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Intergenerational differences of sustainability knowledge in Undergraduate and Graduate Engineering Students in a Colombian University

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Intergenerational differences of sustainability knowledge in undergraduate and graduate engineering students

Abstract

Education for Sustainable Development (EDS) has been an increasing concern and an urgent response to face environmental, social, and economic challenges worldwide. Due to the negative impact of human actions on the earth's ecosystems that has driven global warming, ESD represents a prominent approach to address environmental, social, and economic issues to promote personal and societal transformations. Therefore, Higher Education Institutions play a pivotal role in educating the next generation of engineering leaders. Although the knowledge of sustainability differs among generations, the role of each generation in fostering sustainability is significant. More research is needed to evaluate and measure the impact of sustainability initiatives within curriculum. Hence, this paper aims to measure sustainability knowledge and analyze the intergenerational differences of sustainability knowledge between engineering students from generation Z and generation Y.

At present, generation Z is becoming the most dominant generation in terms of population. At present, Gen Z (born between 1993 and 2005) holds about 23.4% of the global population while Gen Y (born between 1977 and 1993), also known as Millennials, holds 28.6% of the world's population. Understanding the cross-generational disparities between engineering students who are part of generation Z and generation Y helps educators to design better strategies to integrate sustainability into curriculum. Thus, the hypothesis proposed is generation Z students from engineering programs achieve higher sustainability knowledge scores than those generation Y students who are enrolled in engineering programs at the graduate level.

The sample comprises 94 students enrolled in undergraduate and graduate engineering programs in Bogota, Colombia. This cross-sectional study utilized a standardized Sustainability Literacy Test (Sulitest). A t-test analysis was applied. The results show statistically significant differences of sustainability knowledge scores between engineering students, reporting generation Z ($M=53.8$, $SD=5.01$) scored higher than generation Y ($M=44.3$, $SD=0.27$, $t(92) = -4.1964$, $p = .01374$. The findings provide (a) meaningful insights to foster EDS, (b) a better understanding of measuring sustainability knowledge among engineering students from generation Z and generation Y, and (c) recommendations to incorporate sustainability curriculum development initiatives for future sustainable global engineering courses.

Introduction

Higher Education Institutions (HEIs) are crucial in fostering sustainability awareness, which is fundamental to building a prosperous and equitable society [1,2,3,4,5,6]. Consequently, integrating sustainability into curricula has become a global priority in higher education [6]. By HEIs empower students across all disciplines to understand the needs of present and future generations, by educating them about environmental degradation, societal challenges (such as inequality and resource scarcity), and sustainable production and consumption practices, as well as encourage them to develop sustainable solutions that address those needs [7].

Within the movement to integrate sustainability into higher education, Sustainability Literacy (SL) has emerged as a critical component. SL encompasses the "skills, attitudes, competencies, dispositions and values that are necessary for surviving and thriving in the declining conditions of the world" [4]. Given the increasing recognition of SL and its importance in education [1,3,5], there is a growing need not only to integrate it into academic programs but also to assess the current levels of SL among higher education students.

Training engineers in sustainability is particularly vital, as they are at the forefront of developing sustainable products, services, and solutions worldwide [8,9]. Engineering programs are intrinsically linked to complex sustainability issues and play a significant role in transforming technologies, infrastructure, and management projects to prioritize planetary well-being. This transformation includes advancements in renewable energy, sustainable materials, and resilient infrastructure. Recognizing the importance of fostering SL among engineering students to building a sustainable future, this study aims to: (1) measure the current level of sustainability knowledge among undergraduate and graduate engineering students at a higher education institution in Colombia, and (2) compare these scores against benchmarks at the university, national, and global levels.

This comparative analysis will provide valuable insights into the effectiveness of current sustainability education efforts and inform future curriculum development. Furthermore, this research will contribute to a broader understanding of how engineering education can be better aligned with the urgent need for sustainable solutions. A statistical analysis was conducted to evaluate the sustainability knowledge of engineering students and compare their performance across different academic levels: undergraduate, master's, and doctoral). The null hypotheses are:

H1: Undergraduate engineering students demonstrate higher sustainability knowledge scores than master's-level engineering students.
H2: Undergraduate engineering students demonstrate higher sustainability knowledge scores than doctoral-level engineering students.
H3: Master's-level engineering students demonstrate higher sustainability knowledge scores than doctoral-level engineering students.

