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Associating Sustainability Literacy with educational level of Industrial Engineering Students

Sandra Jennina Sanchez, Florida International University

Ph.D. student in Higher Education at Florida International University. Ph.D. in Business Competitiveness and Economic Development from University of Deusto in Spain. Master of Business Administration (MBA) from University of Dallas, Texas. B.S. in Business Administration from Externado University in Colombia. Bilingual in English, and Spanish. Expert in transforming educational models, with 12 years of experience in the education sector, managing and leading programs of high academic recognition and international positioning. 10 years of business experience in financial and administrative areas, leading organizational change management processes

Jose Daniel Ballen
MILTON JANUARIO RUEDA VARON, Universidad Ean
Douglas Lee Robertson, Florida International University

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Sustainability Literacy has become crucial in promoting Education for Sustainable Development (ESD). Embedding ESD in the design of global engineering courses implies the incorporation of Sustainability Literacy into curricula. Then, teaching and assessing sustainability knowledge in Higher Education Institutions (HEIs) is essential to enhance sustainability awareness and to foster sustainable development. As a result, there is an increasing need in educating engineering students about sustainability knowledge to tackle sustainability related issues. In response to that need, this study aims to examine the increase of sustainability knowledge in the Industrial Engineering students at UniMinuto University in Colombia.

Students answered the Sustainability Literacy Test (Sulitest), an online standardized assessment tool that tests sustainability knowledge. The sample frame comprises 105 industrial engineering students at UniMinuto University in the city of Buga, Colombia. A binary logistic regression was applied to assess the significance of sustainability knowledge in relation to the students' educational level. The results exhibit statistically significant differences between sustainability knowledge scores and the semester enrolled in the program.

Higher educational levels are associated with a higher likelihood of obtaining a better overall sustainability knowledge score. The probability of achieving higher overall sustainability knowledge scores is approximately 20% as industrial engineering students advance in the program. In addition, in the logistic regression model, confidence intervals can be calculated for the odds, where it is seen that the influence of the educational level can range from 1% to 43%. This is consistent with the fact that students are exposed to sustainability issues as they proceed through their studies, leading to greater knowledge of this topic. The results are valuable because they point out the significant importance of designing sustainable global courses in academic engineering programs. To the extent that HEIs incorporate and assess sustainability learning outcomes into curriculum, the future generations of leaders will promote a more sustainable future.

Key words:
Education for Sustainable Development, Sustainability Literacy, ESD, Sustainability competencies, sustainability learning outcomes, sustainability knowledge, environmental literacy.

1. Introduction

Higher Educational Institutes (HEIs) have a significant impact on educating the future generation of leaders and engineers whose decision-making consider social, economic, and environmental effects. HEIs are one of the most important contributors in fostering Education for Sustainable Development (ESD) [1,2]. HEIs have the responsibility to equip young students with the knowledge, values, and skills to prepare them in dealing with social, economic, and environmental challenges.

Embedding ESD in the design of global engineering courses implies the incorporation of Sustainability Literacy (SL) into curricula. SL is crucial in the effort of fostering a sustainable

future for all [3]. SL is defined as "the knowledge, skills, and mindsets that allow individuals to become deeply committed to building a sustainable future and assisting in making informed and effective decisions to this end" [4].

Although the number of publications about sustainability has grown exponentially since 2010 [5], there is still scarce quantifiable studies regarding what undergraduates learn and retain [6]. In addition, there is a need to assess sustainability learning outcomes [7] and measure sustainability knowledge across different disciplines [3]. In response to those gaps, this study aims to examine the increase in sustainability knowledge of Industrial Engineering students at UniMinuto University in Colombia. In addition, the research question asks to what extent does the semester influence the sustainability knowledge scores of students within the industrial engineering academic program.

The remainder of this paper is organized into the following sections: Section 2 offers a theoretical framework of education for sustainable development and their importance in HEIs. Section 3 provides information about the institutional context and sustainability practices at UniMinuto University. Section 4 describes the methodology which includes the research design, the instrument, and the sample. Section 5 presents the findings from the logistic regression. Section 6 discusses the increase of knowledge resulting from the incorporation of sustainability topics into curricula. Section 7 includes the research limitations. Section 8 provides concluding comments and recommendations of integrating sustainability in education.

