows that Levene's test statistic doesn't reach any significance level and hence the parametric One-Way ANOVA is carried out to determine if there are any differences in students' sustainability KAB based on their place of living. Since the ANOVA p-value is 0.853 (> 0.05), we fail to reject the null hypothesis. Since no significant differences are revealed between the groups (place of living) by ANOVA, no post hoc tests for inter-group comparisons are carried out as. Hence, no differences due to place of living in sustainability KAB could be established.

RQ4: Which actions can be taken from a degree and course perspectives to fill the gap in sustainability KAB?

Even though this was an anonymous survey, it is possible that students from every year of study must have chosen "Agree" as the most convenient answer for many questions. The true awareness of sustainability cognizance among students cannot be established until a thorough investigation is carried out to assess their understanding of sustainability concepts, real-life challenges and expectations. Nevertheless, this is a good starting point to get a general sense of whether students are familiar with the concept of sustainability, existence of SDGs and to get a general feel of what students think and believe about sustainability.

One noticeable thing in the results presented and discussed so far is that none of the sustainability KAB questions received an overwhelming "Strongly Agree" response. Also, many of the important questions received a considerable proportion (an average of 30%) of responses taking a neutral stance. This is not desirable as the world needs future engineers to be strong proponents of sustainability and be leading advocates of integrating sustainability as the core driving principle in personal and professional lives. Based on these observations, it can be deduced that there is still a long way to go before we can safely say that we are on track to building a sustainable future. All the stakeholders including academic institutions, government, public and private organizations should devise strategies with mutual collaboration that will help with the dissemination of sustainability knowledge and awareness [67,68]. Along with curriculum changes, institutions should explore various media sources such as email, social networks, or traditional media to deliver information on sustainability and SDGs to students.

Results indicate the students from upper levels of the engineering program are more familiar with the existence of SDGs. But the observation that there is no statistically significant difference in sustainability KAB between students from different years of study especially between freshman and senior is interesting. This lack of progress calls for action-oriented initiatives to gradually integrate sustainability concepts into engineering curricula. Based on the results of the inferential testing, we observe that there is no significant difference in the levels of students' sustainability KAB based on year of study or place of living. But with respect to SDG awareness, seniors and juniors had higher ratings than freshman or sophomore. This SDG awareness among the upper-level students could be leveraged to introduce introductory courses in sustainability analysis and design as a pilot program.

 doi:10.20944/preprints202409.1920.v

Based on the reception and success of this course, it can be further enhanced and extended to students from different years and majors.

A significant emphasis needs to be placed on the involvement of professors in promoting sustainability and providing necessary support at the curriculum and institutional level. Researchers have identified the absence of sustainability component in university rankings as another major obstacle in the way of actively promoting sustainability at the university level [69]. Most of the time, the university staff and faculty are focused on research and competency and little time is dedicated to activities promoting sustainability (Zamora-Polo, 2019). But efforts are being made via initiatives such as "University Impact Ranking" promoted by Times Higher Education [68]. This initiative analyzes the degree of commitment of HEIs towards SDGs. Such initiatives are welcome steps in the right direction since they help to put sustainability on the agenda of HEIs and incentivize those who do their part in preparing our future generation for a sustainable future.

5. Limitations

Though we took measures to explain the importance and anonymity of the study to students, it is possible that students may have chosen any convenient answer although they did not feel that way, to finish and submit the survey sheet. Still, we believe this study is essential in establishing a baseline of future mechanical engineers' knowledge about SDGs and to evaluate their level of sustainability KAB. Since this sample is collected from a regional institution in a south Asian country, it may not be representative of the global population. Thus, reproduction of the study with different student groups from diverse backgrounds is needed to get a comprehensive view regarding our future generations' awareness about SDGs and sustainability. Although we may not be able to draw universal conclusions due to this limitation, we believe that it allows us to understand at a basic level and serves as a steppingstone for future studies.