The Sustainability Literacy Test (Sulitest) was chosen as the assessment instrument for this study. Its selection was based on its suitability as a diagnostic tool capable of measuring sustainability knowledge across the range of educational levels, in this case, sustainability knowledge of undergraduate, master, and doctoral students within the university's engineering department. As a result, the rejection of any of these null hypotheses would have significant implications for curriculum development.

For instance, if master's or doctoral students were found to score significantly lower than undergraduates in sustainability knowledge (leading to the rejection of H1 or H2, respectively), this would clearly indicate a need to revise and adjust postgraduate curricula. Such a finding would suggest that despite the increased specialization expected at the postgraduate level, foundational sustainability knowledge is not being adequately reinforced or expanded upon. Similarly, rejection of H3, demonstrating lower knowledge among doctoral students compared to master's students, would highlight a greater gap in the integration of sustainability within doctoral programs. Consequently, the validation or rejection of these hypotheses provides crucial information for curricular decision-making. Analyzing these hypotheses allows faculty to identify specific areas requiring curricular interventions to ensure that engineering students at all levels acquire a robust and up-to-date understanding of sustainability principles and practices to address environmental, social and economic challenges.

Beyond the need for curriculum adjustments based on the hypotheses testing, it is crucial to consider the influence of generational change. Newer generations of students, often referred to as Millennials and Generation Z, have grown up with heightened awareness of environmental and social issues and generally demonstrate greater interest and engagement with sustainability [10,11,12]. Consequently, undergraduate students, typically being younger, may have greater exposure to sustainability information and discourse through various channels such as social media, news outlets, and secondary education. This increased exposure could influence their performance on sustainability knowledge assessments. Therefore, when interpreting the results of the hypotheses, it is important to consider this generational context. If significant differences are observed between educational levels, it is necessary to consider not only curricular deficiencies in postgraduate programs but also the possibility that undergraduate students already possess a baseline level of sustainability knowledge due to their generational context. Consequently, postgraduate curricula should focus not only on reinforcing fundamental concepts but also on delving into more complex and specialized topics. For instance, addressing sustainability from a more advanced perspective, tailoring the specific needs of each educational level, as well as acknowledging the generational shift and the varying levels of prior exposure to sustainability literacy.

Research design

To address the research objectives and test the stated hypotheses, Sulitest, a widely recognized instrument for measuring sustainability knowledge across various dimensions, including environmental, social, and economic aspects, was employed to assess the sustainability knowledge of undergraduate, master's, and doctoral engineering students. Random stratified sampling was utilized to ensure representation across different engineering disciplines and academic levels, enhancing the generalizability of the findings. A 95% confidence level and a 10% margin of error were selected, representing a balance between precision and feasibility for this study. Participation in the sustainability literacy test was voluntary, and students were assured of the anonymity and confidentiality of their responses, ensuring ethical data collection practices. This study is particularly timely given the increasing global focus on sustainability and the urgent need to equip future engineers with the necessary knowledge and skills to address complex environmental and social challenges.

The instrument

Sulitest is a globally accessible online platform designed for the enhancement and evaluation of Sustainability Literacy (SL). Sulitest assesses sustainability knowledge among engineering students at the undergraduate, master's, and doctoral levels. Prior studies have determined the instrument’s reliability, yielding a Cronbach’s alpha of 0.79 [13], a value considered acceptable for demonstrating internal consistency in social research [14]. The instrument generates an average score for the Core International module, representing a composite measure of each participant’s overall sustainability knowledge. These Core International results enable comparative analyses across national and global benchmarks, as well as between different educational levels within the university.

Sulitest was selected as the assessment instrument due to its suitability as a diagnostic tool for measuring learning outcomes in sustainability knowledge across the various academic levels within the university's engineering department. The instrument is a standardized online multiple-choice questionnaire consisting of 30 questions randomly drawn from the Core International Module, a standardized component administered internationally [15]. Endorsed by the United Nations, Sulitest has been administered to over 240,000 individuals since its launch [16], indicating its widespread use and recognition within the field. Offered in eight languages, the Spanish version was administered to the Spanish-speaking participants in this study, ensuring accessibility and comprehension.

Sulitest evaluates participants’ current understanding of sustainable development within the framework of the 17 Sustainable Development Goals (SDGs) [16], a critical framework guiding global sustainability efforts. The test is structured around four interconnected thematic areas: (a) Sustainable humanity and ecosystems, (b) Global and local human-constructed systems to answer people’s needs, (c) Transitions towards sustainability, and (d) The roles to play in fostering systemic changes. (a) Sustainable humanity and ecosystems evaluate participants’ knowledge of key concepts such as ecosystems, humanity’s interaction with the natural world, the multifaceted concept of sustainability, and both ecological and social perspectives [15].

