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Measuring Sustainability Literacy in Undergraduate and Graduate Engineering Students in a Colombian University

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Abstract

The role of Higher Education Institutions (HEIs) and engineering programs is crucial in the effort of creating sustainable awareness for building a prosperous and equitable society for all. Improving Sustainability Literacy (SL) worldwide contributes to both the advancement of Education for Sustainable Development and the progress of Sustainable Development Goals. Given the noteworthy contribution of both sustainability literacy and engineering programs in building a sustainable future for all, this paper aims to measure sustainability knowledge and to make comparisons among the educational levels of students enrolled in engineering programs such as undergraduate, master, and Ph.D.

The sample is composed of 94 students from engineering programs at all levels of higher education: undergraduate, master, and doctoral engineering related programs in a university in Bogota, Colombia. The instrument used in this study is the Sustainability Literacy Test (Sulitest), a standardized assessment tool endorsed by the United Nations to measure the level of sustainability knowledge. The instrument has been administered through an online platform to measure the Sustainability Literacy knowledge of Engineering students in both undergraduate and graduate academic programs. Analysis of variance (ANOVA) was applied to test the hypotheses and make comparisons. The results show statistically significant differences in sustainability knowledge scores between students from undergraduate and graduate levels.

One major finding involved the effect of generation on sustainability literacy. The sample's undergraduates come from Generation Z, students who were born between 1993 and 2005, while the sample's graduate students (Ph.D. and Master) come from Generation Y, students who were born between 1977 and 1993. Generation Z has a significantly higher sustainability literacy compared to Generation Y. Within Generation Y (when generation is held constant), education level (Ph.D. or Masters) explains differences in sustainability literacy, with Ph.D. students having significantly higher SL knowledge scores than master's students. The findings provide significant insights to understand students' sustainability knowledge in higher education institutions and strengthen the design of future sustainable global engineering courses.

Key words:
Global sustainable engineering courses, sustainability literacy, sustainability awareness, Integration of sustainability in courses.

Introduction

The role of Higher Education Institutions (HEIs) is vital in the effort of creating sustainable awareness for building a prosperous and equitable society for all [1,2,3,4,5,6]. Embedding sustainability into curricula has become relevant in the education of college and university students worldwide [6]. By teaching students of all ages about environmental degradation, threats to society, and sustainable production and consumption, they will be more aware of the needs of present and future generations and provide sustainable solutions for those demands [7].

In the efforts of integrating sustainability into higher education curricula, SL has become an essential factor. SL has been defined as the "skills, attitudes, competencies, dispositions and values that are necessary for surviving and thriving in the declining conditions of the world to slow down that decline as far as possible" [4]. Since SL is becoming increasingly important in education [1,3,5], there are growing needs to both measure SL and integrate SL into curricula.

Training engineers in sustainability issues in HEI is essential as they develop sustainable products, sustainable services, and sustainable solutions worldwide [8.9]. Engineering programs are connected to the complex issues of sustainability and play a significant part in the transformation of technologies, infrastructure, and management projects in favor of the conservation of the planet. Given the noteworthy contribution of both SL and engineering programs to build a sustainable future for all, this paper aims to measure the current level of sustainability knowledge of students enrolled in undergraduate and graduate engineering programs at an international university located in Colombia, as well as to make comparisons of the sustainability knowledge scores among the different educational levels at the university, country, and global benchmarks.

To assess the sustainability knowledge of the engineering students and make comparisons between the different levels of education in engineering programs such as undergraduate, master, and doctoral level, a statistical analysis was performed. The null hypotheses in this study are described as follows:

H1. Undergraduate students from engineering programs achieve higher sustainability knowledge scores than those who are enrolled in engineering programs at the master level.

H2. Undergraduate students from engineering programs achieve higher sustainability knowledge scores than those who are enrolled in engineering programs at the doctoral level.

H3. Master students from engineering programs achieve higher sustainability knowledge scores than those who are enrolled in engineering programs at the doctoral level.

In this study, the Sustainability Literacy Test (Sulitest) was selected to assess students' knowledge and awareness of sustainability. This instrument was suitable for this research because it provides a diagnostic tool for measuring sustainability knowledge at a variety of educational levels within the university's Department of Engineering at the university.