2. Theoretical framework

The theoretical framework of this study is organized by major topics such as Education for Sustainable Development, Sustainability Literacy, and the integration of ESD into curricula.

2.1 Education for Sustainable Development

Sustainability is a multidimensional concept [8]. Defining sustainability involves the adoption of three key dimensions that drive sustainable development (SD): environmental, social, and economic dimensions [8, 9]. Additionally, [10] stated SD is an endeavor to ensuring an equilibrium among economic growth, environmental integrity, and social well-being. As a result, understanding the environmental, social, and economic dimensions as well as their interconnections implies a certain level of complexity in the effort of incorporating sustainability in education.

The concept of sustainability is related to the concept of sustainable development [11]. The most cited definition of sustainable development has been provided by Brundtland Commission Report or the "Report of the World Commission on Environment and Development: Our Common Future" published by the United Nations in 1987. According to the Brundtland Commission Report, SD is defined as "development that meets the needs of the current generation without compromising the ability of future generations to meets their own needs" [12].

Education stands as a fundamental cornerstone in achieving Sustainable Development [13]. Education for Sustainable Development (ESD) has garnered growing recognition since the 1990s, following the United Nations (UN) emphasis on the significant role of education in transitioning towards the new paradigm of sustainable development [14]. Education for sustainability, Sustainable Education, and Education for Sustainable Development are interchangeable terms [15]. Education for Sustainable Development gives learners the knowledge, skills, and values to deal with global challenges such as climate change, loss of biodiversity, unsustainable use of resources, and inequality [16].

Moreover, [17] underscored how imperative it is to equip professionals with knowledge, skills, and values pertinent to sustainability. Embedding ESD into curricula involves students becoming sustainability literate. Sustainability literacy enables students to identify sustainability issues and make decisions that contribute to the preservation of the environment, the welfare of society, and economic prosperity.

2.2 Integration of Sustainability Literacy into curricula

As the notion of sustainability literacy has progressed, there is a growing demand for research focused on the integration of sustainability literacy into educational curricula [18, 19, 20, 21]. Several definitions of Sustainability Literacy exist in the literature. For instance, the United Nations (2018) defines Sustainability Literacy as "the knowledge, skills, and mindsets that allow individuals to become deeply committed to building a sustainable future and assisting in making informed and effective decisions to this end" [4]. In addition, [22] describes SL as "the competence in and knowledge of sustainability concepts."

Sustainability literacy refers to the ability and disposition to think, solve problems, make decisions, and take actions that contribute to achieving sustainability [23]. There is not a unique model to incorporate SL into curricula; indeed, there are several sustainability frameworks that can be adapted to education [24]. For instance, the Engineering for One Planet (EOP) Framework is a sustainability framework that integrates sustainability education into curricula [25]. Arguably, the selection of the appropriate sustainability framework for the educational institution depends on many factors. For example, the academic program, the university's philosophy, the institutional context, the faculty training and experience, the curricula, etc.

Similarly, there are multiple pedagogical approaches to integrate sustainability literacy into curricula. Although [26] stated there is no clear information about how exactly sustainability curricula are implemented, there is data about the types of pedagogical approaches to incorporate sustainability within academic programs. For example, [27] studied different types of pedagogical approaches in sustainability and offered a categorization of high, medium, and low relevance sustainability studies pedagogies. Table 1 shows the high relevance sustainability pedagogies defined by [27]. Although this study does not focus on demonstrating the most effective pedagogical strategies, it is important to mention that Uniminuto University employs high relevance sustainability pedagogies such as problem-based learning, collaborative learning, and active learning in their daily teaching practices.

