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Integration of Sustainability in STEM Programs: Assessing Student Knowledge and Perceptions

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Abstract

In recent years, there has been a growing emphasis on integrating sustainability into STEM education, driven by the urgent need to address environmental and social challenges and equip future generations with the knowledge and skills necessary to promote sustainable development. It is essential to adapt science, technology, engineering, and mathematics education to contemporary needs, including sustainable development, ethical competencies, and preparation for the evolving demands of the global STEM landscape. Numerous educational efforts are underway to incorporate these competencies into STEM curricula, ensuring that future professionals can design innovative and sustainable solutions to emerging economic, environmental, and social challenges. To effectively integrate the competency of "sustainability" into these programs, it is crucial to assess the current state of sustainability learning among students to develop comprehensive strategies. This research aims to evaluate the level of knowledge among Geology and Industrial Engineering students regarding sustainability and the United Nations' Sustainable Development Goals (SDGs). Additionally, it seeks to measure students' understanding and perception of the importance of the SDGs in their daily lives and academic training. The study employed a quantitative, non-experimental, descriptive research design. Data were collected via an adapted and validated questionnaire administered to first- and fifth-year students from both programs at a private Chilean university. The instrument measured knowledge, attitudes, and perceptions of sustainability and the SDGs across multiple constructs. The findings revealed that while students recognize the relevance of sustainability and the SDGs, significant differences exist between programs, with Industrial Engineering students consistently scoring higher than Geology students. Differences by academic year were minimal, and the sample was composed predominantly of first-year students. Students valued the role of sustainability in both personal and educational contexts yet reported limited exposure to sustainability topics in formal coursework. These results highlight the need for more systematic and integrated sustainability education in STEM programs. This study contributes to the growing body of research on sustainability education in geosciences and engineering in Latin America, offering insights for curriculum development and policy formulation to prepare professionals committed to sustainable development.

Keywords: engineering education for sustainability, SDGs, student perceptions, sustainable development, sustainability education

INTRODUCTION

In recent years, there has been an increasing emphasis on integrating sustainability into geoscience education, driven by the need to address environmental challenges and equip future generations with the knowledge and skills necessary to promote sustainable development [1-3]. This shift seeks to incorporate sustainability and related skills into curricula, fostering competencies to face global challenges. Additionally, it is crucial to highlight the importance of adapting engineering education to contemporary needs, including sustainable development and preparation for global demands [4]. This approach not only contributes to training technically skilled engineers but also professionals who are ethical and committed to creating sustainable solutions for current environmental problems [5]. To define how the competence of "sustainability" should be integrated into the curricula of STEM programs, it is essential to assess current knowledge of sustainability and design strategies to improve its integration into academic programs [6].

The relevance of sustainability and engineering education lies in the urgent need to train engineers who not only possess technical skills but are also committed to sustainable development. For this purpose, engineering education must prioritize not only technical skills but also the social, economic, and environmental dimensions of sustainability [7]. As the world faces unprecedented environmental and social challenges, it is critical for engineers to develop competencies in sustainability, ethics, and social responsibility. Ethics and social responsibility are essential to ensuring that engineers consider the societal and environmental impacts of their work [7]. Numerous educational efforts aim to integrate these competencies into engineering programs, ensuring that future professionals can design innovative and sustainable solutions to emerging economic, environmental, and social challenges, including education, gender equality, and resource management [8]. Education for Sustainable Development (ESD) must go beyond mere knowledge transfer, fostering critical thinking, creativity, and the capacity to take action [9-10].

Engineering discipline is the cornerstone of all Sustainable Development Goals. According to Décamps et al. [11], engineers must possess sustainability literacy to make informed decisions and act responsibly. This includes understanding sustainability principles and the ability to apply these principles in engineering practice. However, the extent to which engineering contributes to achieving these goals will depend on the profession's ability to reorient its focus on education, training, and the development of engineers [12]. Sustainability is not merely an additional component but a central axis in training engineers capable of leading the transition toward a more equitable and sustainable future. Related studies have reported that active and collaborative methodologies and an emphasis on interdisciplinarity and internationalization are essential to developing these competencies and ensuring that engineers are prepared to contribute meaningfully to global well-being and sustainable development [11, 13-14].

Background

Over the years, Education for Sustainable Development (ESD) has gained international recognition as an integral component of quality education and a key enabler of sustainable development. ESD aims to empower individuals and future leaders to address 21st-century challenges by promoting changes in values, attitudes, and lifestyles. It is intrinsically linked to the United Nations' 2030 Agenda and its Sustainable Development Goals (SDGs) [11]. The integration of sustainability into STEM curricula has been extensively studied, with the literature identifying four major research areas, as outlined by Narong & Hallinger (2024) [8]: (1) Reforming engineering education toward sustainability, (2) Competencies, pedagogy, and curricula for sustainability in engineering, (3) Evaluating engineering curricula and sustainability benchmarks, and (4) Sustainable technologies in engineering. Regarding the third area, research has primarily focused on assessing the effectiveness of incorporating sustainability into engineering education [15-17].

To evaluate the effectiveness of sustainability integration in engineering education, several studies have employed surveys and questionnaires to measure students' conceptual knowledge, skills, competencies, and attitudes toward sustainability [6, 16-18]. These investigations have been validated using questionnaires, surveys, and scoring rubrics to assess students' knowledge, skills, and attitudes. Collaborative tools such as the "Sulitest" survey have also been employed to support and evaluate sustainability literacy in higher education [11]. The findings suggest that while students acknowledge the importance of sustainability values and goals in engineering, they face challenges in applying a sustainability mindset to engineering practice [15-16, 19].

Surveys have also evaluated integrating sustainability topics into engineering education programs [6, 19]. These surveys focus on the relationship between engineering and the environment, with less attention paid to sustainable development's social and economic dimensions. Furthermore, engineering students often lack familiarity with environmental legislation, policies, and standards [8, 15]. This highlights the need for more systematic and balanced coverage of sustainability topics within engineering [20]. The literature also shows that most research in this field has been conducted in the United States, Europe, and Asia, particularly China [8]. However, the dominance of developed nations in contributing to this knowledge base underscores the need to pay greater attention to educational trends in developing societies [16]. This will ensure that the knowledge base on sustainability education in engineering generates solutions relevant to societies worldwide.

