Sustainable Development Awareness among Pre-Service Mathematics Teachers in Türkiye: Insights from a Case Study

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Abstract: This study examines the awareness of Sustainable Development Goals (SDGs) and Education for Sustainable Development (ESD) among pre-service mathematics teachers at Erciyes University, Türkiye. As future educators, these teachers play a vital role in raising students' awareness of sustainable practices and stimulating active engagement in sustainability initiatives. The study explores how sustainability awareness varies based on gender, academic year, and membership in environmental organizations. Findings indicate that over 60% of participants are familiar with the SDGs, though many expressed concerns about Türkiye's progress in achieving them. The results provide valuable insights for developing strategies to enhance sustainability training for future educators in Türkiye.

Keywords: Education for Sustainable Development (ESD), Environmental Awareness in Education, Sustainability in Mathematics Education, Case Study in Türkiye

INTRODUCTION

Over the past century, rapid industrialization has significantly increased human demand for natural resources, and that leads to unsustainable practices that have severely disrupted the planet's ecological balance. Critical levels of environmental degradation have been reached due to deforestation, overfishing, and the depletion of water resources (Mebratu, 1998). In response, Sustainable Development (SD) has emerged as a comprehensive framework that integrates economic, social, and environmental considerations. The aim was to ensure that present needs are

met without compromising the ability of future generations to fulfill their own (Schaefer & Crane, 2005).

As awareness of sustainability challenges continues to grow, education has become a central tool in addressing these issues. Recognizing its transformative potential, the United Nations (UN) introduced the 17 Sustainable Development Goals (SDGs) to guide global sustainability efforts, with SDG 4 ("Quality Education") playing a pivotal role in fostering sustainability awareness and action. SDG 4 underscores the importance of inclusive, equitable, and high-quality education in promoting lifelong learning and enhancing global sustainability consciousness (UN General Assembly, 2015).

Education for Sustainable Development (ESD) serves as a fundamental approach to raising both individual and collective awareness of sustainability. Through curricula and pedagogy, education shapes behaviors, attitudes, and values that promote sustainable living (Tanriverdi, 2009). Teachers, particularly pre-service teachers, are central to this process, since they are responsible for imparting sustainability-related knowledge and values in future generations. To support this mission, the UNESCO Greening Curriculum Guidance provides a structured framework for integrating sustainability principles into education at all levels. The guide aims to cultivate environmental literacy and enhancing problem-solving skills among learners (UNESCO, 2024).

Recent international agreements, such as the COP28 Climate Change Conference, have reinforced the urgency of embedding climate change education into national policies. COP28 recognizes education as a key enabler of sustainability and calls for the integration of climate literacy in curricula, the mobilization of financial resources, and the advancement of climate-smart education systems (UNFCCC, 2023). Equipping future educators with the necessary knowledge, skills, and pedagogical approaches is essential for effectively teaching sustainability concepts and preparing students to address global challenges (Kioupi & Voulvoulis, 2019).

One of the most powerful tools for promoting sustainability within education is mathematics. Mathematics education provides students with essential analytical and problem-solving skills required to address complex sustainability issues (Guterres, 2020). Many critical environmental and societal challenges such as climate change, resource management, and economic sustainability require mathematical proficiency in data analysis, statistical modeling, and quantitative reasoning (Alsina, 2022). For instance, statistical methods are crucial for tracking climate change patterns, assessing carbon footprints, and evaluating the effectiveness of environmental policies. Similarly, optimization techniques contribute to improving resource allocation, renewable energy planning, and sustainable urban development. Mathematical modeling further supports sustainability efforts by predicting ecological trends and enabling policymakers to develop more effective environmental strategies (Guterres, 2020).

Recognizing the critical role of mathematical literacy in sustainability, SDG 4 emphasizes the need to strengthen mathematical education to enhance learning outcomes in both literacy and numeracy

(Boeren, 2019). Integrating sustainability within mathematics education develops students' ability to interpret sustainability indicators. At the same time, it cultivates critical thinking and evidence-based decision-making, which are essential for addressing global sustainability challenges.

By embedding sustainability-focused topics into mathematics curricula, educators can enhance students' understanding of real-world issues, such as climate change, deforestation, energy consumption, and environmental resource management (Hui-Chuan & Tsung-Lung, 2020). Incorporating real-world data and interdisciplinary approaches in mathematics instruction helps bridge the gap between theoretical knowledge and practical applications. For instance, teachers can design lessons that involve analyzing carbon emission trends through statistical methods, applying optimization techniques for resource allocation, and modeling climate scenarios using differential equations. These strategies not only strengthen students' mathematical competencies but also cultivate a deep-rooted sustainability consciousness (Barwell, 2013; Bögeholz et al., 2014; Vásquez et al., 2021).

Despite the potential of mathematics education to promote sustainability awareness, limited research has explored how pre-service mathematics teachers perceive and integrate SDGs into their teaching practices, particularly in Türkiye. This study aims to address this knowledge gap by investigating how gender, academic level, and environmental club membership influence sustainability awareness among pre-service mathematics teachers. The findings will contribute to the development of strategic improvements in teacher training programs to enhance sustainability education in Türkiye and other similar countries.

MATERIALS AND METHODS

This section outlines the research model, participants, and methodology used to assess pre-service mathematics teachers' awareness of the SDGs at Erciyes University, Türkiye, during the 2023/2024 academic year.

Participants

The study involved a total of 154 pre-service mathematics teachers from the Department of Mathematics and Science Education at Erciyes University. The sample consisted of 132 female and 22 male participants at all four academic levels of Freshman, Sophomore, Junior and Senior. The distribution of participants by academic year is presented in Table 1.

Class	Number
Freshman	14
Sophomore	47
Junior	56
Senior	37
Total	154

Table 1. Distribution of pre-service teachers by academic year

Study Objectives and Research Questions

This study aimed to:

1. Identify the primary sources of information on sustainable development among pre-service mathematics teachers.
2. Assess participants' awareness of ESD.
3. Examine variations in sustainability awareness based on gender, academic level, and environmental club membership.
4. Analyze participants' ability to match sustainable development concepts with development indicators.
5. Gather opinions on the perceived achievement levels of SDGs in Türkiye.