Research design

To address the purpose and the hypotheses in this research, the authors utilized an online standardized instrument to measure sustainability knowledge from undergraduate, master, and Ph.D. students. Using random stratified sampling, this study used a random error of 10% and a confidence level of 95%. The data was collected from undergraduate and graduate students enrolled in engineering programs, between December 2022 and February 2023. The students took the sustainability literacy test voluntarily and the application was not subject to any additional grade in the course.

The instrument

The instrument utilized in this study was the Sustainability Literacy Test, Sulitest, a worldwide open online platform designed to enhance and evaluate SL. IT assesses the sustainability knowledge of the engineering students among the different levels of higher education: undergraduate, master, and doctoral level. The instrument has been validated in previous studies obtaining a Cronbach's alpha equal to 0,79 [10], which demonstrates its reliability. The alpha above 0.7 shows internal consistency and is considered an acceptable value in social research [11]. The instrument shows an average score of the core international, which is the measurement of the overall sustainability knowledge by each participant. The core international results allow the authors to make comparisons not only between the country and global results but also within the different levels of education inside the university.

This instrument was suitable for this study because it serves as a diagnostic tool to measure learning outcomes in sustainability knowledge across the different educational levels within the department of engineering at the university. It is a standardized online multiple-choice questionnaire composed of 30 multiple choice questions, extracted randomly from the Core International Module common to every country [12]. The survey has been endorsed by the United Nations and more than 240,000 Sulitest awareness tests have been taken since its launch [13]. This instrument is offered in eight different languages; considering the participants in this study are Spanish speakers, they took the online questionnaire in Spanish.

Sulitest measures the participant's current knowledge of sustainable development on the scope of the 17 sustainable development goals [13]. As a result, the taxonomic level of learning provided by Sulitest is knowledge, as the items in the questionnaire refer to facts and concepts [13;14]. Assessing knowledge involves the ability to remember facts, concepts, and theories; it is located at the at the bottom of the Bloom's taxonomy of cognitive objectives [13]. Although the Foundational Matrix of Sulitest is based mainly on knowledge, it is expected that the instrument could include questions that not only assess skills, but also mindset components in the future [13].

The test is composed of four themes of knowledge: (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. The Sustainable Humanity and Ecosystems theme measures the participants' knowledge of the following themes: ecosystems, humanity, sustainability, ecological perspective, and social

perspective [12]. The theme of Global and Local Human-constructed Systems to Answer People's Needs assesses knowledge of local and global social structures and governance as well as global economic systems. It includes variables such as education, culture, land use, production, distribution, consumption of goods and services, life cycles, water, energy, and food [12].

The theme of Transitions Towards Sustainability measures students' knowledge about how system changes can be initiated, reinforced, or accelerated. It also assesses the understanding of initiatives towards sustainability such as The United Nations, Global Compact, or Global Reporting Initiative, among others; concepts, tools, or frameworks such as cradle to cradle, natural capitalism, or ecological footprint. The instrument also provides examples in which participants can learn from such as case studies of successes or failures in addition to technological, strategic, and social innovations [12]. The theme of Roles to Play in Fostering Systemic Changes evaluates participants' knowledge of how to create awareness of individuals' roles and impacts [12]. Overall, the instrument shows the sustainability knowledge scores for the core international module and for each theme, which allows for comparisons across the different educational levels within the university, country, and global benchmarks.

Sample

The sample consisted of 94 students. The unit of analysis was composed by students 18 years and older who were enrolled in engineering programs in a Hispanic higher education institution located in Colombia. The sample was determined by applying both the simple random sampling technique and the finitude correction technique. The data was collected through Sulitest, an online survey to measure SL.

In determining the sample size, it was necessary to establish the level of confidence and degree of error; for this case, a confidence level of 95% and an error of 10% were established. After calculating the required sample size with the established parameters, the sample was estimated by groups of educational level. For this purpose, the participation of each group in the analysis was established as it is displayed in Table 1:

Table 1. Sample characteristics

Students	Total	%	Sample
Ph.D.	58	1.5%	23
Master	1603	42.7%	39
Undergraduate	2096	55.8%	32
Total	3757	100%	94

Once the size of the population was determined, the sample size was calculated, using the following formula for n:

$$\mathbf{n} = \frac{\mathbf{N}(\mathbf{z}_{\mathbf{1-\alpha}})^{\mathbf{2}}\boldsymbol{\sigma}^{\mathbf{2}}}{\mathbf{N}e^{\mathbf{2}} + (\mathbf{z}_{\mathbf{1-\alpha}})^{2}\sigma^{2}}$$

Institutional Context

Located in Bogota, Colombia, the university is focused on sustainable entrepreneurship, leadership, and innovation as its institutional pillars. The university is aware of the immediate and long-term impact of individuals' actions, which is why it welcomes the Goals for Sustainable Development and Social Progress promoted by UNESCO. The university has begun to adopt a circular economy approach by utilizing the concept of Cradle to Cradle (C2C) in the design and construction of new institutional infrastructure.