The literature on integrating sustainability into STEM education highlights significant progress in developing instruments to evaluate knowledge, competencies, and attitudes toward sustainability. However, it also emphasizes the importance of further investigation into these topics, particularly in specific contexts that allow for deeper exploration of aspects relevant to local and regional characteristics. In this study, the instrument developed by Zamora-Polo et al. [16] serves as the foundation, supplemented with additional questions designed to explore issues specific to our educational context.

The main objective is to comprehensively assess the level of knowledge, skills, and attitudes toward sustainability among higher education students in STEM programs at a private Chilean university. This assessment will include an analysis of students' perceptions regarding the relevance of the Sustainable Development Goals (SDGs) in their personal lives and future professional careers. The findings will provide key information for designing appropriate strategies in the future to integrate sustainability into academic programs effectively. These strategies will ensure that they are educational, effective, and contextualized, addressing STEM programs' specific needs and characteristics in the studied context.

The research questions guiding this study are:

What is the level of knowledge students at a private Chilean university have about sustainability and the United Nations SDGs? How have these students learned about the SDGs?

What level of importance do students attribute to the SDGs in their personal lives and future professional careers? How do these differences vary based on the student's year of study and academic program?

This article is structured as follows: The Methodology section describes the instrument and data collection procedure; the Results section presents the main findings on students' knowledge, skills, and attitudes toward sustainability and the SDGs; the Discussion analyzes the results considering existing literature; and the Conclusions synthesize the study's contributions, limitations, and future directions.

METHODOLOGY

The present study used a quantitative approach and a non-experimental descriptive research design. This approach allows for diagnosing the level of knowledge and understanding of sustainability and the SDGs among students at different stages of their university education.

Sample and context

The sample comprised 121 students from the Geology (n=71) and Industrial Engineering (n=50) programs. Both groups included first-year (n=79) and fifth-year students (n=42), allowing for a comparison of perceptions and levels of knowledge about sustainability at different stages of their academic training. This research was conducted at a private university with three campuses nationwide—Santiago, Vina del Mar, and Concepcion—focusing on the Concepcion campus. Although Geology is a scientific field, it is housed within the Faculty of Engineering at this university. At the Concepción campus, Geology and Industrial Engineering are the programs with the most active students, with 207 and 155 students, respectively. In addition to academic program and year, gender was considered a relevant demographic variable in the analysis. This allowed the study to explore whether perceptions and knowledge about sustainability varied by gender.

Instrument

A literature review of previous studies on questionnaires measuring sustainability knowledge in students was conducted. The instrument developed by Zamora-Polo et al. [16] was selected as the most suitable for achieving the study’s objectives. The selected questionnaire is designed and validated to measure the level of knowledge of the Sustainable Development Goals (SDGs) and is structured into five blocks of questions:

1. Sociological data of the students.
2. Prior knowledge of the SDGs and the sources of this knowledge.
3. Relationship between the SDGs and the profession for which students are trained.
4. Relationship between the SDGs and their personal lives.
5. Development of SDG-related topics during university studies.

Except for the first block (sociological data), the questions were answered using a five-point Likert scale, ranging from 1 ("Strongly disagree") to 5 ("Strongly agree").
Additionally, the questionnaire included extra questions at the end, covering:

- The sustainability education received during university.
- The socio-economic impact of sustainability-related topics.
- The university’s engagement with sustainability.

These additional questions were also answered using the five-point Likert scale.
Finally, the questionnaire underwent a process of translation, contextual adaptation, and student validation, following the methodology reported by Zamora-Polo et al. and Sánchez-Carracedo et al. [16, 18]. The process involved two stages:

- Validation by a group of students: They assessed the clarity of the items and the time required to complete the questionnaire.
- Review by a group of experts: They analyzed the clarity and relevance of each question concerning the study’s objectives.

Data process

JASP (version 0.18.3) was used as the statistical analysis software to analyze the obtained data. The normality of the data was assessed using the Shapiro-Wilk test. Since the p-value was less than 0.05 for all variables, the null hypothesis of normality was rejected. As a result, non-parametric statistical techniques, which do not assume data normality, were applied for subsequent analyses. The Mann-Whitney U test was employed to evaluate differences between groups by academic program, year of study (first vs. fifth year), and gender, and the results are summarized in Table 2.

Descriptive analyses were also conducted to complement the inferential results. Tables 3 and 4 present detailed descriptive statistics, including means, standard deviations, standard errors, and coefficients of variation, organized by academic program and gender, respectively. These descriptive insights provide further context to the differences observed in students' perceptions of topics related to the Sustainable Development Goals (SDGs). All tests were conducted at a significance level of $\alpha=0.05$, corresponding to a 95% confidence interval. The hypothesis tested was $G1 \neq G2$.

RESULTS

The adapted questionnaire of Zamora-Polo et al. [16] measures eight different constructs. The first of them (C1) is related to the student’s perception of the knowledge of Sustainable Development Goals (involving Q5–Q8). The second one (C2) is associated with the source of this knowledge (Q9–Q12). The following three constructs (C3, C4, and C5) attempt to measure the degree of relationship perceived by the students between the SDGs and their future professional life (Q13–Q29), their personal life (Q30–Q46), and the training received in the university environment (Q47–Q63), respectively. Additionally, the sixth construct (C6) focuses on the perception of sustainability in university education (involving Q64–Q66). The seventh construct (C7) evaluates the relationship between the university environment and sustainability (Q67–Q69). Finally, the eighth construct (C8) measures the socio-economic impact of university sustainability policies (Q70–Q71).

Descriptive analysis

This section presents the results of the descriptive analysis conducted to understand students' perceptions of topics related to the Sustainable Development Goals (SDGs) across different constructs (Table 1). The analysis examined the average responses to key questions grouped by construct, differentiating between study programs (Geology and Industrial Engineering) and academic years (first and fifth year). This analysis aims to identify patterns and differences in student perceptions, providing an overview of their level of knowledge, involvement, and valuation of the SDGs within the context of higher education.