Accordingly, the study was guided by the following research questions:

- How do pre-service mathematics teachers in Türkiye acquire information on sustainable development?
- To what extent does their awareness of ESD align with sustainable development concepts, and how do gender, academic level, and environmental club membership influence their perceptions of SDG achievement?

These research questions seek to explore pre-service teachers' recognition of sustainability within their educational perspectives and how their awareness may shape their future teaching practices.

Data Collection Procedure

The data collection tool was structured into four sections:

1. Personal Information Form – Collected demographic details, including gender, academic level, and environmental club membership, along with basic knowledge of SD and ESD.
2. Attitude Scale Towards ESD – A 22-item Likert scale measuring participants' perceptions of the individual and societal benefits of ESD and its significance in education.
3. Sustainability and Indicators Scale – A 32-item questionnaire assessing the perceived importance of various sustainability principles in relation to development indicators.
4. SDG Achievement Levels – A 17-item scale measuring participants' opinions on Türkiye's progress in achieving the 17 SDGs, rated on a scale from "Definitely Not Achieved" to "Definitely Achieved

Scales developed in Gökmen, 2014 were used to determine the awareness of pre-service mathematics teachers about sustainable development goals (Gökmen, 2014). Scales developed by Leiva-Brondo were used to learn pre-service mathematics teachers' opinions about the achievement levels of sustainable development goals (Leiva-Brondo et al., 2022). The study did not involve providing teachers with instructional materials on sustainability. Instead, the questionnaire was used solely to assess their pre-existing awareness and understanding of sustainability concepts.

Instrument Reliability

Cronbach's alpha coefficients were calculated for each scale to confirm the reliability and validity of the survey instruments.

- Attitude Scale Towards ESD: $\alpha = 0.927$
- Scale for Matching SD and Development Indicators: $\alpha = 0.953$
- SDG Achievement Level Scale: $\alpha = 0.868$

A Cronbach's alpha coefficient above 0.70 indicates good internal consistency and this confirms the reliability of the instruments (Kalaycı, 2017). Table 2 shows the distribution of data collection tool sections and number of questions.

Section Number	Section Topic	Multiple Choice Questions	Open Ended Questions	Total
1	Personal information form	5	3	8
2	Attitude scale towards ESD	22	0	22
3	Scale for matching SD and development indicators	32	0	32
4	Achievement level of SDGs	17	0	17

Table 2. Distribution of data collection tool sections and number of questions

Data Analysis

Statistical analyses were conducted using IBM's SPSS software. Descriptive statistics, including frequencies and percentages, were calculated for each survey item to provide a graphical representation of the results. This initial step offered a comprehensive overview of participants' responses regarding their awareness of sustainability and ESD.

To determine the suitability of the data for parametric analysis, normality was assessed using skewness, kurtosis, and the skewness-to-standard error ratio. Following established guidelines, acceptable thresholds were defined as -2 to +2 for skewness and kurtosis, and -1.96 to +1.96 for the skewness-to-standard error ratio (George & Mallery, 2010).

The normality assessment for each scale is summarized as follows:

- **Attitude Scale Towards ESD:** Skewness (-0.13), kurtosis (1.39), and skewness-to-standard error ratio (0.627) were within acceptable limits. Despite a Kolmogorov-Smirnov test p-value of 0.007 ($p < 0.05$), the data were considered sufficiently normal for parametric analysis.
- **Matching Sustainable Development and Indicators Scale:** Skewness (0.10), kurtosis (0.54), and skewness-to-standard error ratio (0.512) indicated normality. Although the Kolmogorov-Smirnov test yielded $p = 0.000$, the data met the criteria for parametric testing.
- **SDG Achievement Level Scale:** Skewness (-0.25), kurtosis (0.36), and skewness-to-standard error ratio (-1.229) confirmed normality. The Kolmogorov-Smirnov test result ($p = 0.200$, $p > 0.05$) supported the use of parametric statistical methods.

For inferential analysis, independent t-tests were applied to examine gender-based differences, while One-Way ANOVA was used to analyze variations across academic levels. Table 3 presents the mean, skewness, and kurtosis values for each scale used in the study.

Scale	Value	Statistics	Standard Error
Attitude scale towards ESD	Mean	86.93	0.49
	Skewness	-0.13	-0.20
	Kurtosis	1.39	0.40
Scale for matching SD and development indicators	Mean	127.87	1.14
	Skewness	0.10	0.20
	Kurtosis	0.54	0.40
Achievement level of SDGs	Mean	44.36	1.57
	Skewness	-0.25	0.20
	Kurtosis	0.36	0.40

Table 3. Mean, Skewness, and Kurtosis values of the scales

RESULTS AND DISCUSSION

The primary objective of this study was to investigate the sources of information on SD and ESD among pre-service mathematics teachers.

Sources of Information

Main sources through which pre-service mathematics teachers acquire knowledge about sustainability were identified. Responses were quantified, and frequencies were analyzed to determine percentage distributions. The results are presented in Figure 1.

The study achieved a 62% participation rate, which exceeds those reported in similar research (Leiva-Brondo et al., 2022). This higher response rate may be attributed to the administration of the survey during class time, a method known to improve participation rates (Diliman et al., 2009).

Findings indicate that the internet serves as the primary source of information on SD for pre-service mathematics teachers, playing a crucial role in disseminating sustainability-related knowledge. Lectures emerged as the second most significant source, contributing substantially to students' understanding of sustainability concepts. Meanwhile, traditional media—including television and newspapers—had a relatively minor influence in shaping sustainability awareness.

Although traditional educational channels remain relevant, the increasing reliance on digital resources highlights the internet's dominant role in shaping sustainability awareness among future educators.