The university is a member of the Steering Committee of the Global Compact, and it has adhered to the Principles for Responsible Management Education (PRME) that provides a global network to promote sustainability and corporate social responsibility. After the construction of its most recent building, based on the C2C architectural design method, the university has achieved certification in the gold category of the LEED program.

The university has more than eleven thousand students of which more than three thousand are enrolled in engineering programs at the undergraduate, master, and doctoral level. It is committed to fostering a community that thinks globally and acts locally in favor of sustainability. Education for sustainability is embedded in the organizational culture and promoted into curricula at the different educational levels.

Results

Statistical analysis was performed using software R studio, version R-4.2.2. Analysis of variance (ANOVA) was applied to test the hypotheses. The sample groups were undergraduate, master, and Ph.D. students enrolled in engineering programs within the Department of Engineering. Tukey's pairwise contrasts were used to analyze the comparison among the different educational levels.

Through the data analysis, a statistically significant difference was considered if the p-value was less than 0.05 [16,16]. Table 2 shows the significant differences between the undergraduate and both masters and Ph.D. student groups' results. The survey results confirmed a significant difference ($p < 0.05$) between the sustainability knowledge scores for the sample of undergraduate and Ph.D. students. In addition, the survey results show a statistically significant difference ($p < 0.05$) between the sustainability knowledge scores for the sample of undergraduate and master students. Moreover, the outcomes confirmed there is no significant difference between students from the master program and Ph.D. program.

Table 1. Multiple Comparisons of Means from educational level: Tukey Contrasts

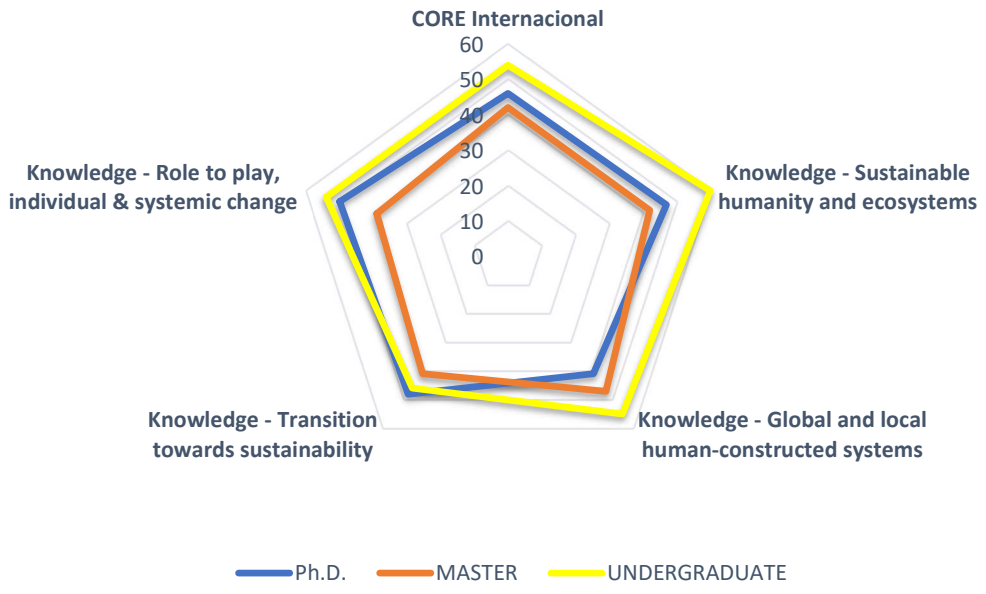
Linear Hypotheses	Estimate	Std.Error	t_value	Pr(>|t|)
Mater-Ph.D.=0	-4.200	2.455	-1.711	0.24124
Undergraduate - Ph.D.=0	7.400	2.455	3.014	0.02694*
Undergraduate – Master=0	11.600	2.455	4.725	0.00137**

Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 (Adjusted p values reported -- single-step method)

The results show the sustainability knowledge score for the core international module and for each specific theme at the different educational levels. Figure 1 illustrates the sustainability knowledge scores per educational level within the university. The average score of the core international module, which is the measurement of the participants' overall sustainability knowledge, at the undergraduate level was 54, master level was 42, and doctoral level was 46. This finding confirmed that undergraduate engineering students outperformed masters and Ph.D. students in their score of sustainability knowledge.