Table 1 shows the average for each construct by study program and academic year. Overall, very few differences were observed between the results obtained for first and fifth-year students across all constructs. It was also noted that the averages for C1 and C2, related to students' prior knowledge of the SDGs and the sources of such knowledge, are lower than the rest of the constructs.

Table 1. Average perception of students on SDG-related topics by construct and subgroups.

Construct	Topic	Mean (Total)	Mean_ Geo	Mean_ Ind	Mean_ 1stY	Mean _5thY
C1	Knowledge of SDGs	3.112	2.901	3.410	3.133	3.071
C2	Sources of information	3.045	2.845	3.330	3.025	3.083
C3	Professional implication of SDGs	3.768	3.648	3.939	3.759	3.784
C4	Personal implication of SDGs	3.624	3.597	3.662	3.581	3.706
C5	Training received at the university	3.571	3.399	3.814	3.599	3.517
C6	Sustainability in university education	3.785	3.634	4.000	3.819	3.722
C7	Relationship between the university environment and sustainability	3.972	3.840	4.160	4.059	3.810
C8	Socio-economic impact	3.876	3.739	4.070	3.994	3.655

Figure 1 shows the average scores for questions corresponding to Construct 1 by study program and academic year. The overall average for this construct was 3.112 on a scale of 1 to 5. Students from Industrial Engineering achieved the highest score (3.410), while students from Geology scored lower (2.901).

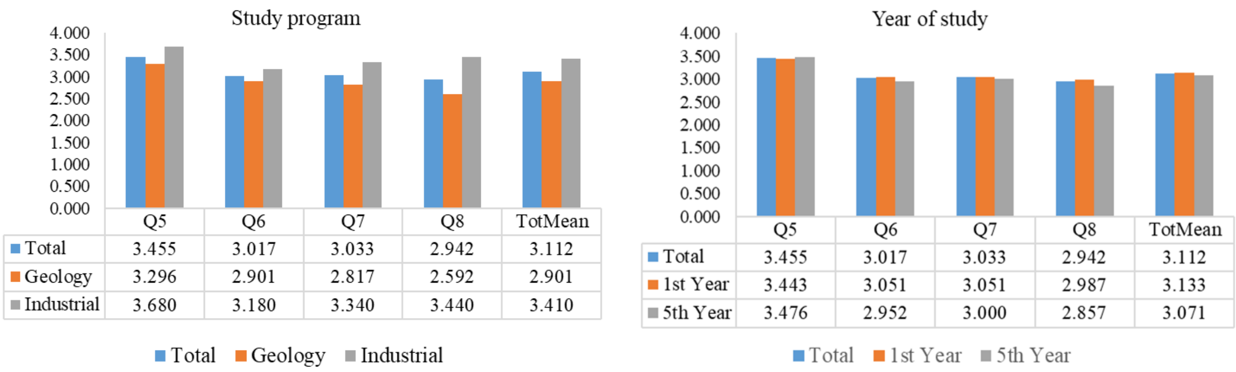


Figure 1. Mean scores Construct 1 (Knowledge of SDGs) by study program and year of study.

Regarding the individual questions within this construct (Q5-Q8), students appear to have a general understanding of the SDGs but limited knowledge about the countries they target, the timeframe for their implementation, the total number of SDGs, and their specific goals. No differences were observed between the knowledge displayed by first-year and final-year students in either study program.

A similar pattern is observed in questions related to Construct 2 (C2). In questions Q9–Q12, students shared their opinions on where they have received information about the SDGs (Figure 2). Overall, the scores for all four items were lower among Geology students. For both study programs, formal education (Q11) was the most frequent source of information. At the same time, traditional media (press, radio, and/or television) and informal training through activities with nonprofit organizations received the lowest scores. No significant differences were observed between first and fifth-year students.

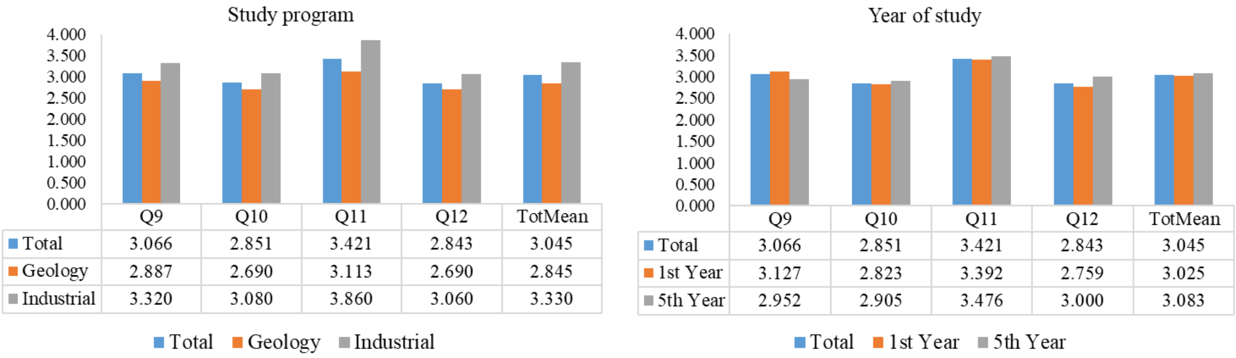


Figure 2. Mean scores for Construct 2 (Sources of Information) by study program and year of study.

For the questions related to Construct 6 (C6, Q64–66), students shared their opinions on the education they received about sustainability at the university (Figure 3). Lower scores were also observed among Geology students. For both study programs, the item with the lowest score (Q64) referred to instructors' emphasis on sustainability topics in their classes. Students from both programs agreed that sustainability should be applied to the development of their learning processes, with an average score of 3.975 (Q65), and that the university has an impact on the social and productive sectors in terms of sustainability, with an average score of 3.884 (Q66). No significant differences were found between first and final-year students in any of the questions within the construct.