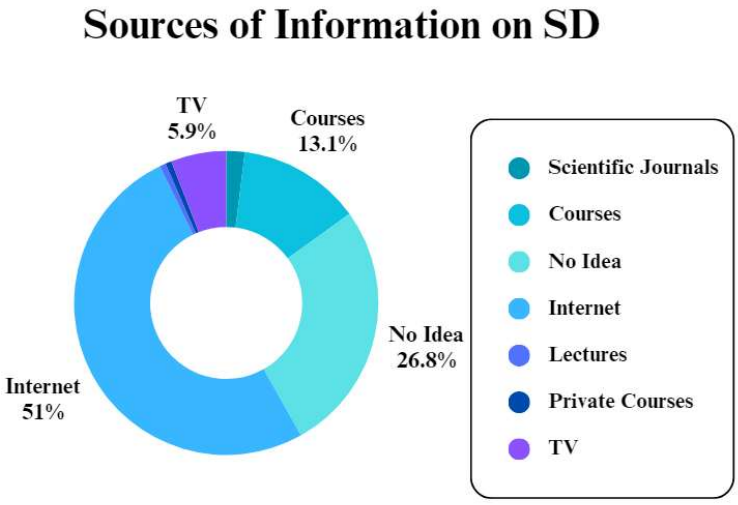

Figure 1. Sources of information on SD for pre-service mathematics teachers

As shown in Figure 1, 73.4% of pre-service mathematics teachers demonstrated awareness of sustainability issues, exceeding the awareness levels reported among Spanish students (28.1%) but slightly trailing behind Japanese students (73.7%) (García-Gonzalez et al., 2020; Ando et al., 2019). In contrast, SDG awareness among the general public remains below 20% (OECD, 2017), highlighting higher sustainability awareness among university students.

Sustainability awareness among mathematics teachers plays a crucial role in education, as mathematics serves as a powerful tool for analyzing real-world sustainability issues. Teachers who integrate sustainability into mathematics instruction can enhance student engagement by embedding real-world problem-solving scenarios into lessons. For instance, mathematics educators can use:

- Probability and statistics to analyze climate change trends,
- Optimization techniques to model resource allocation strategies, and
- Algebraic reasoning to explore financial planning for sustainable homes and workplaces (Silveira, 2018; Su, 2023; Renert, 2011).

Mathematics teachers who are conscious of sustainability can also promote critical thinking by assigning interdisciplinary problem-solving tasks. By incorporating sustainability-related challenges into mathematics education, teachers achieve two key objectives:

1. Developing students' analytical skills through real-world data interpretation.
2. Promoting responsible citizenship by raising environmental awareness and encouraging informed decision-making.

Given these benefits, sustainability training should be a core component of teacher education to prepare future educators for the multidisciplinary teaching challenges they will encounter (Su, 2023). Integrating sustainability principles into mathematics education will enable students to develop solutions for current and future sustainability challenges. They are expected to understand the interconnections between natural and social systems, and apply critical thinking to real-world problems (Alsina, 2022; Bögeholz et al., 2014; Vásquez et al., 2021).

However, despite the high overall awareness levels, 26.8% of participants reported lacking knowledge of SD. Among respondents who were familiar with SD, the internet emerged as the dominant information source (51%), followed by lectures (13.1%) and television (5.9%), mirroring global trends where digital media serves as the primary channel for SDG-related information (Gangadharbatla et al., 2014).

Figure 2 illustrates pre-service mathematics teachers' knowledge of Education for Sustainable Development (ESD). The findings reveal that 39.7% of respondents identified the internet as their primary ESD information source, while 38.5% reported having no prior ESD knowledge. Table 4 presents moderate ESD understanding, with mean scores of 39.17 (SD = 3.79) for ESD practices and 32.29 (SD = 3.61) for individual and social benefits.

These findings emphasize the need for teacher education programs to further strengthen sustainability-related knowledge and pedagogical practices. While digital media plays a dominant role in shaping sustainability awareness, it also raises concerns about the reliability and depth of online information. This underscores the importance of structured educational interventions to ensure accuracy, critical evaluation, and comprehensive sustainability literacy among future educators.

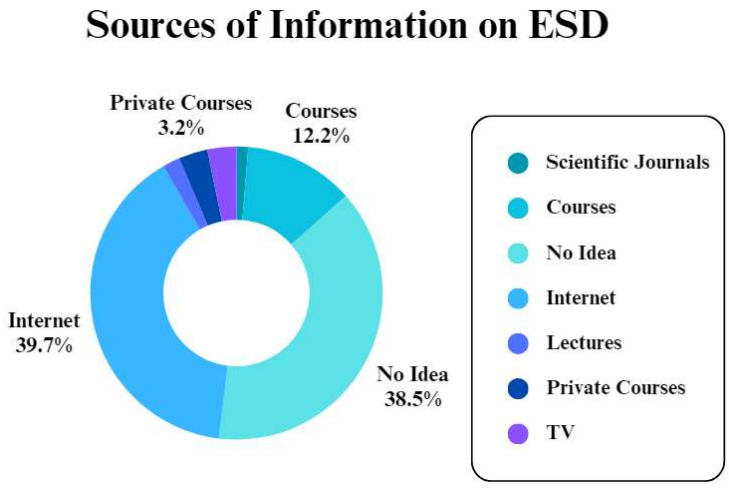

Figure 2. Knowledge of education for SD among pre-service mathematics teachers

Table 4 shows descriptive statistics of pre-service mathematics teachers' attitudes towards ESD. It provides insights into pre-service mathematics teachers' attitudes toward ESD by categorizing their responses into three key dimensions: practices within schools, individual and social benefits.

A closer examination of the data reveals that pre-service teachers exhibit a solid grasp of both ESD practices in schools and its individual and societal benefits and this suggests a recognition of sustainability's role in education and broader social contexts. However, their responses indicate a weaker understanding of how sustainability goals translate into classroom applications. This shows a gap between theoretical awareness and practical implementation. The relatively lower mean score in the goals and applicability category suggests that while pre-service teachers value sustainability, they may lack the pedagogical tools or training necessary to integrate these concepts into their instructional strategies effectively.

These findings point to the need for targeted professional development initiatives aimed at bridging the disconnect between knowledge and application. Incorporating structured training on sustainability pedagogy within teacher education programs could enhance pre-service teachers' ability to translate their awareness into actionable classroom strategies. Strengthening this aspect of teacher preparation would not only enrich mathematics education but also qualify future educators to cultivate sustainability literacy among their students in a more meaningful and practical way.