Table 1 The high relevance sustainability pedagogies

High Relevance and High Confidence Sustainability Pedagogies	
Pedagogical Approach	**Description/Example**
Project/problem-based learning (in an organization/community)	Learning through actively attempting to study/address a community/organizational problem or undertake a project deemed necessary/useful by the class/community/organization.
Integrative learning (inter-and transdisciplinary)	Integrating knowledge/methodologies/methods from more than one disciplinary framework to understand/address complex and context-sensitive issues—contextualizing knowledge and action within relevant socio-ecology.
Project/problem-based learning (in class)	Simulations that mimic actively attempting to study/address a community/organizational problem—undertaking an individual/group/class project deemed by the student(s) and professor to be necessary and useful within a known context but without engaging or by only minimally engaging stakeholders outside of the class.
Active learning (in class)	Learning in which students are actively involved in constructing meaning, making interpretations, and/or applying knowledge—contrasts with passive learning in which students receive content and are expected to internalize and recall that content in basically unchanged form.
Collaborative learning	Learning that involves active collaboration with classmates, community members, and/or others to generate/explore/analyze/interpret/apply several ideas/practices.

3. Institutional Context

Uniminuto is a private catholic university founded in 1990, with a student body of 92,000 as of 2022 [28]. Notably, 59% of the degrees are offered through distance learning, 14% are totally virtual, and 27% are in-person. It has more than 20 campuses in different cities and towns in Colombia. In its institutional philosophy, the university adopted the “Laudato Si”, from Pope Francisco’s Encyclic which refers to promoting sustainable development and “the care of the common home.”

Uniminuto is recognized for its social innovation research activities and Social Innovation Scientific Innovation Park created in 2012 [29]. The primary research focus is addressing transdisciplinary problems in rural and urban communities to conduct cocreation processes that provide solutions aligned with context and territory. For instance, Uniminuto’s engineering students participate in multiple community problem-based learning projects throughout their academic program. The faculty team also fosters and implements research projects focused on sustainable social innovation. For instance, the application of Internet of Things (IoT) and data analytics studies are employed in a rural context with the purpose of improving the productivity in a local farmers association [28].

Moreover, Uniminuto University works together with other Latin-American universities in applying pedagogical strategies such as active learning, collaborative learning, and problem-based learning. For example, Uniminuto University and The Tecnologico de Monterrey have performed several Collaborative Online International Learning (COIL) initiatives to increase

knowledge and awareness in sustainability by analyzing and providing solutions to the regional sustainability issues [31].
The industrial engineering program lasts ten semesters. During the tenth and final semester, students forego traditional classes and instead focus on a final research project and an internship. As a result, the data collection covers a range of students who are distributed from the first to ninth semesters.

4. Research design

To examine the increasing sustainability knowledge of Industrial Engineering students at UniMinuto University Buga Campus, this study used a cross-sectional quantitative research design. The research has the institutional permissions obtained from Uniminuto University's IRB. The student's participation in the study was voluntary and it was not subject to any additional grade obtained in the class. This research was conducted in a rural campus located in a small town called Buga, which offers an in-person BS in industrial engineering.

To collect the data, one of the researchers created the online session that allowed the students to take the Sulitest directly from the Sulitest website. The Sulitest was available for one month, specifically from May 5th to June 5th, 2023. Once the students accessed the Sulitest, the instrument was open until the student completed it within the timeframe. The test results were kept anonymous and confidential and there was no possibility to connect participants to their responses. The courses in which the Sultiest was applied are social responsibility, contemporary social development, legislation, economy, cleaner production, and renewable energy.

To determine to what extent the semester influences the sustainability knowledge scores of the industrial engineering students, this research applied a binary logistic regression. In this section, the instrument used to collect data and the sampling strategy are described as follows.

4.1 The instrument

Sulitest is a standardized online test endorsed by UNESCO that assesses sustainability knowledge and awareness. This instrument was suitable for the study because it serves as a diagnostic tool to assess students' sustainability knowledge at UniMinuto. Sulitest has been validated, indicating a Cronbach's alpha reliability of 0.79 and a standardized Cronbach's alpha of 0.8 in this study, which demonstrates internal consistency. This instrument was administered online, using the Sulitest Platform in the Spanish language.

The instrument comprises 30 multiple choice questions, each with 5 answer options. The final sustainability score can range from 0 to 100 points. The questions are selected randomly from the Core International Module that is widely shared across all countries [12]. Sulitest includes topics such as fundamental and regulatory planetary boundaries, social well-being, governance, economics and finance, science, and technology. It is important to mention that wrong answers do not affect the total score or reduce the number of points obtained from each student.