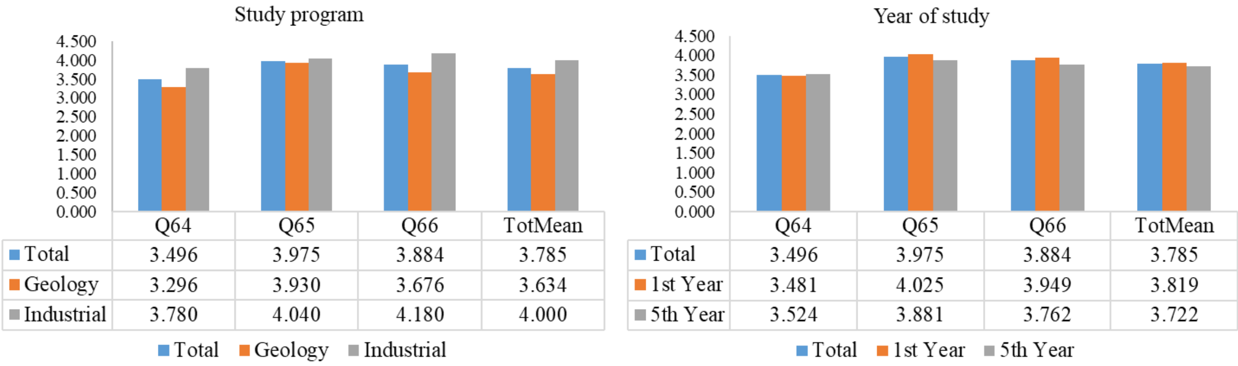
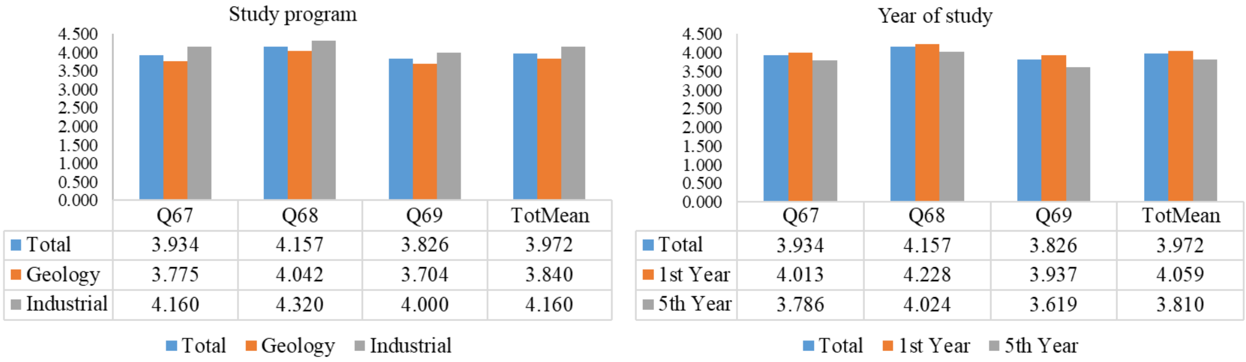


Figure 3. Mean scores for Construct 6 (Sustainability in University Education) by study program and year of study.

In the questions related to Construct 7 (C7, Q67–69), students shared their opinions on the university's engagement with sustainability issues (Figure 4). Lower scores were again observed among Geology students. This construct had the highest overall average (3.972). For both study programs, the item with the lowest score (Q69) was related to the existence of a sustainability policy at the university. The item with the highest score (4.157) reflected students' importance of sustainability for training, academic development, and professional growth (Q68). Regarding the item where students consider that sustainability initiatives are implemented at their university (Q67), the average score was 3.934.

Unlike other constructs, differences were observed between first and final-year students for each question in this construct. First-year students tended to agree more strongly with the questions in this construct than final-year students.

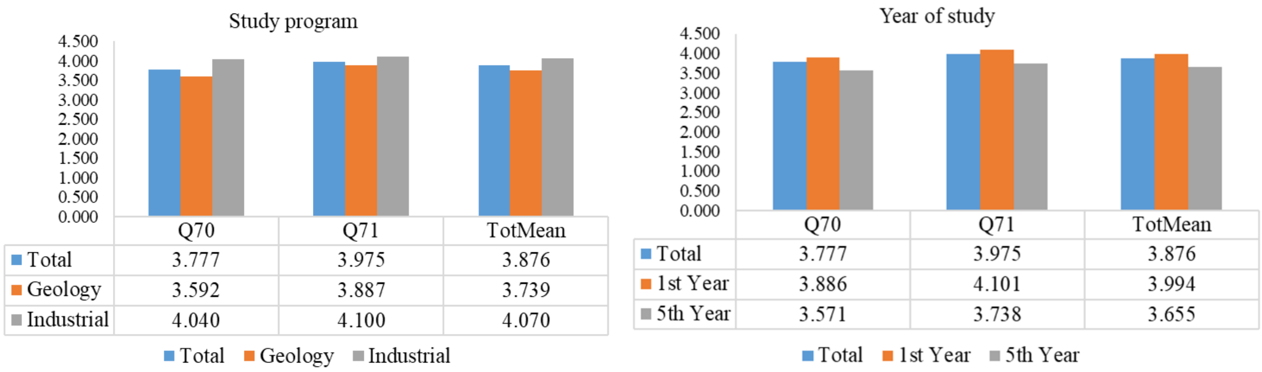


Study program	Q67	Q68	Q69	TotMean
Total	3.934	4.157	3.826	3.972
Geology	3.775	4.042	3.704	3.840
Industrial	4.160	4.320	4.000	4.160

Year of study	Q67	Q68	Q69	TotMean
Total	3.934	4.157	3.826	3.972
1st Year	4.013	4.228	3.937	4.059
5th Year	3.786	4.024	3.619	3.810

Figure 4. Mean scores for Construct 7 (Relationship between the university environment and sustainability) by study program and year of study.