Dimension	N	Min	Max	Mean	SD	Related Survey Questions
ESD practices in schools	154	25.00	45.00	39.17	3.79	1,4,7,10,13,16,18,20,22
Individual and social benefits of ESD	154	21.00	40.00	32.29	3.61	2,5,8,11,14,17,19,21
Goals and applicability of ESD	154	11.00	24.00	15.40		3,6,9,12,15
Valid N (listwise)	148					

Table 4. Descriptive statistics of pre-service mathematics teachers' attitudes towards ESD

Goals and Applicability of ESD

The findings indicate that pre-service mathematics teachers demonstrate a baseline understanding of the goals and applicability of Education for SD, as reflected in a mean score of 15.40 (SD = 2.03). However, their grasp of sustainability extends unevenly across different dimensions, as summarized in Table 5, which shows descriptive statistics of pre-service mathematics teachers on the SD and indicators scale.

While awareness of ecological and social sustainability appears strong, as both dimensions share a mean score of 63.69 (SD = 7.66), knowledge of economic sustainability is notably lower, with a mean score of 15.43 (SD = 2.36). This incompability suggests that although pre-service teachers recognize the environmental and societal aspects of sustainability, they may lack a comprehensive understanding of its economic implications. Examples include resource management, financial planning for sustainability, and the long-term economic effects of environmental policies.

These results underscore the need for teacher education programs to incorporate a more balanced and integrative approach to sustainability. By strengthening economic sustainability education alongside ecological and social dimensions, pre-service teachers can develop a holistic perspective on sustainable development. This enables them to better integrate these principles into their future teaching practices. Addressing this gap would enhance their ability to prepare students for real-world sustainability challenges, ensuring that all three pillars (e.g. environmental, social, and economic sustainability) are given equal emphasis in education.

Survey dimension	N	Min.	Max.	Mean	SD	Related Survey Questions
Ecological Dimension	148	38.00	75.00	63.69	7.66	1,4,7,10,13,15,17,19,21,23,25,27, 29,31,32
Social Dimension	148	38.00	75.00	63.69	7.66	2,5,8,11,14,16,18,20,22,24,26, 28,30
Economical Dimension	148	8.00	20.00	15.43	2.36	3,6,9,12
Valid N (listwise)	148					

Table 5. Descriptive statistics of pre-service mathematics teachers on the SD and indicators scale

Achievement Level of SDGs

Table 6 shows descriptive statistics of pre-service mathematics teachers' SDGs achievement level scale. The achievement levels of SDGs among pre-service mathematics teachers reveal incompabilities in their understanding of sustainability dimensions. The findings indicate that awareness of ecological sustainability remains limited, with a mean score of 10.73 (SD = 3.40). This suggests a lack of familiarity with ecological targets, including environmental sustainability issues such as climate action, biodiversity conservation, and responsible resource consumption.

In contrast, a higher mean score of 23.53 (SD = 7.44) suggests that the social dimension of sustainability is better understood by the participants. This indicates a stronger grasp of social justice, equity, and community well-being, suggesting that pre-service teachers are more attuned to the societal aspects of sustainable development.

The noticeable disparity between ecological and social dimensions highlights the need for targeted interventions in teacher education programs. While social sustainability awareness is relatively well-developed, enhancing ecological literacy is crucial. This will ensure that future educators can effectively address all aspects of sustainability within their teaching. Strengthening ecological knowledge will better equip pre-service mathematics teachers to integrate sustainability principles holistically, ensuring that students gain a comprehensive understanding of environmental, social, and economic sustainability.

Survey dimension	N	Min.	Max.	Mean	SD	Related survey questions
SDG ecological dimension	145	4.00	20.00	10.73	3.40	12,13,14,15
SDG social dimension	148	1.00	45.00	23.53	7.44	1,2,3,4,5,6,7,11,16
SDG economical dimension	146	3.00	15.00	7.61	2.70	8,9,10
Revitalizing the global partnership for the SDGs	145	1.00	5.00	2.88	0.97	
Valid N (listwise)	145					

Table 6. Statistics of pre-service mathematics teachers' SDGs achievement level scale

Economic Dimension and Overall Perceptions of SDG Achievement

The findings indicate that pre-service mathematics teachers demonstrate moderate awareness of the economic dimension of SDGs, with an average score of 7.61 (SD = 2.70). However, this awareness remains lower compared to the social and ecological dimensions. This suggests that economic sustainability concepts, such as responsible consumption, financial literacy, and sustainable economic growth, may not be as well-integrated into their understanding of sustainable development.

Notably, the "Global Partnerships" dimension, which emphasizes international collaboration for SDG implementation, received the lowest average score of 2.88 (SD = 0.97). This reflects a significant gap in understanding global cooperation mechanisms. That might underscore the need for targeted educational initiatives to strengthen awareness of the interconnected and globalized nature of sustainability challenges.

As illustrated in Figure 3, perceptions of SDG achievement in Türkiye vary widely among participants, reflecting a mix of optimism and skepticism. The results show that 15.1% of pre-service teachers believe the SDGs have not been achieved, while 33.3% feel they are only marginally achieved. Meanwhile, 26.1% hold a neutral stance, and a smaller proportion—23% and 2.5%—consider the SDGs either achieved or highly achieved, respectively.

These findings show that while pre-service teachers recognize sustainable development goals, skepticism remains regarding Türkiye's progress in achieving them. This highlights the importance of integrating sustainability education within teacher training programs. That will ensure that future educators are equipped not only with knowledge of SDGs but also with the ability to advocate for and contribute to sustainable development initiatives effectively. Strengthening economic and global sustainability literacy within teacher education could foster a more comprehensive understanding of sustainability challenges and empower educators to instill these principles in their future classrooms.