Sulitest comprises four dimensions and the students receive not only an overall score but also a score for each dimension. The dimensions are described as follows [4]:

1. Sustainable Humanity and Ecosystems: it refers to the individual knowledge of ecosystems, humanity, sustainability, ecological perspective, and social perspective.
2. Global and Local Human-constructed Systems to Answer People's Needs: it examines the participant's knowledge of global and local social structures, governance, and global economic systems. For instance, the use of land, production, consumption, water, energy, and food.
3. The Roles to Play in Fostering Systemic Changes: it measures the knowledge and awareness of the individuals' roles and the impact of their decision-making.
4. Transitions towards Sustainability: it assesses the knowledge of initiatives, concepts, or frameworks towards sustainability. For instance, the framework of cradle to cradle, natural capitalism, or ecological footprint.

4.2 The sample

The sample comprised 105 industrial engineering in-person students, enrolled from the first to the ninth semester at UniMinuto University, in the city of Buga, Colombia. To estimate the sample, a simple random sampling technique and the finitude correction technique was used. This cross-sectional study employed a subgroup of the population representing the 153 which correspond to the entire population of students enrolled in the Industrial Engineering Program. The level of confidence was 95%, the error was 5.5%, and the coverage rate is 70%. Given the homogeneity of the university's student population, this information can be completely extrapolated to the entire student population. The sample size was estimated using the following formula for n:

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

5. Results

A binary logistic regression was applied to assess the significance of sustainability knowledge in relation to the students' educational level. The results show that the variable semester significantly affect the global students' score. To analyze the effect of the variable semester, this model used the odds ratio.

The odds ratio is a statistical measure used to quantify the strength and direction of the association between two binary variables in a case-control study or logistic regression analysis. It provides insight into how the odds of an event or outcome occurring in one group compare to the odds of the same event occurring in another group. The odds ratio is particularly useful when studying the relationship between independent variables and the probability of an event happening. Table 2 shows the coefficients are as follows:

Table 2 The coefficients

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-0.51201	0.43700	-1.172	0.2413
Semester	0.18679	0.08763	2.132	0.0330*

Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Null deviance: 145.55 on 104 degrees of freedom
Residual deviance: 137.29 on 102 degrees of freedom
AIC: 143.29
The ratio can be interpreted in the following way:
Odds Ratio > 1: This indicates that the event is more likely to occur in Group A compared to Group B. In other words, there is a positive association between Group A and the event.

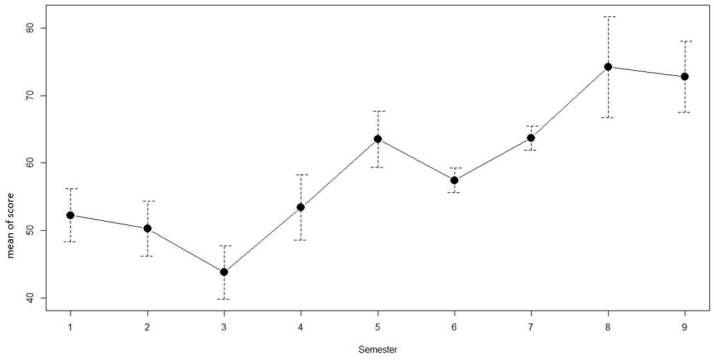
Odds Ratio < 1: This suggests that the event is less likely to occur in Group A compared to Group B. In this case, there is a negative association between Group A and the event.
The Significant Exponentiated coefficients ("odds ratios") for the variable semester is 1.2053698. The probability of achieving higher overall sustainability knowledge scores is approximately 20% as industrial engineering students advance in the academic program. As a result, the variable that significantly affect the global score is semester. In addition, in the logistic regression model, confidence intervals can be calculated for the odds. In this model, the Akaike Information Criterion (AIC) was utilized to select the significant variables. The exponentiated coefficients and the confidence bounds are exhibited in Table 3 where it is seen that the influence of the educational level can range from 1% to 43%.