(b) Global and local human-constructed systems to answer people’s needs, assesses understanding of local and global social structures, governance mechanisms, and global economic systems, incorporating crucial variables such as education, culture, land use, production, distribution, consumption patterns, product life cycles, and resource management related to water, energy, and food systems [15]. (c) Transitions towards sustainability, measures comprehension of how systemic changes toward sustainability can be initiated, reinforced, or accelerated, as well as general understanding of key sustainability initiatives such as Global Compact or Global Reporting Initiative, and concepts like ecological footprint.

Finally, (d) Roles to play in fostering systemic changes, evaluates participants’ understanding of how to raise awareness of individual and collective roles and impacts in driving systemic change [12]. Overall, the instrument provides comprehensive sustainability knowledge scores for the Core International module and for each thematic area, facilitating comparative analyses across different educational levels within the university, as well as against national and global benchmarks, allowing for a more nuanced understanding of student learning and informing targeted interventions.

Sulitest offers several significant advantages in the context of assessing and promoting sustainability literacy in higher education, particularly within engineering disciplines. First, Sulitest provides a standardized and globally recognized platform, facilitating the comparison of results across different institutions, countries, and regions. This standardization enables comparative analysis of sustainability knowledge at an international scale, ensuring the validity and reliability of collected data, thereby strengthening the foundation for informed decision-making regarding curriculum design and educational policies. Second, Sulitest aligns with the United Nations' Sustainable Development Goals (SDGs) framework, ensuring that the assessment encompasses the key dimensions of sustainability: environmental, social, and economic. This alignment with a globally accepted framework enhances the assessment's relevance and pertinence by linking it to current global challenges, emphasizing the interconnectedness of sustainability issues and the need for holistic solutions. Third, Sulitest's online, multiple-choice format facilitates large-scale administration, enabling efficient data collection from a broad student sample.

Moreover, its availability in multiple languages, including Spanish, guarantees accessibility and equity in participation, ensuring inclusivity and minimizing language-related biases. Finally, although its primary focus is on assessing knowledge, Sulitest acknowledges the need for a more holistic evaluation of sustainability literacy, encompassing skills and attitudes. In this regard, the instrument is expected to evolve to include these dimensions in future versions, making it an adaptable tool responsive to the changing needs of the field of education for sustainable development. Taking together, these advantages make Sulitest a valuable tool for diagnosing the level of sustainability understanding among students, identifying areas for improvement in curricula, and monitoring progress towards a more sustainability-oriented education, contributing to the formation of professionals committed to building a more sustainable future.

Sample

Generating an optimal sample is of paramount importance in academic research, as its quality directly impacts the validity and generalizability of the findings. An optimal sample, representative of the study population, allows researchers to draw conclusions with a high degree of confidence, extrapolating the findings to the broader population. Conversely, an inadequate sample, whether due to insufficient size, selection bias, or lack of representativeness, can lead to erroneous or poorly generalizable conclusions, compromising the internal and external validity of the research and limiting its contribution to scientific knowledge.

The study sample comprised 94 students, with the unit of analysis defined as individuals aged 18 and over enrolled in engineering programs at a Hispanic higher education institution in Colombia. Sample selection was conducted using a combination of simple random sampling and the finite population correction technique. Data collection was facilitated through Sulitest, an online instrument designed to measure Sustainability Literacy (SL).

Sample size determination necessitated the establishment of a confidence level and margin of error. For this study, a 95% confidence level and a 10% margin of error were adopted. Following the calculation of the required sample size based on these parameters, the sample was stratified by educational level. The distribution of participants across each educational level is detailed in Table 1.

Table 1. Sample distributions

Educational Level	Total Enrollment	Percentage of Total Enrollment	Sample Size
Doctoral	58	1.5%	23
Master's	1603	42.7%	39
Undergraduate	2096	55.8%	32
Total	**3757**	**100%**	**94**

Following the determination of the population size, the sample size (n) was calculated using the subsequent formula:

$$n = \frac{N z_{1-\propto}^2}{N^2 e^2 + z_{1-\propto}^2 \sum_h N_h \sigma_h^2}$$

where:

σ_h^2, Corresponds to the inherent variation within the population of interest in stratum h,

N is the population size,

e^2 Corresponds to the maximum permissible error,

$z_{1-\propto}^2$ Confidence level.