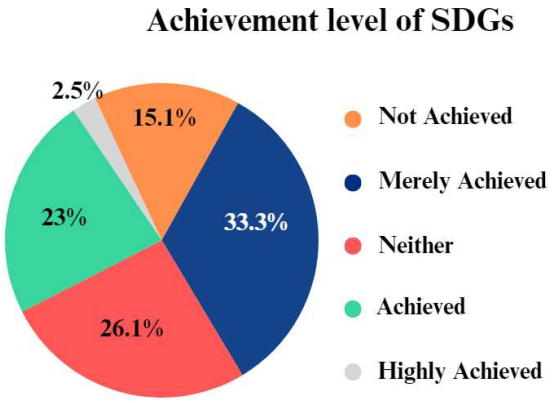

Figure 3. Average percentages of pre-service mathematics teachers' SDG achievement levels

SDG Achievement, Cross-Cultural Variations, and Implications for Math Education

The analysis revealed that pre-service mathematics teachers most frequently identified SDG 4 (Quality Education), SDG 5 (Gender Equality), and SDG 8 (Decent Work and Economic Growth) as the most achieved goals. In contrast, SDG 1 (No Poverty) and SDG 6 (Clean Water and Sanitation) were perceived as the least achieved. These findings provide insights into how future educators assess sustainability progress and where they see the most pressing challenges.

Türkiye's 2023 Sustainable Development Report indicates a score of 70.8, ranking the country 72nd globally and falling below the regional average of 77.8 (Sachs et al., 2023). National data suggests that SDG 1, SDG 4, and SDG 13 (Climate Action) are among Türkiye's strongest-performing goals, which partially aligns with the perceptions of pre-service teachers in this study.

Comparisons with other countries highlight notable variations in SDG awareness and perceived achievement. Spanish students prioritized SDG 3 (Good Health), SDG 5, and SDG 6, whereas SDG 14 (Life Below Water) and SDG 15 (Life on Land) were ranked the lowest (Leiva-Brondo et al., 2022). In contrast, Japanese students viewed SDG 2 (Zero Hunger) and SDG 6 as the most fulfilled, while SDG 5 was perceived as the least achieved (Ando et al., 2019). The differences in SDG awareness among Turkish, Spanish, and Japanese pre-service teachers may stem from variations in cultural values, national policies, and sustainability education within teacher training programs. Additionally, the unique sustainability challenges faced by each country likely contribute to differing perceptions of SDG progress.

Countries that have explicitly integrated sustainability education into teacher training programs tend to produce pre-service teachers with a more developed understanding of ecological, social, and economic sustainability (Sachs et al., 2023; Biermann, 2022). Conversely, in education systems where sustainability is not an integral part of the curriculum, awareness often depends on personal interest rather than structured instruction. Socioeconomic factors and national sustainability priorities also play a critical role in shaping perceptions of sustainable development. Countries with strong environmental policies tend to foster greater sustainability awareness among teachers, which subsequently influences how sustainability is incorporated into their teaching. These variations underscore the need for internationally aligned and systematically developed frameworks to integrate sustainability into teacher education programs worldwide.

The inclusion of sustainability education in national curricula and teacher training programs is essential for developing students' sustainability competencies (Li, 2021). Cultural attitudes toward sustainability also influence awareness levels. Countries that prioritize environmental policymaking and maintain strong public discourse on sustainability often cultivate higher student engagement with SDGs (Edsand, 2020; Hajdukiewicz, 2020; Berglund, 2020). While Türkiye has made progress in integrating sustainability into education, SDG-focused curricula in teacher training remain underdeveloped. This emphasizes the urgent need for a more systematic and structured incorporation of sustainability content in mathematics teacher education.

Sustainability awareness among teachers directly enhances the effectiveness of mathematics education, making lessons more interdisciplinary, relevant, and problem-solving oriented. Teachers equipped with sustainability knowledge can integrate real-world data and case studies into mathematics instruction. These teachers can help students understand climate trends, resource efficiency, and economic sustainability through quantitative reasoning (Vásquez et al., 2023). A sustainability-conscious mathematics teacher encourages critical thinking in the classroom, enabling students to engage with real-world exercises related to environmental and social challenges. Through interdisciplinary learning, mathematics can be effectively connected with environmental science and economics, encouraging a systems-thinking approach to problem-solving (Tesfamicael, 2024). Ultimately, students taught by sustainability-aware educators are expected to develop strong ethical and critical thinking skills, equipping them to become active and responsible global citizens.

Gender-Based Analysis

To assess the impact of gender on SDG awareness and perceptions, the data were analyzed using non-parametric statistical methods due to the unequal gender distribution within the sample (132 females, 22 males). Although all three scales exhibited normal distribution, the small male sample size ($n < 30$) necessitated the use of the Mann-Whitney U test to compare gender differences in sustainability awareness and perceptions of SDG achievement.

Gender Effects on Sustainable Development Awareness

Table 7 shows distribution of pre-service mathematics teachers' attitudes towards ESD by gender. The results highlight notable gender-based differences in attitudes toward ESD practices in schools. The findings indicate that female pre-service teachers demonstrated stronger awareness and understanding of ESD integration, with a mean score of 79.88, compared to male participants, who scored significantly lower at 65.18.

This disparity suggests that female students may benefit from different educational experiences, socialization patterns, or a stronger inclination toward environmental responsibility. It is possible that socio-cultural influences, educational exposure, or personal engagement with sustainability-related topics contribute to this variation.

Addressing this gender gap requires targeted strategies within teacher education programs to ensure that male pre-service teachers receive equal exposure to sustainability education. Promoting equitable awareness across genders will enable future educators to integrate sustainability principles more effectively into their teaching. That is expected to result in a more inclusive and comprehensive approach to sustainability education in mathematics classrooms.

Survey Dimension	Gender	N	Mean
ESD practices in schools	Female	131	79.88
	Male	22	65.18
	Total	153	
Individual and social benefits of ESD	Female	131	76.61
	Male	22	79.34
	Total	**153**	
Goals and applicability of ESD	Female	131	74.38
	Male	22	92.59
	Total	**153**	

Table 7. Distribution of pre-service mathematics teachers' attitudes towards ESD by gender

Gender Differences in ESD Dimensions

The survey assessed pre-service mathematics teachers' perceptions of ESD practices in schools as well as its individual and social benefits, revealing variations in gender-based responses.

The findings indicate that both female and male participants demonstrated comparable recognition of ESD's personal and societal impacts. Female students score an average of 76.61 and male students score slightly higher at 79.34 in the individual and social benefits dimension.