Finally, in the questions related to Construct 8 (C8, Q70 -71), students shared their opinions on the socio-economic impact of university sustainability initiatives (Figure 5). Lower scores were again observed among Geology students. The question regarding the impact of their university's sustainability policy on sustainable education (Q70) had an average score of 3.777. In contrast, the question of whether universities should undertake projects that impact society in social, economic, and environmental aspects (Q71) received an average score of 3.975. Similar to Figure 3, first-year students showed stronger agreement with the construct's questions than final-year students.



Study program	Q70	Q71	TotMean
Total	3.777	3.975	3.876
Geology	3.592	3.887	3.739
Industrial	4.040	4.100	4.070

Year of study	Q70	Q71	TotMean
Total	3.777	3.975	3.876
1st Year	3.886	4.101	3.994
5th Year	3.571	3.738	3.655

Figure 5. Mean scores for Construct 8 (Socio-economic impact) by study program and year of study.

In summary, the results show minimal differences between first and fifth-year students, although variations between study programs are evident, with Industrial Engineering students generally achieving higher scores. Constructs related to prior knowledge and sources of information (C1 and C2) stand out as having the lowest averages, while constructs related to sustainability within the university environment (C6 and C7) reflect a more favorable perception. These findings underscore the importance of strengthening sustainability education and integrating the SDGs into academic programs to impact student development positively.

Notably, the number of first-year respondents (n=79) is notably higher than that of fifth-year students (n=42). This uneven distribution may partly explain why the total means across constructs tend to align more closely with the values reported for first-year students. This factor has been acknowledged when interpreting the results.

Inferential Analysis

The normality of the data was assessed using the Shapiro-Wilk test. Since the p-value was less than 0.05 for all variables, the null hypothesis of normality was rejected. Consequently, non-parametric. Statistical techniques were employed for subsequent analyses, which do not assume data normality. The tests were conducted at a significant level of α=0.05, corresponding to a 95% confidence interval. The hypothesis tested was $G1 \neq G2$

Table 2. Mann-Whitney U Test results for differences in SDG perceptions by academic program and gender.

Construct	Comparison	Significativity (p-value, W)
C1	Male/Female	0.273, 1897.000
	Geology/Industrial	***0.003, 1221.500***
C2	Male/Female	0.875, 1664.500
	Geology/Industrial	***0.002, 1176.500***
C3	Male/Female	0.299, 1501.000
	Geology/Industrial	***0.008, 1269.000***
C4	Male/Female	0.309, 1505.000
	Geology/Industrial	0.576, 1668.500
C5	Male/Female	0.234, 1473.000
	Geology/Industrial	***0.020, 1334.000***
C6	Male/Female	0.186, 1451.000
	Geology/Industrial	***0.005, 1243.000***
C7	Male/Female	0.145, 1427.000
	Geology/Industrial	***0.010, 1291.500***
C8	Male/Female	***0.045, 1329.000***
	Geology/Industrial	***0.029, 1369.500***

Note. Mann-Whitney U test. Significativity <0.05.

Following the inferential analysis, descriptive statistics and the corresponding tables presenting the means and detailed summaries of the analyzed variables are provided (Tabs. 3 & 4). These tables further illustrate the differences observed in the perceptions of students from Geology and Industrial Engineering programs and between male and female students regarding the Sustainable Development Goals (SDGs).

Table 3. Descriptive statistics by study program.

	Group	N	Mean	SD	SE	Coefficient of variation
MTC1	Geo	71	2.915	1.017	0.121	0.349
	Ind	50	3.434	0.917	0.130	0.267
MTC2	Geo	71	2.859	0.998	0.118	0.349
	Ind	50	3.354	0.730	0.103	0.218
MTC3	Geo	71	3.642	0.696	0.083	0.191
	Ind	50	3.940	0.598	0.085	0.152
MTC4	Geo	71	3.593	0.734	0.087	0.204
	Ind	50	3.662	0.702	0.099	0.192
MTC5	Geo	71	3.393	1.020	0.121	0.300
	Ind	50	3.820	0.790	0.112	0.207
MTC6	Geo	71	3.632	0.833	0.099	0.229
	Ind	50	4.002	0.819	0.116	0.205
MTC7	Geo	71	3.841	0.751	0.089	0.195
	Ind	50	4.162	0.833	0.118	0.200

	Group	N	Mean	SD	SE	Coefficient of variation
MTC8	Geo	71	3.739	0.894	0.106	0.239
	Ind	50	4.070	0.886	0.125	0.218

Note. MT stands for Mean Total, and C represents the construct.

Table 4. Descriptive statistics by gender.

	Group	N	Mean	SD	SE	Coefficient of variation
MTC1	Female	44	3.243	0.949	0.143	0.293
	Male	77	3.065	1.038	0.118	0.339
MTC2	Female	44	3.041	0.957	0.144	0.315
	Male	77	3.077	0.915	0.104	0.297
MTC3	Female	44	3.682	0.695	0.105	0.189
	Male	77	3.813	0.657	0.075	0.172
MTC4	Female	44	3.541	0.744	0.112	0.210
	Male	77	3.668	0.704	0.080	0.192
MTC5	Female	44	3.468	0.883	0.133	0.255
	Male	77	3.627	0.990	0.113	0.273
MTC6	Female	44	3.673	0.817	0.123	0.222
	Male	77	3.849	0.858	0.098	0.223
MTC7	Female	44	3.859	0.772	0.116	0.200
	Male	77	4.039	0.811	0.092	0.201
MTC8	Female	44	3.682	0.934	0.141	0.254
	Male	77	3.987	0.870	0.099	0.218

Note. MT stands for Mean Total, and C represents the construct.

The results reported in Table 2 focused on evaluating students' perceptions from two academic programs, Geology and Industrial Engineering, and between male and female students, on topics related to the Sustainable Development Goals (SDGs). The results for each construct are detailed below:

A significant difference was found between Geology and Industrial Engineering students in their Knowledge of SDGs (C1) ($p=0.003$, $\mu_{geo}=2.915$, $\mu_{ind}=3.434$). This suggests that students from these two programs have varying levels of familiarity with the SDGs. Similarly, for Sources of Information (C2), the results show a significant difference ($p=0.002$, $\mu_{geo}=2.859$, $\mu_{ind}=3.354$), indicating distinct ways these groups access information about SDGs.