Table 3 Exponentiated Coefficients and Confidence Bounds

	Estimate	**2.5%**	**97.5%**
Semester	1.2053698	1.0189	1.439335

Moreover, Figure 1 shows the mean of the scores obtained per semester along with a confidence interval to observe the variation in the students' responses. With each subsequent semesters, the mean in the total sustainability score increases, which confirms the aforementioned results.

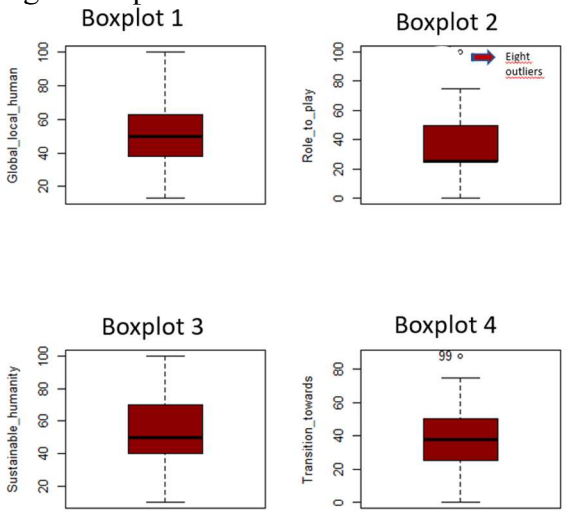
Fig. 1 Mean of total scores per semester



Furthermore, Figure 2 exhibits the boxplots for each of the dimensions. On the Y axis, the score for these dimensions is displayed, and the graph shows the total score as well as the dispersion of those scores. Boxplot 1 refers to Global and Local Human and boxplot 3 corresponds to Sustainable Humanity and Ecosystems. Boxplots 1 and 3 represent homogeneous behaviors distributed throughout the range of values that oscillate between 0 and 100. It is important to highlight that the minimum values observed are 13 and 10, respectively, which represent the existence of some sustainability knowledge on those topics. Likewise, the mean of those two dimensions is 54 and 51, respectively, offering the highest values of the 4 dimensions. For boxplots 2 and 4, Roles to Play in Fostering Systemic Changes and Transitions towards

Sustainability, the lowest mean values are 37 and 38, respectively. These two dimensions demonstrate that there are students with a high level of sustainability knowledge and others with a low level of sustainability knowledge. Boxplot 2 contains 8 outliers while boxplot 4 shows 1 outlier (points outside the expected range). As a result, it is evident that students have high individual sustainability knowledge although the group mean is lower.

Fig. 2 Boxplots for each of the dimensions



6. Discussion

The role of higher education is pivotal in fostering sustainable development at a local and global scale. In this sense, Uniminuto University has promoted education for sustainable development across both urban and rural campuses. At Buga Campus, the industrial engineering curriculum has incorporated sustainability competencies into curricula. Consequently, embracing sustainability into curricula helps future graduates to increase the sustainability-relevant knowledge, skills, and values [17].

By integrating sustainability topics into curricula and combining active learning pedagogical strategies, students can develop sustainability literacy. For instance, at Uniminuto Buga Campus, during the first two semesters of enrollment in the industrial engineering program, the students take a social responsibility course. In addition, through the last two semesters of enrollment in the program, the students take cleaner production and renewable energy applications courses. Table 4 shows the courses and topics that students can take in the Industrial Engineering program.

Table 4 Courses and Topics

Semester	Course Title	Topics
1-2	Social Responsibility	Introduction to the SDGs.
3-4	Contemporary social development	Social equity, planetary boundaries.
5-6	Legislation	Country's system of laws, public policies and their effects on society and the environment.
7-8	Economy	Supply and demand, new theories of development, planetary limits.

9 -10	Cleaner production or Renewable energy (Electives)	Clean energy sources and how to apply them in the Latin American context.

Taking those courses help students to enhance their knowledge in sustainability, as well as to become sustainability literate. Indeed, this study indicates that while students advance in the industrial engineering program, there is approximately 20% probability of obtaining higher overall sustainability knowledge. This is consistent with the fact that students are exposed to sustainability issues as they proceed through their studies, leading to greater knowledge of this topic as they advance in the academic program.