Institutional Context

Recognizing the immediate and long-term consequences of individual actions, this private institution situated in Bogota, Colombia, embraces the Goals for Sustainable Development and Social Progress promoted by UNESCO. The university's central focus is sustainable entrepreneurship grounded in the holistic development of its students. Demonstrating a commitment to circular economy principles, the university has integrated the Cradle to Cradle (C2C) framework into the design and construction of its new infrastructure, achievement of the LEED Gold certification for its newest building. The university's student body comprises over eleven thousand students, with more than three thousand enrolled in engineering programs across undergraduate, master's, and doctoral levels. The institution is dedicated to cultivating a community that adopts a global perspective while acting locally to advance sustainability. Education for sustainability is integrated into the organizational culture and actively promoted within curricula at all educational levels.

Results

Statistical analysis was conducted using the R statistical computing environment (R Studio), a widely used and robust platform for statistical computing and data visualization in academic research. To analyze potential differences in sustainability literacy across generational cohorts represented by undergraduate, master's, and doctoral engineering students within the department of engineering, a paired t-test was deemed the appropriate statistical method. This approach is suitable for comparing means across three or more independent groups, allowing for the assessment of whether significant variations exist in sustainability knowledge based on educational level, which is used here as a proxy for generational cohort. Furthermore, framing the analysis in terms of generational cohorts recognizes the growing body of research exploring the influence of generational factors on attitudes, values, and knowledge related to sustainability, providing a relevant and contemporary context for the study. These results are shown in Table 2.

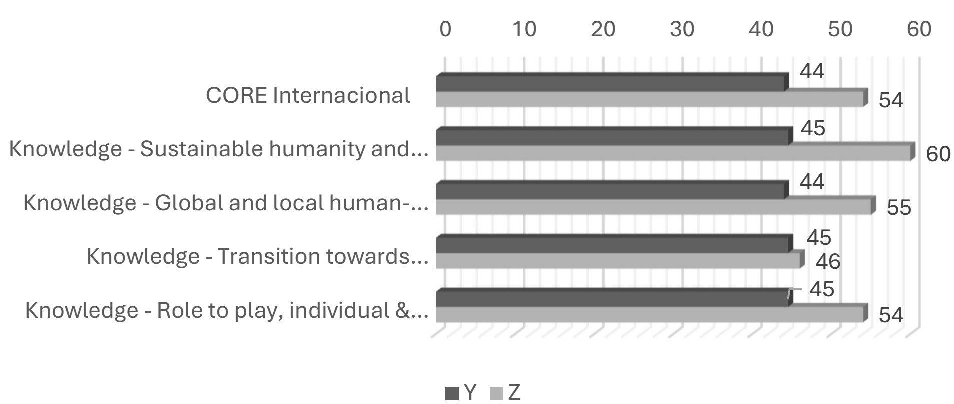
Table 2. Paired t-test

t = -4.1964,
p-value = 0.01374
alternative hypothesis: true mean difference is not equal to 0
95 percent confidence interval: -15.785445, -3.214555
sample estimates: mean difference -9.5

A p-value below 0.05 [16,16] was used as the criterion for statistical significance. A paired-samples t-test was conducted to compare sustainability literacy scores between Generation Y and Generation Z. The results revealed a statistically significant difference between the two groups, t= -4.196, p = .014, d = -0.78. Generation Z demonstrated significantly lower scores (M = 75, SD = 10) compared to Generation Y (M = 84.5, SD = 8), with a mean difference of -9.5 (95% CI [-15.79, -3.21]). This suggests that current educational programs are not adequately addressing the sustainability literacy needs of Generation Z, warranting a review and adaptation of curricula.

Figure 1 illustrates the students' performance across the different topics covered by the Sulitest.

Fig. 1 Students' performance per generation



In general, Generation Z shows higher average scores than Generation Y in almost all the evaluated topics, suggesting a greater understanding of sustainability by Generation Z compared to Y within the sample studied. Consequently, students from generation Z display an advanced knowledge of key concepts of ecosystems, humanity's interaction with the natural world, ecological, and social perspectives [12]. Analysis by Topic:

CORE International: Generation Z (54) outperforms Generation Y (44) by 10 points. This difference suggests a better grasp of basic sustainability concepts by Generation Z.
Knowledge - Sustainable humanity and ecosystems: This is the most notable difference (15 points). Generation Z (60) shows considerably higher knowledge about the interrelation between humanity and ecosystems, as well as a better understanding of the ecological and social perspectives of sustainability.
Knowledge - Global and local human-constructed systems: Generation Z (55) surpasses Generation Y (44) by 11 points. This indicates a greater understanding of social structures, governance, and economic systems in relation to sustainability.
Knowledge - Transition towards sustainability: The difference is minimal (1 point in favor of Generation Y: 46 vs. 45). This suggests that both generations have a similar level of knowledge about the processes and mechanisms of transition towards sustainability. This difference is likely not statistically significant.
Knowledge - Role to play, individual & systemic change: Generation Z (54) outperforms Generation Y (45) by 9 points, suggesting a better understanding of how individuals can contribute to systemic changes toward sustainability.

Likewise, Table 3 displays the discrepancies in the results obtained concerning the Sustainable Development Goals (SDGs)

Table 3. Discrepancies in the Sustainable Development Goals (SDGs) by generations

SDG	Z	Y
SDG01 - No Poverty	29	28
SDG02 - Zero Hunger	29	34
SDG03 - Good Health and Well-Being	54	52
SDG04 - Quality Education	52	46
SDG06 - Clean Water and Sanitation	16	16
SDG07 - Affordable and Clean Energy	46	27
SDG08 - Decent Work and Economic Growth	46	49
SDG09 - Industry, Innovation and Infrastructure	41	51
SDG10 - Reduced Inequality	29	31
SDG11 - Sustainable Cities and Communities	45	44
SDG12 - Responsible Consumption and Production	50	48
SDG13 - Climate Action	53	48
SDG14 - Life Below Water	72	61
SDG15 - Life on Land	69	44
SDG16 - Peace and Justice, Strong Institutions	64	46
SDG17 - Partnerships for the Goals	62	43

Overall, Generation Z tends to score higher than Generation Y on most SDGs, suggesting a potentially greater awareness and understanding of these global goals. However, there are exceptions, and the magnitude of the differences varies considerably across the different SDGs.

Analysis of mean scores across the Sustainable Development Goals (SDGs) revealed notable generational differences between Generations Y and Z. While similar levels of understanding were observed for SDGs 1 (No Poverty), 3 (Good Health and Well-Being), 6 (Clean Water and Sanitation), 10 (Reduced Inequalities), 11 (Sustainable Cities and Communities), and 12 (Responsible Consumption and Production), more pronounced variations emerged in other areas. Generation Z demonstrated substantially higher mean scores for SDGs 7 (Affordable and Clean Energy), 14 (Life Below Water), 15 (Life on Land), 16 (Peace, Justice, and Strong Institutions), and 17 (Partnerships for the Goals), indicating a potentially stronger grasp of these interconnected global challenges. Conversely, Generation Y exhibited slightly higher scores for SDGs 2 (Zero Hunger), 8 (Decent Work and Economic Growth), and 9 (Industry, Innovation, and Infrastructure). These findings suggest potential variations in generational priorities and knowledge bases regarding the diverse dimensions of sustainable development.

These generational variations in SDG understanding are particularly relevant in the current global context. Generation Z, having grown up amidst increasing awareness of climate change, biodiversity loss, and social inequalities, may demonstrate heightened concern and knowledge regarding environmental and social sustainability. Their higher scores on SDGs related to energy, oceans, terrestrial ecosystems, and institutional frameworks could reflect this exposure and concern. The slightly higher scores of Generation Y on SDGs related to hunger, economic growth, and infrastructure could potentially be attributed to their entry into the workforce during periods of economic instability and heightened focus on economic development. These findings underscore the importance of tailored educational and engagement strategies that address the specific knowledge gaps and strengths of each generation to effectively promote the achievement of the SDGs. Further research incorporating larger and more diverse samples, alongside qualitative data collection, is warranted to explore the underlying factors contributing to these observed generational differences

Discussion

This study analyzed generational differences in sustainability literacy between engineering students from Generation Y and Generation Z, utilizing the Sulitest assessment framework. While the initial analysis of mean scores (Figure 1) suggested a general trend of higher sustainability knowledge in Generation Z across most Sulitest topics, a paired-samples t-test revealed a statistically significant difference in overall sustainability literacy favoring Generation Y ($t = -4.196$, $p = .014$, $d = -0.78$). This seemingly contradictory finding, with Generation Z scoring lower overall despite higher scores in individual topics, warrants further examination. The significant negative effect size (Cohen's $d = -0.78$) indicates a practically meaningful difference, suggesting that Generation Y's higher overall score is not merely a statistical artifact. This discrepancy could be attributed to the relative significance or weight of different Sulitest topics in the overall score calculation or the presence of specific items within the overall assessment where Generation Y performed substantially better, offsetting Generation Z's advantages in other areas. This highlights the importance of not solely relying on overall scores and considering performance across individual sub-domains.