Regarding the Professional Implications of SDGs (C3), the analysis revealed a significant difference ($p=0.008$, $\mu_{geo}=3.642$, $\mu_{ind}=3.940$), highlighting how students from these programs perceive the professional relevance of SDGs differently. However, no significant difference was found for Personal Implications of SDGs (C4) ($p=0.576$, $\mu_{geo}=3.593$, $\mu_{ind}=3.662$), suggesting that both groups share similar views on how the SDGs impact them personally.

Regarding Training Received at the University (C5), a significant difference was observed ($p=0.020$, $\mu_{geo}=3.393$, $\mu_{ind}=3.820$), indicating that students from these two programs perceive the training on SDGs provided by their universities differently. Likewise, for Sustainability in University Education (C6), a significant difference ($p=0.005$, $\mu_{geo}=3.632$, $\mu_{ind}=4.002$) was found, suggesting varied perspectives on how sustainability is incorporated into their academic programs.

The construct Relationship Between the University Environment and Sustainability (C7) showed a significant difference ($p=0.010$, $\mu_{geo}=3.841$, $\mu_{ind}=4.162$), revealing differing perceptions about how the university environment supports sustainability efforts. Finally, regarding Socio-Economic Impact (C8), there was a significant difference between the two programs ($p=0.029$, $\mu_{geo}=3.739$, $\mu_{ind}=4.070$), indicating that students from Geology and Industrial Engineering perceive the socio-economic implications of SDGs differently.

When comparing male and female students, no significant differences were found in most constructs ($p>0.05$), except for Socio-Economic Impact (C8), where a significant difference was identified ($p=0.045$, $\mu_{male}=3.987$, $\mu_{female}=3.682$). This finding suggests that male and female students perceive the socio-economic impact of SDGs differently. At the same time, their views on other constructs, such as Knowledge of SDGs (C1), Sources of Information (C2), and Professional Implications of SDGs (C3), are consistent.

In conclusion, Industrial Engineering students consistently showed higher perceptions across most constructs than Geology students, with notable differences in areas like Knowledge of SDGs (C1) and Training Received at the University (C5). Additionally, male students exhibited higher perceptions of the Socio-Economic Impact (C8) than female students. Tests were also conducted to compare first-year and fifth-year student groups, but no significant differences were found between these groups.

DISCUSSION

This study explored the knowledge and perceptions of sustainability and the Sustainable Development Goals (SDGs) among Geology and Industrial Engineering students at a private Chilean university. Its objective was to assess students' knowledge, skills, and attitudes toward sustainability and analyze their perceptions of the relevance of SDGs in personal and professional contexts.

Using a quantitative, non-experimental descriptive design, the research evaluated students' understanding of sustainability across different stages of their education, study programs, and gender. Data analysis combined descriptive statistics with the Mann-Whitney U test to identify significant differences between groups and examine construct-level trends.

Notable findings emerged from the inferential analysis. The findings highlight significant differences between programs, with Industrial Engineering students consistently showing higher perceptions than Geology students across most constructs. Notable differences were observed in Knowledge of SDGs (C1) ($p=0.003$, $\mu_{geo}=2.915$, $\mu_{ind}=3.434$) and Training Received at the University (C5) ($p=0.020$, $\mu_{geo}=3.393$, $\mu_{ind}=3.820$). Additionally, Industrial Engineering students scored higher in Sources of Information (C2) and Sustainability Education (C6), reflecting a broader understanding and engagement with sustainability topics. Male students reported higher perceptions of the Socio-Economic Impact of Sustainability (C8) than female students ($p=0.045$, $\mu_{male}=3.987$, $\mu_{female}=3.682$). No significant gender differences were found in other constructs, and both groups shared similar views on the personal implications of SDGs (C4, $p=0.576$). These results underscore the need for targeted interventions to address program-specific gaps and further integrate sustainability into the academic curriculum.

As shown in the responses to questions Q5–Q8, students' knowledge of the SDGs reached an average score of 3.112 out of 5.000. This result is significantly higher than the average of 1.918 reported by Zamora-Polo et al. in 2019, which revealed very limited knowledge of the SDGs among university students from different programs [16]. This discrepancy could be attributed to the time elapsed since that study and the differences between European and Latin American countries.

The responses to questions Q11–Q14 revealed that, for both study programs, formal education (Q11) was the most frequent source of SDG information, while traditional media (press, radio, and television) and informal training through nonprofit organizations scored the lowest. This is partially consistent with Zamora-Polo et al. [16], who concluded that there is still room for improvement in disseminating the SDGs within the university community and their integration into formal and informal education. Their study also emphasized that the role of non-governmental organizations is not yet reflected in university education. In contrast to 2019, this study highlights the growing relevance of social media, which ranked as the second most frequent source of SDG information for students.

Regarding questions related to sustainability education at the university (Q47–Q63), university engagement in sustainability (Q64–66), and the socio-economic impact of sustainability topics (Q70–71), these constructs showed the highest average scores, reflecting the importance students place on sustainability-related competencies. For example, students from both programs agreed on integrating sustainability into their learning processes, with an average score of 3.975(Q65). This result underscores an opportunity to incorporate sustainability into engineering curricula, either transversally or directly, through strategies such as guided practice and customized tools for different institutional settings. Furthermore, it is recommended that sustainable engineering principles be included in both core and elective courses [8].

One illustrative example is the educational experience designed by Ramos-Gavilán et al. [21], in which students from five engineering and architecture programs at the Polytechnic School of Zamora (EPSZ) at the University of Salamanca participated in an online course focused on the 2030 Agenda. A pre-test was conducted to evaluate students' prior knowledge, followed by a post-test after the intervention. The results showed a significant improvement in students' understanding of sustainable development, with an average increase of 3 points out of 10. At the end of the experience, the satisfaction survey demonstrated positive student and faculty feedback.