The logistic regression model shows that students can boost sustainability knowledge up to 43% each semester. In other words, the influence of the variable semester on the increasing in sustainability knowledge can range from 1% to 43%. Higher educational levels, in terms of semesters at the university, are associated with a higher likelihood of obtaining a better overall sustainability knowledge score. Exposing engineering students to local community problems and having them provide solutions to address sustainability issues allows them to develop sustainability literacy. This finding supports the idea that SL can be learned because of direct instruction in sustainability topics [32] and several teaching strategies can be used [33].

Even though there are multiple pedagogical strategies to foster sustainability knowledge in higher education, problem-based learning is one of the most relevant teaching strategies [27]. At Uniminuto Buga Campus, faculty implement a variety of teaching strategies such as but not limited to lecturing, project-based learning, research-based learning, group discussion, and collaborative learning. For instance, the industrial engineering program has a strong emphasis on research and project-based learning because during the first two semesters, students have a research seminar focused on how to solve a real engineering problem. The students work on performing an analysis of the problem in their first two semesters and a solution to the same problem during their last two semesters of enrollment in the program.

Particularly in this rural campus, the industrial engineering students and faculty developed new products and services to respond to the local community's sustainability needs. By supporting community projects that incorporate encyclical principles and provide sustainable solutions to address local sustainability problems, the engineering industrial students, guided by a group of professors, created a biodigester prototype to enhance efficiency and take advantage of waste from agricultural production. Every semester, more engineering problems related to sustainable development are observed, researched, and analyzed, such as carbon footprint measurement, green logistics, renewable energies, or energy efficiency. As a result, Uniminuto University is an example of the positive impact of promoting education for sustainable development in a local community.

7. Limitations

This research is limited to engineering students. In the future, it would be interesting to compare sustainability literacy in other academic programs and disciplines, for instance, business administration related programs, civil engineering, construction management, social work, and teacher education. A cross-sectional design is suitable for this research because it provides an understanding of the state of sustainability knowledge among the sample of industrial

engineering students enrolled in 2023 at Uniminuto University. However, longitudinal studies can offer the opportunity to analyze the increase in sustainability knowledge across different periods and potential causal associations.

Furthermore, this research provides an overall understanding of the industrial engineering students' sustainability knowledge at a specific point in time. It constitutes of a starting point to analyze the progress and increase in knowledge at this Higher Education Institution. However, examining the increase in sustainability knowledge and its relationships with other variables such as types of generations, socio-economic conditions, or cultural context can provide useful information about the effects on sustainability learning.

8. Conclusion

Rural and urban educational institutions can boost economic growth, environmental integrity, and social well-being by increasing sustainability knowledge and awareness across faculty, students, and their communities. The findings are consistent with the fact that students are exposed to sustainability issues as they proceed through their studies, leading to greater knowledge of this topic as they advance in the academic program. This study highlights the importance of incorporating sustainability competencies into curricula. It mentions a variety of pedagogical strategies and provides examples of how the application of project-based and research-based learning contribute to increased sustainability literacy across engineering curricula.

In the future, studies that measure the effectiveness of the different pedagogical strategies to improve sustainability knowledge are needed. Further research that includes sustainability literacy in curricula is essential, particularly pre and post interventions that explain causality relationships. Research can also be extended to assess sustainability knowledge and to measure sustainable behavior and attitudes toward sustainability in HEIs located in developed and developing countries.

The results exhibit statistically significant differences between sustainability knowledge scores and the semester students are enrolled in the program, demonstrating that students' sustainability knowledge and skills increase while they are receiving formal instruction at the higher educational institution. The results are valuable because they point out the significant importance of designing sustainability courses and integrating sustainability competencies in academic engineering programs. This study contributes to a better understanding of the integration of sustainability into curricula. Even though this is a process that implies curricular change, faculty's professional development, and a noteworthy effort in the implementation of different pedagogical strategies, the results lead to a paradigm shift in educating students for sustainable development. More research is needed in promoting education for sustainable development.