However, a more noticeable difference emerged in perceptions of ESD goals and applicability, where male students scored significantly higher (92.59) compared to female students (74.38). This suggests that male participants held a more positive outlook on the applicability of ESD in educational contexts.

Table 8 summarizes dimensions of the attitude scale toward ESD. Despite these observed differences, Table 8 shows that p-values for all dimensions exceeded 0.05. This indicates that the gender-based variations in attitudes toward ESD were not statistically significant. These findings suggest that while subtle differences exist in perceptions of ESD dimensions, they do not reflect significant disparities in overall attitudes toward sustainability education. Further investigation is needed to explore the underlying factors contributing to these variations. Possible factors could include potential differences in exposure, engagement with sustainability topics, or broader socio-cultural influences.

Test	ESD practices in schools	Individual and social benefits of ESD	Goals and applicability of ESD
Mann-Whitney U	1181.00	1389.50	1098.00
Wilcoxon W	1434.00	10035.50	9744.00
Z	-1.36	-0.27	-1.81
p	0.17	0.79	0.07

Table 8. Dimensions of the attitude scale toward ESD

3.6.3 Matching Sustainable Development and Development Indicators

Table 9 shows distribution of pre-service mathematics teachers' matching of SD and related indicators by gender. The alignment of sustainable development goals with relevant indicators among pre-service mathematics teachers was assessed, with results presented in Table 9. The findings reveal a slight gender-based variation in ecological awareness, as female students scored an average of 74.23, compared to 72.53 for male students. This suggests that female participants demonstrated marginally stronger ecological awareness.

Understanding the relationship between sustainable development and its indicators is essential for integrating sustainability principles into educational settings. Given the importance of ecological literacy in promoting sustainable practices, it is crucial that all pre-service teachers, regardless of gender, receive equitable exposure to sustainability education. The observed gender disparity, although minor, may be attributed to differences in educational experiences, engagement with sustainability topics, or societal influences.

These findings emphasize the need for comprehensive and inclusive training in teacher education programs. As a result, all future educators can develop a well-rounded understanding of ecological, social, and economic sustainability. Strengthening this knowledge base will better equip teachers to integrate sustainability concepts into mathematics instruction, ultimately achieving greater environmental consciousness among students.

Survey dimension	Gender	N	Mean
Ecological dimension	Female	127	74.23
	Male	20	72.53
	Total	**147**	
Social dimension	Female	127	74.23
	Male	20	72.53
	Total	**147**	
Economical dimension	Female	127	74.61
	Male	20	70.10
	Total	**147**	

Table 9. Pre-service mathematics teachers' matching of SD and indicators by gender

Gender Differences in Social and Economic Dimensions

The analysis of pre-service mathematics teachers' understanding of sustainable development indicators revealed minimal gender-based variations across the social and economic dimensions. Table 10 shows pre-service mathematics teachers' sub-dimensions in the SD and related indicators scale. As shown in Table 10, female participants scored slightly higher than their male counterparts in both dimensions, though the differences were not statistically significant ($p > 0.05$).

In the social dimension, female students achieved an average score of 74.23, compared to 72.53 for males, indicating strong awareness among both genders. Similarly, in the economic dimension, female participants scored 74.61, while male students had a slightly lower mean of 70.10, reflecting moderate awareness overall.

These findings suggest that pre-service teachers, regardless of gender, demonstrate a comparable ability to link sustainable development goals to their corresponding dimensions. While females exhibited marginally higher scores, the absence of statistically significant differences implies that both groups possess similar levels of competency in understanding sustainability concepts.

Further research is needed to explore potential factors influencing these slight variations, such as differences in educational experiences, exposure to sustainability topics, or personal engagement with environmental and economic issues. To achieve equitable awareness across all dimensions, teacher education programs should continue integrating sustainability into training curricula. That will equip future educators with the necessary knowledge and pedagogical strategies to advocate for and effectively incorporate sustainability into their classrooms.

Test	Ecological Dimension	Social Dimension	Economical Dimension
Mann-Whitney U	1240.50	1240.50	1192.00
Wilcoxon W	1450.50	1450.50	1402.00
Z	-0.17	-0.17	-0.45
p	0.87	0.87	0.65

Table 10. Pre-service mathematics teachers' sub-dimensions in the SD and indicators scale

Gender Differences in Perceptions of SDG Achievement

The analysis of pre-service mathematics teachers' perceptions of SDG achievement revealed gender-based differences in how sustainability progress is assessed. Table 11 shows distribution of pre-service mathematics teachers' views on SDG achievement by gender. As summarized in Table 11, female participants demonstrated more optimistic views regarding social and economic SDG achievements compared to their male counterparts.

In the social dimension, female pre-service teachers recorded an average score of 75.18, whereas male students scored 66.05, indicating that females perceive greater progress in social sustainability areas, such as gender equality, social justice, and community well-being. A similar trend was observed in the economic dimension, where female respondents scored 73.45, compared to 69.83 for males. This suggests a more positive outlook on economic sustainability advancements.

These findings suggest that female pre-service teachers exhibit greater optimism or heightened awareness regarding social and economic sustainability achievements. The reasons for these differences could stem from varying educational experiences, exposure to sustainability-related topics, or broader socio-cultural influences shaping gendered perspectives on SDGs.

To ensure balanced perspectives on SDG implementation, teacher training programs should incorporate targeted educational strategies that address these gender-based disparities. Providing equitable learning opportunities and fostering critical engagement with sustainability issues will better prepare all future educators to advocate for sustainability in their teaching practices, ensuring a comprehensive and inclusive approach to sustainability education.

Survey dimension	Gender	N	Mean
SDG social dimension	Female	128	75.18
	Male	19	66.05
	Total	**147**	
SDG economical dimension	Female	127	73.45
	Male	18	69.83
	Total	**145**	
SDG ecological dimension	Female	126	74.19
	Male	18	60.69
	Total	**144**	
Revitalizing the global partnership for the SDGs	Female	126	73.79
	Male	18	63.44
	Total	**144**	

Table 11. Pre-service mathematics teachers' views on SDG achievement by gender

Gender Differences in Ecological Dimension and Global Partnerships

The findings reveal gender-based differences in pre-service mathematics teachers' perceptions of SDG achievements, particularly in the ecological dimension and global partnerships. Table 12 summarizes sub-dimensions of pre-service mathematics teachers' SDG achievement level. As shown in Table 12, female participants demonstrated more positive perceptions in both areas compared to their male counterparts.