Another important finding is that Industrial Engineering students consistently scored higher than Geology students across all constructs evaluated. This aligns with the findings of Gerbaudo et al. [5], who examined SDG awareness among young geoscientists in Italy. Their study, based on 229 survey responses, highlighted that while young members of the geoscience community are aware of the implications of their work for sustainability, their familiarity with the 2030 Agenda remains low. There is a pressing need for sustainability education efforts and interdisciplinary and transdisciplinary teaching approaches to address this gap.

In the current study, despite a shared curriculum for Geology and Industrial Engineering students, one key difference lies in the first-year course. Industrial Engineering students take "Introduction to Engineering," which includes specific but limited information on the SDGs and their implications. In contrast, Geology students take "Earth System," which does not include sustainability-specific content. This may partially explain the observed differences between programs.

The findings from this study contribute to the existing body of knowledge on sustainability education in engineering and geosciences, providing an empirical basis for the continuous improvement of educational programs. Ultimately, these results could inform educational policy and curriculum design, promoting the development of engineers and scientists committed to sustainable development and prepared to address global challenges.

CONCLUSIONS

This study provides valuable insights into the level of knowledge and perceptions of sustainability and the Sustainable Development Goals (SDGs) among students in the Faculty of Engineering at a private Chilean university, addressing the research questions posed.

The findings reveal that students demonstrate a moderate level of knowledge about sustainability and the SDGs. Industrial Engineering students perceive themselves as having greater knowledge of the topic compared to Geology students. While both groups show a general understanding of what the SDGs are, their knowledge about the specific goals and implications remains limited.

Formal education emerges as the primary source through which students obtain information about sustainability and the SDGs. In contrast, traditional media and informal or non-formal training are the least utilized sources of information. This highlights the need for improved dissemination strategies to integrate sustainability topics across various educational and media platforms effectively.

Regarding sustainability education at the university, students from both programs agree on the importance of integrating sustainability into their learning processes. They also recognize the university's impact on the social and productive sectors in addressing sustainability issues. Furthermore, students value sustainability for its role in professional training, academic development, and career growth.

These conclusions align with the findings discussed, where Industrial Engineering students consistently scored higher in constructs such as Knowledge of SDGs (C1) and Training Received at the University (C5). Both groups emphasized the importance of sustainability education but highlighted gaps in their familiarity with the specifics of the SDGs. Male students reported higher perceptions of the Socio-Economic Impact (C8), further indicating potential gender differences in how sustainability is valued.

Regarding the limitations of this study, first, the sample was limited to students from two STEM programs at a single private Chilean university, which may not represent the broader diversity of students in other disciplines, institutions, or countries. Second, using self-reported surveys could introduce bias, as students overestimate or underestimate their knowledge and perceptions. Third, the cross-sectional design prevents assessing changes over time or the long-term impact of sustainability education. Fourth, the sample distribution was unbalanced, with a higher proportion of first-year students (n=79) compared to fifth-year students (n=42). This disparity may influence the interpretation of overall means, as aggregate results are more likely to reflect the perspectives of the larger subgroup. While disaggregated data were presented to support more nuanced analysis, this limitation should be considered when generalizing the findings.

Future efforts should focus on developing targeted interventions to bridge knowledge gaps, enhance the role of informal and non-formal education, and further integrate sustainability into engineering curricula. Strengthening interdisciplinary and practical approaches to sustainability education can foster a deeper understanding and greater preparedness among future engineers and geoscientists to address global challenges. Expanding the sample to include students from diverse academic programs and institutions will enable comparative analyses across contexts. Additionally, longitudinal studies are recommended to evaluate the progression of sustainability knowledge and attitudes throughout university education. Incorporating mixed methods approaches, such as interviews or focus groups, can provide deeper insights into the factors influencing students' perceptions and the effectiveness of sustainability education strategies.

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References

[1] A. E. Hale, C. C. Shelton, J. Richter, y L. M. Archambault, “Integrating Geoscience and Sustainability: Examining Socio-Techno-Ecological Relationships Within Content Designed to Prepare Teachers”, *J. Geosci. Educ.*, vol. 65, n.o 2, pp. 101-112, may 2017, doi: 10.5408/16-177.1. Available in: https://www.tandfonline.com/doi/full/10.5408/16-177.1

[2] M. Occhioni, A. Beccaceci, y E. Paris, “Environmental education in distance learning: using Virtual Worlds to link geosciences and sustainability”, *J. Geosci. Educ.*, pp. 1-15, oct. 2023, doi: 10.1080/10899995.2023.2266863. Available in: https://www.tandfonline.com/doi/full/10.1080/10899995.2023.2266863

[3] M. A. Pelch y D. A. McConnell, “How Does Adding an Emphasis on Socioscientific Issues Influence Student Attitudes About Science, Its Relevance, and Their Interpretations of Sustainability?”, *J. Geosci. Educ.*, vol. 65, n.o 2, pp. 203-214, may 2017, doi: 10.5408/16-173.1. Available in: https://www.tandfonline.com/doi/full/10.5408/16-173.1

[4] S. C. Nyarko, G. A. Fore, y K. Licht, "The role of ethical care in the geosciences: examining the perspectives of geoscience undergraduates", *J. Geosci. Educ.*, vol. 71, n.o 4, pp. 540-552, oct. 2023, doi: 10.1080/10899995.2023.2170621. Available in: https://www.tandfonline.com/doi/full/10.1080/10899995.2023.2170621

[5] A. Gerbaudo, F. Lozar, M. Lasagna, M. D. Tonon, y E. Egidio, “For a Sustainable Future: A Survey about the 2030 Agenda among the Italian Geosciences Community”, *Sustainability*, vol. 15, n.o 14, p. 11397, jul. 2023, doi: 10.3390/su151411397. Available in: https://www.mdpi.com/2071-1050/15/14/11397

[6] O. Leifler y J.-E. Dahlin, “Curriculum integration of sustainability in engineering education – a national study of programme director perspectives”, *IJSHE*, vol. 21, n.o 5, pp. 877-894, jun. 2020, doi: 10.1108/IJSHE-09-2019-0286. Available in: https://www.emerald.com/insight/content/doi/10.1108/IJSHE-09-2019-0286/full/html