The insights provided in this study open an avenue for conducting research in topics such as sustainability literacy, sustainability competencies, sustainability learning outcomes, and evaluation for sustainability at the micro-level through teaching and learning courses. This study offers an invitation to the academic community to explore how to better integrate sustainability literacy into curricula; how to assess components of learning outcomes in other regions and

disciplines; how to incorporate flexible and adaptable sustainability frameworks to foster ESD. Further studies should investigate the influence of sustainability literacy, sustainability competencies, and sustainability learning outcomes on knowledge, attitudes, and sustainable behaviors. More research is needed to understand the associations between sustainability knowledge, attitudes towards sustainability, intention to adopt pro-environmental behaviors, and pro-environmental behaviors among faculty and students at all educational levels. Additional research is necessary to delve into the differences between educational levels, generations, urban/rural students, socio-demographic factors, and their impact on promoting sustainability literacy.

Moreover, there is a necessity for conducting qualitative studies aimed at exploring sustainability literacy, sustainability knowledge, attitudes towards sustainability, and sustainable behaviors across different academic disciplines and geographical zones to foster education for sustainable development. Furthermore, quantitative studies need to be pursued to understand the impact of sustainability literacy and ESD on educational settings. Besides mixed methods and quantitative approaches, experimental research between-subject designs, withing group designs, quasi-experimental, correlational, as well as cross-sectional and longitudinal designs are needed to comprehend the influence of sustainability literacy on educational interventions. Additional research on sustainability literacy encourages faculty, deans, and educational leaders to motivate change at the macro-level through fostering new programs, initiatives, and curricula that incorporate sustainability across higher education institutions. Finally, it is important to highlight to the extent that HEIs incorporate and assess sustainability learning outcomes into curriculum, the future generations of leaders will be prepared to promote a more sustainable future.

References

1. A.V. Agbedahin. "Sustainable development, Education for Sustainable Development, and the 2030 Agenda for Sustainable Development: Emergence, efficacy, eminence, and future." *Sustainable Development* 27.4 (2019): 669-680.
2. G. Cebrián, D. Pascual, and A. Moraleda. "Perception of sustainability competencies amongst Spanish pre-service secondary school teachers." *International Journal of Sustainability in Higher Education* 20.7 (2019): 1171-1190.
3. S.J. Sanchez, M. Rueda, and D.L. Robertson. "Measuring Sustainability Literacy in Undergraduate and Graduate Engineering Students in a Colombian University." *2023 ASEE Annual Conference & Exposition*. 2023.
4. A. Décamps, G., Barbat, J.C., Carteron, V. Hands, and C.Parkes. "Sulitest: A Collaborative Initiative to Support and Assess Sustainability Literacy in Higher Education." *The International Journal of Management Education*, vol. 15, no. 2, July 2017, pp. 138–152, https://doi.org/10.1016/j.ijme.2017.02.006
5. M.R. Gavinolla, L. Agita, and K.S. Sampada. "State of the Research on Teacher Education and Sustainability: A Bibliometrics Analysis." *Journal of Teacher Education for Sustainability* 24.2 (2022): 147-165.
6. L. Zizka, and P. Varga. "Teaching sustainability in higher education institutions: Assessing hospitality students' sustainability literacy." *Journal of hospitality & tourism education* 33.4 (2021): 242-257.