6. Conclusions and Future Work

The main objective of the current study is to gauge the level of KAB of undergraduate ME students about sustainability and to assess their level of awareness about SDGs. The results show a positive level of KAB from students towards sustainability and to our best knowledge, this is the first study focused specifically on ME students. However, this study could easily be extended to evaluate sustainability KAB of students from any discipline across the world. As future research, authors plan to replicate the current methodological procedure in undergraduate engineering programs from other HEIs and carry out comparative studies. This would be useful to broaden the debate about students' perception regarding sustainability issues. Results from such studies can be used to analyze the existing curricula in engineering programs and prioritize sustainability initiatives needed to prepare future engineers to tackle the grand challenges of 21st century. There is still much that needs to be done to promote SDGs at the university level which is the primary learning center for our future generations. A collective effort from all stakeholders through a strong collaboration between academic, government and corporate institutions is required to achieve the SDGs and to ensure that we are on track to a sustainable future.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Table S1: SCQ Questionnaire; Table S2: Coding for KAB Statements; Table S3: Percentage of Students' Knowledge on SDGs; Table S4: Percentage of Students' Attitude on SDGs; Table S5: Percentage of Students' Behavior on SDGs; Table S6: Agree Likert Scale Numerical Ranges; Table S7: Mean of KAB Scores by Year of Study; Table S8: Mean of KAB Scores by Place of Living

Author Contributions: Conceptualization, S.S. and A.V.; methodology, S.S.; validation, S.S. and A.V.; formal analysis, S.S.; investigation, S.S.; data curation, A.V.; writing—original draft preparation, S.S.; writing—review and editing, S.S. and A.V.; visualization, S.S.; project administration, A.V.; All authors have read and agreed to the published version of the manuscript.

 doi:10.20944/preprints202409.1920.v

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of The University of Pittsburgh (IRB: STUDY24010085; 1/31/2024). for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Keeble, B. R., 1988. The Brundtland report: 'Our common future'. Medicine and war, 4(1), 17-25.
2. Rio, M., Reyes, T., Baouch, Y., de Carvajal, R. C., Robin, V., Perpignan, C., ... & Saada, P., 2022, June. Integrating Sustainability in Industry of the Future Technological Learning Programs-A Platform to Co-create and Mutualise Course Experiences. In 28th International Sustainable Development Research Society Conference-ISDRS.
3. Burleson, G., Lajoie, J., Mabey, C., Sours, P., Ventrella, J., Peiffer, E., ... & Aranda, I., 2023. Advancing sustainable development: emerging factors and futures for the engineering field. Sustainability, 15(10), 7869.
4. Annan-Diab, F., & Molinari, C., 2017. Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. Int. J. Educ. Manag., 15(2), 73-83.
5. Burleson, G., Machado, M., & Aranda, I., 2021, November. 'Engineering for Global Development 'in Academic Institutions: An Initial Review of Learning Opportunities Across Four Global Regions. In 2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC) (pp. 153-158). IEEE
6. Kumar, V., Haapala, K. R., Rivera, J. L., Hutchins, M. J., Endres, W. J., Gershenson, J. K., ... & Sutherland, J. W., 2005. Infusing sustainability principles into manufacturing/mechanical engineering curricula. J. Manuf. Syst., 24(3), 215-225.
7. Woodhouse, E. J., 2003. Overconsumption and engineering education: Confronting endless variety and unlimited quantity. Int. J. Eng. Educ., 19(1), 124-131.
8. Sonetti, G., Brown, M., & Naboni, E., 2019. About the triggering of UN sustainable development goals and regenerative sustainability in higher education. Sustainability, 11(1), 254.
9. Novieastari, E., Pujasari, H., Abdul Rahman, L. O., Ganefianty, A., & Rerung, M. P., 2022. Knowledge, perception, and awareness about Sustainable Development Goals (SDGs) among students of a public university in Indonesia. Int. J. Health. Promot. Ed., 60(4), 195-203.
10. United Nations (UN). (2015). The 17 Goals. Available: https://sdgs.un.org/goals (accessed: May 7 2024).
11. Shaik, S., Kuruppuarachchi, L. N., & Franchetti, M. J., 2022. Push and pull: sustainability education for 21st century engineers. In Higher Education for Sustainable Development Goals (pp. 141-169). River Publishers.
12. Staniškis, J. K., & Katiliūtė, E., 2016. Complex evaluation of sustainability in engineering education: Case & analysis. J. Clean. Prod., 120, 13-20.
13. Guerra, A., 2017. Integration of sustainability in engineering education: Why is PBL an answer? Int. J. Sust. Higher Ed., 18(3), 436-454.
14. Romero, S., Aláez, M., Amo, D., & Fonseca, D., 2020. Systematic review of how engineering schools around the world are deploying the 2030 agenda. Sustainability, 12(12), 5035.
15. Fenner, R. A., & Morgan, D. C., 2021. The Barcelona Declaration revisited: core themes and new challenges.
16. Accreditation Policy and Procedure Manual (ABET)., 2017. 2017-2018 Accreditation Cycle. Available: https://www.abet.org/accreditation/accreditation-criteria/accreditation-policy-and-procedure-manual-appm-2017-2018/ (accessed 03.29.2024).
17. Zelinka, D., & Amadei, B., 2017, June. A methodology to model the integrated nature of the Sustainable development goals: Importance for engineering education. In 2017 ASEE Annual Conference & Exposition.