In the ecological dimension, female pre-service teachers reported a mean score of 74.19, significantly higher than 60.69 for males, suggesting that female participants perceive greater progress in environmental sustainability efforts. Similarly, in the global partnerships dimension, female respondents scored 73.79, compared to 63.44 for males, indicating greater optimism about international collaboration in achieving SDGs.

Despite these observed gender-based variations, statistical analysis revealed no significant differences ($p > 0.05$), suggesting a general consensus among participants regarding SDG achievement. While disparities exist in perceptions of specific dimensions, they do not indicate fundamental differences in overall sustainability awareness.

These findings emphasize the need to provide pre-service teachers with more extensive training and resources related to ecological sustainability and global partnerships. A comprehensive

trainings in these dimensions will equip them with the necessary knowledge and instrctional strategies to effectively integrate sustainability into mathematics education. By immersing pre-service teachers in these areas, teacher training programs can better support SDG implementation in Türkiye and beyond. This will result in a generation of educators who actively contribute to global sustainability efforts.

Test	Social dimension	Economical dimension	Ecological dimension	Revitalizing the global partnership for the SDGs
Mann-Whitney U	1065.00	1086.00	921.50	971.00
Wilcoxon W	1255.00	1257.00	1092.50	1142.00
Z	-0.873	-0.344	-1.29	-1.04
p	0.383	0.731	0.197	0.30

Table 12. Sub-dimensions of pre-service mathematics teachers' SDG achievement level

The analysis revealed no significant gender differences in sustainable development awareness, aligning with findings from previous studies (Leiva-Brondo et al., 2022). However, these results contrast with research suggesting higher awareness among males in certain contexts (Gough et al., 2020) or greater awareness among females in specific aspects of sustainability (Costello et al., 2009).

These discrepancies may stem from a range of factors, including knowledge exposure, personality traits, and political ideology, reflecting the complexity of environmental and sustainability awareness. As such, gender alone is insufficient to fully explain variations in SDG awareness. Future research should explore the broader influences shaping sustainability perceptions, incorporating demographic, psychological, and contextual factors. A deeper understanding of these variables will help develop more effective strategies for promoting sustainability education among pre-service teachers. As a result, a more comprehensive and inclusive approach to sustainability awareness in teacher training programs will be achieved.

Effects of Environmental Club Membership on Sustainability Awareness

The study examined the impact of environmental club membership on pre-service mathematics teachers' awareness and attitudes toward ESD. Among the participants, 20 individuals were members of environmental clubs, including 14 affiliated with TEMA (The Turkish Foundation for

Combating Soil Erosion, for Reforestation, and the Protection of Natural Habitats) and 6 involved in other organizations, while the majority (132 participants) were non-members.

Table 13 shows distribution of pre-service mathematics teachers' survey responses by environmental club membership. As shown in Table 13, club membership was associated with higher awareness and more positive attitudes toward ESD, particularly among female participants. Female club members scored an average of 89.90, indicating strong engagement with sustainability concepts, whereas male club members scored lower, with an average of 74.47.

These findings suggest that involvement in environmental organizations enhances sustainability awareness, with female participants showing greater engagement compared to their male counterparts. Participation in such extracurricular activities provides valuable opportunities for pre-service teachers to deepen their understanding of sustainability, apply theoretical knowledge in real-world contexts, and develop a stronger commitment to environmental responsibility.

Encouraging greater participation in environmental clubs may serve as an effective strategy for strengthening sustainability education in teacher training programs. By integrating extracurricular sustainability initiatives with formal education, pre-service teachers can enhance their competencies in sustainability-related teaching practices, ultimately contributing to more effective integration of ESD in mathematics education.

Survey dimension	Member	N	Mean
Education for sustainable development attitude scale towards	Yes	20	89.90
	No	132	74.47
	Total	**152**	
Development with sustainable development matching indicators scale	Yes	20	90.75
	No	127	71.36
	Total	**147**	
Sustainable development goals achievement level	Yes	20	60.88
	No	128	76.63
	Total	**148**	

Table 13. Pre-service mathematics teachers' responses by environmental club membership

Environmental Club Membership and Sustainable Development Awareness

Table 14 shows environmental club membership of the study participants. The analysis examined the relationship between environmental club membership and sustainable development awareness,

with results summarized in Table 14. The findings indicate differences in sustainability perceptions and understanding based on club membership, though these variations were not statistically significant due to the small sample size.

Regarding the alignment between SDGs and their indicators, female club members scored an average of 90.75, suggesting a strong understanding of the connections between sustainable development goals and their corresponding measures. In contrast, male club members scored lower, with an average of 71.36, indicating less familiarity with SDG-related indicators.

However, in terms of perceived SDG achievement, male participants demonstrated a more favorable outlook, scoring 76.63, compared to 60.88 among female club members. This suggests that male members of environmental clubs may perceive greater progress toward sustainability goals than their female counterparts.

Due to the small sample size of club members ($n < 30$), statistical analysis using the non-parametric Mann-Whitney U test did not reveal statistically significant differences ($p > 0.05$) across the scales. While environmental club membership appears to be associated with higher awareness and positive attitudes toward sustainability, the lack of statistical significance indicates that further research with larger sample sizes is needed to confirm these trends.

These findings underscore the potential value of extracurricular environmental engagement in fostering sustainability awareness among pre-service teachers. While club membership correlates with greater sustainability literacy, additional efforts are needed to ensure that all pre-service teachers—regardless of formal extracurricular involvement—develop a strong foundation in sustainable development principles.