In addition, the scores for the theme of Sustainable Humanity and Ecosystems correspond to undergraduate 60, master 42, and doctoral 47. Moreover, the sustainability knowledge score for the theme of Global and Local Human-constructed Systems were undergraduate 55, master 47, and doctoral 41. Furthermore, there was an average score of 46 on the Transitions Towards Sustainability theme at the undergraduate level, 41 at the master level, and 48 at the doctoral level. Finally, the Roles to Play in Fostering Systemic Changes score at the undergraduate level was 54, the master level was 39, and the doctoral level was 50.

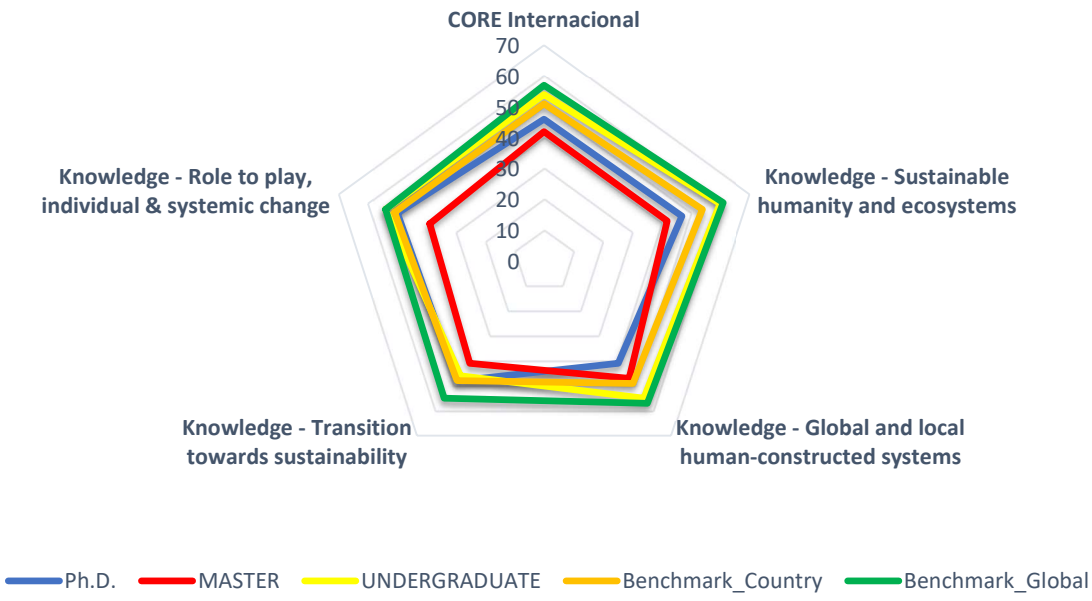
Fig. 1 Sustainability knowledge score per educational level



According to the data, the average global score of the core international module was 57, while at the country level it was 51, compared to the average scores at the undergraduate, master, and doctoral level which were 54, 42, and 46, respectively. Figure 2 displays the results of the sustainability knowledge scores of the university students in comparison to the global and country scores. In the case of the theme of Sustainable Humanity and Ecosystems, the global average corresponds to 61, while the country average score was 54, contrasted to the scores of undergraduate, master, and doctoral students, which were 60, 42, and 47, respectively.

Additionally, the sustainability knowledge score for the theme of Global and Local Human-constructed Systems were globally 57, 49 at the country level, 55 at the undergraduate level, 47 at the master level, and 41 at the doctoral level. Globally, there was a score of 57 for the theme of Transitions Towards Sustainability, at the country level it was 49, while the undergraduate, master, and doctoral scores came out to 41, 41, and 48, respectively. Lastly, the knowledge score for the Role to Play in Fostering Systemic Changes was 54 globally, 51 at the country level, and 54, 39, and 50 for the undergraduate, master, and doctoral levels, respectively.