Analysis of performance on specific Sulitest topics (Figure 1) revealed that Generation Z demonstrated higher average scores in CORE International, Sustainable Humanity and Ecosystems, Global and Local Human-Constructed Systems, and Role to Play, Individual & Systemic Change. These findings suggest that Generation Z possesses a stronger understanding of fundamental sustainability concepts, the interconnectedness of human and natural systems, the impact of human activities on the environment, and the importance of individual and collective action for driving systemic change. The minimal difference observed in Transition Towards Sustainability suggests comparable knowledge levels between the two generations regarding the mechanisms and processes of sustainability transitions.

Furthermore, analysis of mean scores across the Sustainable Development Goals (SDGs) (Table 3) revealed notable generational differences. While similar levels of understanding were observed for SDGs 1 (No Poverty), 3 (Good Health and Well-Being), 6 (Clean Water and Sanitation), 10 (Reduced Inequalities), 11 (Sustainable Cities and Communities), and 12 (Responsible Consumption and Production), more pronounced variations emerged in other areas. Generation Z demonstrated substantially higher mean scores for SDGs 7 (Affordable and Clean Energy), 14 (Life Below Water), 15 (Life on Land), 16 (Peace, Justice, and Strong Institutions), and 17 (Partnerships for the Goals), indicating a potentially stronger grasp of these interconnected global challenges. Conversely, Generation Y exhibited slightly higher scores for SDGs 2 (Zero Hunger), 8 (Decent Work and Economic Growth), and 9 (Industry, Innovation, and Infrastructure).

These generational variations in SDG understanding are particularly relevant in the current global context. Generation Z, having grown up amidst increasing awareness of climate change, biodiversity loss, and social inequalities, may demonstrate heightened concern and knowledge regarding environmental and social sustainability. Their higher scores on SDGs related to energy, oceans, terrestrial ecosystems, and institutional frameworks could reflect this exposure and concern. The slightly higher scores of Generation Y on SDGs related to hunger, economic growth, and infrastructure could potentially be attributed to their entry into the workforce during periods of economic instability and heightened focus on economic development. These findings underscore the importance of tailored educational and engagement strategies that address the specific knowledge gaps and strengths of each generation to effectively promote the achievement of the SDGs. Future research should investigate the weighting of Sulitest topics in the overall score, explore the specific items contributing to the overall difference, and incorporate larger and more diverse samples, alongside qualitative data collection, to further explore the underlying factors contributing to these observed generational differences. This mixed-methods approach would provide a more nuanced understanding of the complexities of generational differences in sustainability literacy.

Conclusion

This research analyzed generational differences in sustainability literacy among engineering students, focusing on their understanding of both general sustainability concepts (assessed via the Sulitest) and the specific targets outlined in the Sustainable Development Goals (SDGs). Further investigation into the weighting of Sulitest topics and specific item analysis is recommended to fully understand this discrepancy.

Regarding the specific Sulitest topics, Generation Z demonstrated higher average scores in CORE International, Sustainable Humanity and Ecosystems, Global and Local Human-Constructed Systems, and Role to Play, Individual & Systemic Change, suggesting a potentially stronger foundation in core sustainability principles, the human-environment nexus, and the importance of individual and collective action. However, no significant difference was found in Transition Towards Sustainability, indicating comparable knowledge levels between the two generations in this domain.

Analysis of SDG understanding (Table 3) revealed more nuanced generational differences. While similar understanding was observed for SDGs related to poverty, health, water and sanitation, inequalities, sustainable cities, and responsible consumption, Generation Z exhibited significantly higher scores in SDGs focused on affordable and clean energy (SDG 7), life below water (SDG 14), life on land (SDG 15), peace, justice, and strong institutions (SDG 16), and partnerships for the goals (SDG 17). 1

This indicates a potentially greater awareness and understanding of interconnected environmental and socio-political challenges among Generation Z. Conversely, Generation Y demonstrated slightly higher scores in SDGs related to zero hunger (SDG 2), decent work and economic growth (SDG 8), and industry, innovation, and infrastructure (SDG 9), suggesting a potentially stronger focus on the economic and developmental aspects of sustainability.

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