 doi:10.20944/preprints202409.1920.v

18. Andrade, N., Smela, E., Nguyen, V., Bigio, D., Egyen-Davis, A., & Nganjo, D., 2022, August. Environmentally and socially responsible engineering-assessing student empowerment. In 2022 ASEE Annual Conference & Exposition.
19. Ashford, N. A., 2004. Major challenges to engineering education for sustainable development: what has to change to make it creative, effective, and acceptable to the established disciplines? Int. J. Sust. High. Ed., 5Th3), 239-250.
20. Mares-Nasarre, P., Martínez-Ibáñez, V., & Sanz-Benlloch, A., 2023. Analyzing sustainability awareness & professional ethics of civil engineering bachelor's degree students. Sustainability, 15(7), 6263.
21. Thürer, M., Tomašević, I., Stevenson, M., Qu, T., & Huisingh, D., 2018. A systematic review of the literature on integrating sustainability into engineering curricula. J. Clean. Prod, 181, 608-617.
22. Mokski, E., Leal Filho, W., Sehnem, S., & Andrade Guerra, J. B. S. O. D., 2023. Education for sustainable development in higher education institutions: an approach for effective interdisciplinarity. Int. J. Sust. High. Ed., 24(1), 96-117.
23. Tejedor, G., Segalás, J., & Rosas-Casals, M., 2018. Transdisciplinarity in higher education for sustainability: how discourses are approached in engineering education. J. Clean. Prod., 175,29
24. Tasdemir, C., & Gazo, R., 2020. Integrating sustainability into higher education curriculum through a transdisciplinary perspective. J. Clean. Prod.
25. Wright, T. S., 2002. Definitions and frameworks for environmental sustainability in higher education. High. Educ. Policy, 15(2), 105-120.
26. Stephens, J. C., Hernandez, M. E., Román, M., Graham, A. C., & Scholz, R. W., 2008. Higher education as a change agent for sustainability in different cultures and contexts. Int. J. Sust. High. Ed., 9(3), 317-338.
27. Sibbel, A., 2009. Pathways towards sustainability through higher education. Int. J. Sust. High. Ed., 10(1), 68-82.
28. Brundiers, K., & Wiek, A., 2011. Educating students in real-world sustainability research: vision and implementation. Innov. High. Educ., 36, 107-124.
29. Wiek, A., Withycombe, L., & Redman, C. L., 2011. Key competencies in sustainability: a reference framework for academic program development. Sustain. Sci., 2011, 6, 203–218
30. Lozano, R., Lozano, F. J., Mulder, K., Huisingh, D., & Waas, T., 2013. Advancing higher education for sustainable development: international insights and critical reflections. J. Clean. Prod., 48, 3-9.
31. Lambrechts, W., Mulà, I., Ceulemans, K., Molderez, I., & Gaeremynck, V., 2013. The integration of competences for sustainable development in higher education: an analysis of bachelor programs in management. J. Clean. Prod., 48, 65-73.
32. Dzimińska, M., Fijałkowska, J., & Sułkowski, Ł., 2020. A conceptual model proposal: Universities as culture change agents for sustainable development. Sustainability, 12(11), 4635.
33. Hermann, R. R., & Bossle, M. B., 2020. Bringing an entrepreneurial focus to sustainability education: A teaching framework based on content analysis. J. Clean. Prod., 246, 119038.
34. Michel, J. O., & Zwickle, A., 2021. The effect of information source on higher education students' sustainability knowledge. Environ. Educ. Res., 27(7), 1080-1098.
35. Narong, D. K., & Hallinger, P., 2024. Traversing the Evolution of Research on Engineering Education for Sustainability: A Bibliometric Review (1991–2022). Sustainability, 16(2), 641.
36. Blottnitz, H.V., Case, J.M., & Fraser, D.M., 2015. Sustainable development at the core of undergraduate engineering curriculum reform: a new introductory course in chemical engineering. J. Clean. Prod., 106, 300-307.
37. Ramanujan, D., Zhou, N., & Ramani, K., 2019. Integrating environmental sustainability in undergraduate mechanical engineering courses using guided discovery instruction. J. Clean. Prod.
38. Weber, N. R., Strobel, J., Dyehouse, M. A., Harris, C., David, R., Fang, J., & Hua, I., 2014. First-year students' environmental awareness and understanding of environmental sustainability through a life cycle assessment module. J. Eng. Educ., 103(1), 154-181.
39. Kilgore, D., Jocuns, A., Yasuhara, K., & Atman, C., 2010. From beginning to end: How engineering students think and talk about sustainability across the life cycle. Int. J. Eng. Educ., 26, 305–313.
40. Eagle, L., Low, D., Case, P., & Vandommele, L., 2015. Attitudes of undergraduate business students toward sustainability issues. Int. J. Sust. High. Ed., 16(5), 650-668.
41. Tan, A., Udeaja, C., Babatunde, S. O., & Ekundayo, D., 2017. Sustainable development in a construction related curriculum–quantity surveying students' perspective. Int. J. Strateg. Prop. Manag., 21(1), 101-113.