Fig. 2 Sustainability knowledge scores at the university, country, and global level



Discussion

The findings demonstrated statistically significant differences of the sustainability knowledge scores between the groups of undergraduate and doctoral students and between the groups of undergraduate and master students. The results show that students from the undergraduate level achieve higher sustainability knowledge scores than students from advanced educational levels. Additionally, students from the master program do not exhibit significant differences compared to students from the Ph.D. program.

It is relevant to mention that there is a cross-generational gap between students from undergraduate and graduate educational levels in engineering programs in this higher education institution. The average age of undergraduate students is 19, that of master students is 27, and that of PhD students is 40. Accordingly, individuals of Generation X were born between 1965 and 1977; individuals of Generation Y, also called Millennials, were born between 1977 and 1993; and individuals pertaining to Generation Z were born between 1993 and 2005 [15]. As a result, undergraduate students belong to Generation Z while master and Ph.D. students belong to Generation Y.

Indeed, some studies have analyzed the relation between age and sustainable behavior [16,17]. Consequently, they have indicated that Generation Z, also known as Zoomers or Gen Zers, is more concerned with sustainability and environmental issues than Generation Y [16]. In addition, Zoomers are more environmentally and socially conscious when they purchase products and services [19,20]. Hence, the data shows that undergraduate students have a higher sustainability knowledge score; therefore, Generation Z display more sustainable behaviors than graduate students. Accordingly, the results show that the education system at the university subject to this study is making the undergraduate students more sustainability literate. Additionally, as undergraduate, and doctoral students had higher sustainability knowledge scores in comparison to master's students, arguably, the more time students spend in engineering curricula, the greater their awareness and knowledge of sustainability grows.

Moreover, comparing the sustainability knowledge scores from each educational level to the country results, it is evident that undergraduate students achieved higher sustainability knowledge scores in each theme. However, assessing the average sustainability knowledge scores from undergraduate and graduate students to the global level, it is evident that participants from this university performed below the average. Sulitest provides a comprehensive picture of the global trend and serves as a diagnostic tool, which is relevant in identifying the need to continue to educate higher education students in sustainability issues in Latin America.

Conclusion

The study assessed sustainability knowledge of students at the undergraduate, master, and doctoral level. Although engineering students have globally achieved some knowledge towards sustainability, it is crucial that sustainability literacy is being reinforced and integrated into the curricula of engineering programs at the different levels of education.

Sulitest is a diagnostic tool to measure knowledge and awareness towards sustainability that can be used to assess learning outcomes, create new pedagogical strategies, and promote research in this field. The findings show significant differences between undergraduate and graduate students, indicating students at the undergraduate level accomplished higher sustainability knowledge than those in advanced educational levels. Accordingly, undergraduate and Ph.D. students achieved higher sustainability knowledge scores than master students. As a result, the study encourages faculty to integrate sustainable practices within higher education institutions to increase sustainability knowledge and awareness across generations and educational levels.

In this research, undergraduate engineering students outperformed masters and Ph.D. students in understanding sustainability, suggesting that undergraduates are more sustainability literate than graduate students. Although this study was applied to students enrolled in engineering programs, it would be interesting to measure sustainability literacy knowledge in pre-engineering students or at the beginning of the first academic term in the bachelor program. This can help the HEIs to understand whether young undergraduates arrive in engineering schools with sustainability knowledge or if they develop sustainability literacy during the engineering course load at the higher education institution. This is encouraging for HEIs to understand the level of existing sustainability knowledge from pre-engineering students, the potential to improve sustainability

knowledge, and the opportunities to increase engagement when future decision-makers face sustainability challenges.

Consequently, future research on sustainability literacy to understand the process in which students develop sustainability knowledge at any educational level is necessary. There is a strong need for educating engineering students in sustainability across engineering higher educational programs worldwide. Measuring sustainability knowledge across different disciplines, educational levels, and cross-generational students can contribute to the advancement and better understanding of both Education for Sustainable Development and Sustainable Development Goals.

Even though the spread of Sulitest in Europe (without France) and the Americas region has reached 15% and 21% respectively [13], there is an invitation to higher education institutions to increase the effort and knowledge of students towards sustainability. This research provides meaningful insights to understanding students' sustainability knowledge in higher education institutions and strengthen the design of future sustainable global engineering courses.
A sustainable future can be feasible if education for sustainable development is disseminated worldwide.

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