[7] F. Trigueiros, J. Kaipainen, F. Silva, N. Geising, y E. A. Tosun, “Student Perspectives On Sustainability In Engineering Education: Multiple Case Study Of European Bachelor’s Programs In Industrial Engineering And Management”, 2023, doi: 10.21427/6Q9X-TF48. Available in: https://arrow.tudublin.ie/sefi2023_respap/119/

[8] K. D. Narong y P. Hallinger, “Traversing the Evolution of Research on Engineering Education for Sustainability: A Bibliometric Review (1991–2022)”, *Sustainability*, vol. 16, n.o 2, p. 641, ene. 2024, doi: 10.3390/su16020641. Available in: https://www.mdpi.com/2071-1050/16/2/641

[9] M. D. L. O. Cuevas-Cancino, M. Peña-Becerril, E. Mondragon-Estrada, y C. Camacho-Zuñiga, “Incorporating vertical collaboration to address sustainable development goals: the Monarch Route Project”, *Front. Educ.*, vol. 9, p. 1246889, ene. 2024, doi: 10.3389/feduc.2024.1246889. Available in: https://www.frontiersin.org/articles/10.3389/feduc.2024.1246889/full

[10] M. Lamere, L. Brodie, A. Nyamapfene, L. Fogg-Rogers, y V. Bakthavatchaalama, “Mapping and enhancing sustainability literacy and competencies within an undergraduate engineering Curriculum” in *Research in Engineering Education Symposium & Australasian Association for Engineering Education Conference*, Perth, WA, Dec. 2021.

[11] A. Décamps, G. Barbat, J.-C. Carteron, V. Hands, y C. Parkes, “Sulitest: A collaborative initiative to support and assess sustainability literacy in higher education”, The International Journal of Management Education, vol. 15, n.o 2, pp. 138-152, jul. 2017, doi: 10.1016/j.ijme.2017.02.006. Available in: https://linkinghub.elsevier.com/retrieve/pii/S1472811717300629

[12] S. Romero, M. Aláez, D. Amo, y D. Fonseca, “Systematic Review of How Engineering Schools around the World Are Deploying the 2030 Agenda”, *Sustainability*, vol. 12, n.o 12, p. 5035, jun. 2020, doi: 10.3390/su12125035. Available in: https://www.mdpi.com/2071-1050/12/12/5035

[13] A. Rodriguez-Dono y A. Hernández-Fernández, "Fostering Sustainability and Critical Thinking through Debate—A Case Study", *Sustainability*, vol. 13, n.º 11, p. 6397, jun. 2021, doi: 10.3390/su13116397. Available in: https://www.mdpi.com/2071-1050/13/11/6397

[14] H. Suh y S. Han, "Promoting Sustainability in University Classrooms Using a STEM Project with Mathematical Modeling", Sustainability, vol. 11, n.o 11, p. 3080, may 2019, doi: 10.3390/su11113080. Available in: https://www.mdpi.com/2071-1050/11/11/3080

[15] A. Azapagic, S. Perdan, y D. Shallcross, "How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum", *Eur. J. Eng. Educ.*, vol. 30, n.o 1, pp. 1-19, mar. 2005, doi: 10.1080/03043790512331313804. Available in: http://www.tandfonline.com/doi/abs/10.1080/03043790512331313804

[16] F. Zamora-Polo, J. Sánchez-Martín, M. Corrales-Serrano, y L. Espejo-Antúnez, "What do university students know about Sustainable Development Goals? A realistic approach to the reception of this UN Program amongst the youth population", *Sustainability*, vol. 11, n.o 13, p. 3533, jun. 2019, doi: 10.3390/su11133533. Available in: https://www.mdpi.com/2071-1050/11/13/3533

[17] D. Olbina, B. Buzatu, L. Kheirawi, y M. Dolmatova, "Engineering Skills And Competences For A More Sustainable World", in Eng. Ed. Sust., Dublin, Ireland, 2023. doi: 10.21427/F2FK-6606. Available in: https://arrow.tudublin.ie/sefi2023_respap/61/.

[18] F. Sánchez-Carracedo, F. Sabaté I. Garriga, y K. Gibert, «A methodology to assess the sustainability competencies in engineering undergraduate programs», *Int. J. Eng. Ed.*, vol. 37, n.o 5, pp. 1231-1243, 2021, Available in: https://upcommons.upc.edu/handle/2117/353759

[19] M. Kirupa Priyadarsini, S. Kritvi, y N. Srimath, "Knowledge, Importance and Inclusion of SDG in Engineering Curriculum – A student's perspective", *JEET*, vol. 37, n.º IS2, pp. 974-979, ene. 2024, doi: 10.16920/jeet/2024/v37is2/24147. Available in: https://journaleet.in/download-article.php?Article_Unique_Id=JPR2147&Full_Text_Pdf_Download=True

[20] M. G. Martínez-Valdés y L. G. Juárez-Hernández, "Diseño y validación de un instrumento para evaluar la formación en sostenibilidad en estudiantes de educación superior" [Design and validation of an instrument to assess sustainability education in higher education students], *IE Revista de Investigación Educativa de la REDIECH*, vol. 10, n.o 19, pp. 37-54, 2019, Available in: https://www.redalyc.org/journal/5216/521658239003/html/

[21] A. B. Ramos-Gavilán, M. A. Rodríguez-Esteban, M. A. Frechilla-Alonso, A. C. Raposeiras, D. Movilla-Quesada, y A. B. González-Rogado, "Raising awareness of the important role of engineering in sustainable development" Heliyon, vol. 10, n.o 1, p. e23494, ene. 2024, doi: 10.1016/j.heliyon.2023.e23494. Available in: https://linkinghub.elsevier.com/retrieve/pii/S240584402310702X.

[22] S. Sanchez, M. Rueda, y D. Robertson, "Measuring Sustainability Literacy in Undergraduate and Graduate Engineering Students in a Colombian University", en 2023 ASEE Annual Conference & Exposition Proceedings, Baltimore , Maryland: ASEE Conferences, jun. 2023, p. 43572. doi: 10.18260/1-2--43572. Disponible en: http://peer.asee.org/43572