7. E. C. Briens, Y. Chiu, D. Braun, P. Verma, G. Fiegel, B. Pompeii, & K. Singh. "Assessing sustainability knowledge for undergraduate students in different academic programs and settings." *International Journal of Sustainability in Higher Education* 24.1 (2023): 69-95.
8. E. Giovannoni and F. Giacomo. "What is sustainability? A review of the concept and its applications." *Integrated reporting: Concepts and cases that redefine corporate accountability* (2013): 21-40.
9. Initiative, Global Reporting. "G4 sustainability reporting guidelines: reporting principles and standard disclosures." *Global Reporting Initiative, Amsterdam* (2013): 7-14.
10. J. Mensah. "Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review." *Cogent social sciences* 5.1 (2019): 1653531.
11. D.L. Little. "Defining sustainability in meaningful ways for educators." *Journal of Sustainability Education* 7 (2014): 1-18.
12. G.H. "Report of the World Commission on Environment and Development: Our common future." *Accessed Feb* 10 (1987): 1-300.
13. M. Barth, J. Godemann, M. Rieckmann, & U. Stoltenberg. "Developing key competencies for sustainable development in higher education." *International Journal of sustainability in higher education* 8.4 (2007): 416-430.
14. M. Ferrer-Estévez, and R. Chalmeta. "Integrating sustainable development goals in educational institutions." *The International Journal of Management Education* 19.2 (2021): 100494.
15. S. Sterling, "The future fit framework: An introductory guide to teaching and learning for sustainability in HE (Guide)."*Journal of Education for Sustainable Development* 7, no. 1, 2013, pp. 134-135.
16. UNESCO web page "Education for sustainable development." https://www.unesco.org/en/education-sustainable-development
17. P. E, Murray. and A. J Cotgrave. “Sustainability Literacy: The Future Paradigm for Construction Education?” *Structural Survey*, vol. 25, no. 1, 10 Apr. 2007, pp. 7–23, https://doi.org/10.1108/02630800710740949
18. UNESCO. *Reimagining our futures together: A new social contract for education*. UN, 2022.
19. K. Ceulemans, I. Molderez, and L.V. Liedekerke. "Sustainability reporting in higher education: a comprehensive review of the recent literature and paths for further research." *Journal of Cleaner Production* 106 (2015): 127-143.
20. C.J. Desha, K. Hargroves, and M. H. Smith. "Addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development." *International Journal of Sustainability in Higher Education* 10.2 (2009): 184-199.
21. M. Shriberg. "Institutional assessment tools for sustainability in higher education: strengths, weaknesses, and implications for practice and theory." *Higher education policy* 15.2 (2002): 153-167.
22. N. Barnes. "Institutional attempts to measure student sustainability knowledge." *Sustainability: The Journal of Record* 7.2 (2014): 104-108.
23. V. Nolet. "Preparing sustainability-literate teachers." *Teachers college record* 111.2 (2009): 409-442.

24. Kopnina, Helen. "Sustainability in environmental education: new strategic thinking." Environment, development, and sustainability 17.5 (2015): 987-1002.
25. Engineering for One Planet, The Engineering for One Planet Framework, Essential Sustainability-Focused Learning Outcomes for Engineering Education (The Lemelson Foundation, Portland, 2022). https://engineeringforoneplanet.org/wp-content/uploads/2022_EOP_Framework_110922.pdf
26. M. Weiss, M. Barth, and H. von Wehrden. "The patterns of curriculum change processes that embed sustainability in higher education institutions." *Sustainability Science* 16.5 (2021): 1579-1593.
27. T.L. Evans. "Competencies and pedagogies for sustainability education: A roadmap for sustainability studies program development in colleges and universities." *Sustainability* 11.19 (2019): 5526.
28. Colombian Ministry of Education. “Public consultation: student population”, 2022. https://hecaa.mineducacion.gov.co/consultaspublicas/poblacionalies?p_anio=2022&p_semestre=0&p_variable=ADMITIDO&p_depto=COL
29. S. Calvo, A. Morales, and J.E. Arias Gómez. "Applying Strategic Niche Management to understand how universities contribute to the development of social innovation niches: the case of the Social Innovation Scientific Park in Colombia." *Recerca. Revista de Pensament i Anàlisi* 23 (2018): 95-130.
30. J. M Osuma “Agtech implementation for the management of the agricultural sector, in the management of crop production, in the province of Tequendama, Colombia.” *Techno Review*, 2.7 (2023)
31. J. Membrillo-Hernández, W. J Cuervo-Bejarano, L. A. Mejía-Manzano, P. Caratozzolo, & P. Vázquez-Villegas. "Global Shared Learning Classroom Model: A Pedagogical Strategy for Sustainable Competencies Development in Higher Education."*International Journal of Engineering Pedagogy* 13.1 (2023).
32. S. Ling, A. Landon, M. Tarrant, & D. Rubin. "The influence of instructional delivery modality on sustainability literacy." *Sustainability* 13.18 (2021): 10274.
33. M. Biasutti, T.De Baz, and H. Alshawa. "Assessing the infusion of sustainability principles into university curricula." *Journal of Teacher Education for Sustainability* 18.2 (2016): 21-40.