 doi:10.20944/preprints202409.1920.v

42. Jung, Y., Park, K., & Ahn, J., 2019. Sustainability in higher education: Perceptions of social responsibility among university students. Soc. Sci., 8(3), 90.
43. Nikolic, V., Vukic, T., Maletaski, T., & Andevski, M., 2020. Students' attitudes towards sustainable development in Serbia. Int. J. Sust. High. Ed., 21(4), 733-755
44. Wang, J., Yang, M., & Maresova, P., 2020. Sustainable development at higher education in China: A comparative study of students' perception in public and private universities. Sustainability, 12(6), 2158.
45. Smaniotto, C., Battistella, C., Brunelli, L., Ruscio, E., Agodi, A., Auxilia, F., ... & Sisi, S., 2020. Sustainable development goals and 2030 agenda: Awareness, knowledge and attitudes in nine Italian universities, 2019. Int. J. Environ. Res. Public. Health, 17(23), 8968.
46. Azapagic, A., Perdan, S., & Shallcross, D., 2005. How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum. Eur. J. Eng. Educ., 30(1), 1-19.
47. Watson, M. K., Noyes, C., & Rodgers, M. O., 2013. Student perceptions of sustainability education in civil and environmental engineering at the Georgia Institute of Technology. J. Prof. Iss. Eng. Ed. Pr., 139(3), 235-243.
48. Vehmaa, A., Karvinen, M., & Keskinen, M., 2018. Building a more sustainable society? A case study on the role of sustainable development in the education and early career of water and environmental engineers. Sustainability, 10(8), 2605.
49. Akeel, U., Bell, S., & Mitchell, J. E., 2019. Assessing the sustainability literacy of the Nigerian engineering community. J. Clean. Prod., 212, 666-676.
50. Trigueiros, F., Kaipainen, J., Silva, F., Geising, N., & Tosun, E. A., 2023. Student Perspectives on Sustainability In Engineering Education: Multiple Case Study Of European Bachelor's Programs In Industrial Engineering And Management. In Annual Conference of the European Society for Engineering Education (pp. 1327-1336).
51. Nicolaou, I., & Conlon, E., 2012. What do final year engineering students know about sustainable development? Eur. J. Eng. Educ., 37(3), 267-277.
52. Aginako, Z., & Guraya, T. (2021). Students' perception about sustainability in the Engineering School of Bilbao (University of the Basque): Insertion level and importance. Sustainability, 13(15), 8673.
53. Yuan, X., Yu, L., & Wu, H., 2021. Awareness of sustainable development goals among students from a Chinese senior high school. Educ. Sci., 11(9), 458.
54. Zamora-Polo, F., Sánchez-Martín, J., Corrales-Serrano, M., & Espejo-Antúnez, L., 2019. What do university students know about sustainable development goals? A realistic approach to the reception of this UN program amongst the youth population. Sustainability, 11(13), 3533. doi: https://doi.org/10.3390/su11133533
55. Leiva-Brondo, M., Lajara-Camilleri, N., Vidal-Meló, A., Atarés, A., & Lull, C., 2022. Spanish university students' awareness and perception of sustainable development goals and sustainability literacy. Sustainability, 14(8), 4552.
56. Ramos-Gavilán, A. B., Rodríguez-Esteban, M. A., Frechilla-Alonso, M. A., Raposeiras, A. C., Movilla-Quesada, D., & González-Rogado, A. B., 2024. Raising awareness of the important role of engineering in sustainable development. Heliyon, 10(1).
57. Obrecht, M., Feodorova, Z., & Rosi, M., 2022. Assessment of environmental sustainability integration into higher education for future experts and leaders. J. Environ. Manage, 316, 115223.
58. Rampasso, I. S., Siqueira, R. G., Anholon, R., Silva, D., Quelhas, O. L. G., Leal Filho, W., & Brandli, L. L., 2019. Some of the challenges in implementing Education for Sustainable Development: perspectives from Brazilian engineering students. Int. J. Sust. Dev. World, 26(4), 367-376.
59. Shealy, T., Valdes-Vasquez, R., Klotz, L., Potvin, G., Godwin, A., Cribbs, J., & Hazari, Z., 2016. Career outcome expectations related to sustainability among students intending to major in civil engineering. J. Prof. Iss. Eng. Ed. Pr., 142(1), 04015008.
60. Nakad, M., & Kovesi, K., 2022. What about sustainability? Investigating engineering students' sustainability awareness and attitude. In SEFI2022-50th Annual Conference.
61. Gericke, N., Boeve-de Pauw, J., Berglund, T., & Olsson, D., 2019. The Sustainability Consciousness Questionnaire: The theoretical development and empirical validation of an evaluation instrument for stakeholders working with sustainable development. J. Sustain. Dev., 27(1), 35-49.

 doi:10.20944/preprints202409.1920.v

62. Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C., 2023. Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations. Asia Pac. J. Manag., 1-39.
63. García-Jurado, A., Pérez-Barea, J. J., & Nova, R. J., 2021. A new approach to social entrepreneurship: A systematic review and meta-analysis. Sustainability, 13(5), 2754.
64. Kleine, M. S., & Lucena, J. C., 2021, April. The world of "engineering for good": Towards a mapping of research, teaching, and practice of engineers doing good. In Middle Atlantic ASEE Section Spring 2021 Conference.
65. Das, C., 2024. The Current Status and Path Forward of Women Engineers in India. Available: https://alltogether.swe.org/2024/06/inwed-women-engineers-in-india/ (accessed: July 1, 2024).
66. PIB. 2023. Ministry of Education releases All India Survey on Higher Education (AISHE) 2020-2021. Available: https://pib.gov.in/PressReleseDetailm.aspx?PRID=1894517 (accessed: July 1, 2024)
67. Dlouhá, J., & Pospíšilová, M., 2018. Education for Sustainable Development Goals in public debate: The importance of participatory research in reflecting and supporting the consultation process in developing a vision for Czech education. J. Clean. Prod., 172, 4314-4327.
68. Caiado, R. G. G., Leal Filho, W., Quelhas, O. L. G., de Mattos Nascimento, D. L., & Ávila, L. V., 2018. A literature-based review on potentials and constraints in the implementation of the sustainable development goals. J. Clean. Prod., 198, 1276-1288.
69. Lazzarini, B., & Pérez-Foguet, A., 2018. Profiling research of the engineering academics who successfully promote education in Sustainable Human Development. J. Clean. Prod., 172, 4239-4253.