Test	Education for sustainable development attitude scale	Development with sustainable development matching indicators scale	Sustainable development goals achievement level
Mann-Whitney U	1052.00	935.00	1007.50
Wilcoxon W	9830.00	9063.00	1217.50
Z	-1.47	-1.9	-1.53
p	0.14	0.06	0.126

Table 14. Environmental club membership

Although membership in environmental clubs is often linked to higher environmental literacy, the findings of this study revealed no significant differences in sustainable development awareness

between members and non-members. This suggests that engagement with sustainability knowledge is not solely dependent on formal participation in environmental organizations.

One possible explanation for this lack of distinction is Generation Z's heavy reliance on digital platforms as primary sources of information. The widespread accessibility of online resources and social media allows young individuals to stay informed and actively engage with sustainability topics outside formal educational or extracurricular settings (Houman et al., 2023). Digital platforms provide immediate access to a vast array of environmental content, fostering sustainability awareness even among those not affiliated with formal environmental groups.

These findings underscore the importance of integrating digital resources into educational programs to align with the evolving information landscape. Leveraging online platforms, interactive learning tools, and digital media can enhance sustainability education, ensuring that pre-service mathematics teachers and other young learners develop comprehensive environmental literacy. By embracing the potential of digital engagement, teacher education programs can expand access to sustainability knowledge, equipping future educators with the tools to promote sustainable practices both inside and outside the classroom.

Academic-Year Effects on Sustainable Development Awareness

Table 15 shows distribution of pre-service mathematics teachers' attitudes towards ESD by academic years. The analysis of pre-service mathematics teachers' attitudes toward ESD by academic year, summarized in Table 15, reveals variations in sustainability awareness across different levels of study. These differences are likely influenced by variations in educational experiences, curricular exposure, and engagement with sustainability concepts over time.

Understanding these patterns is particularly valuable for designing targeted interventions within mathematics teacher education programs. By identifying how sustainability awareness develops over the course of teacher training, educators and policymakers can refine curriculum design, instructional strategies, and extracurricular opportunities. This will enable all pre-service teachers to acquire a comprehensive understanding of sustainable development.

Further curricular analysis, pedagogical improvements, and the integration of sustainability-focused activities can strengthen future teachers' ability to incorporate sustainability principles into their own classrooms. Developing a structured approach to embedding sustainability across different academic levels will better equip pre-service mathematics teachers to effectively promote sustainable development in education.

Survey dimension	Class	N	Mean

ESD practices in school	Freshman	14	76.50
	Sophomore	47	79.46
	Junior	56	74.63
	Senior	37	79.73
	Total	**154**	
Individual and social benefits of ESD	Freshman	14	92.07
	Sophomore	47	73.22
	Junior	56	77.14
	Senior	37	77.96
	Total	**154**	
Goals and applica-bility of ESD	Freshman	14	66.86
	Sophomore	47	78.57
	Junior	56	76.63
	Senior	37	78.45
	Total	**154**	
Attitudes towards ESD	Freshman	14	84.25
	Sophomore	47	77.05
	Junior	56	75.57
	Senior	37	78.43
	Total	**154**	

Table 15. Distribution of pre-service math teachers' attitudes towards ESD by academic years

Academic-Year Differences in Attitudes Toward ESD

Table 16 presents the dimensions of the attitude scale toward ESD, summarizing the results of the Kruskal-Wallis test conducted to analyze variations in pre-service mathematics teachers' attitudes toward ESD across academic years. Given the limited number of freshman participants ($n < 30$), non-parametric methods were used for statistical analysis.

The findings indicate no statistically significant differences ($p > 0.05$) in attitudes toward ESD across academic years, suggesting a consistent level of sustainability awareness among pre-service teachers, regardless of their academic standing. This uniformity may reflect a standardized implementation of sustainability-related curriculum and experiences throughout the teacher training program.

Despite the absence of significant differences, further research is needed to examine curriculum content, instructional approaches, and extracurricular opportunities to assess their effectiveness in

enhancing sustainability education. A deeper investigation into how sustainability is integrated at different academic levels can help identify areas for improvement. This will ensure that pre-service teachers develop strong sustainability competencies by the time they enter the profession.

Although no substantial variations across academic years were observed, the findings emphasize the need for continuous efforts to strengthen sustainability education. Enhancing curriculum depth, incorporating innovative teaching strategies, and expanding sustainability-focused extracurricular activities will further reinforce pre-service teachers' ability to integrate sustainable development concepts into their future classrooms.

Test	ESD practices in school	Individual and social benefits of ESD	Goals and applicability of ESD	Attitudes towards ESD
Chi-Square	0.43	1.97	0.91	0.45
df	3	3	3	3
p	0.94	0.58	0.82	0.93

Table 16. Dimensions of the attitude scale toward ESD

Academic-Year Effects on Matching Sustainable Development and Development Indicators

Table 17 shows distribution of pre-service mathematics teachers' matching of SD and related indicators by academic year. This analysis assesses whether academic progression influences the understanding of how sustainable development aligns with specific indicators. That will provide insights into the effectiveness of the curriculum in fostering sustainability literacy.

The findings serve as a valuable tool for evaluating the impact of curriculum design, instructional methods, and learning experiences on pre-service teachers' preparedness to integrate sustainability into their teaching. Identifying trends or inconsistencies across academic levels can help educators refine pedagogical approaches and adapt course content to ensure a more comprehensive and progressive development of sustainability competencies throughout teacher training programs.

By analyzing how sustainability awareness evolves over time, teacher education programs can implement targeted improvements that strengthen pre-service teachers' ability to apply sustainability principles in mathematics instruction. A structured approach to reinforcing the connection between sustainable development and its indicators will better equip future educators to incorporate sustainability concepts into their teaching practices.

Survey dimension	Class	N	Mean

Ecological dimension	Freshman	14	76.21
	Sophomore	44	77.44
	Junior	54	74.80
	Senior	36	69.79
	Total	**148**	
Social dimension	Freshman	14	76.21
	Sophomore	44	77.44
	Junior	54	74.80
	Senior	36	69.79
	Total	**148**	
Economical dimension	Freshman	14	73.89
	Sophomore	44	74.82
	Junior	54	75.61
	Senior	36	72.68
	Total	**148**	
Development with Sustainable Development Matching Indicators Scale	Freshman	14	81.18
	Sophomore	44	73.11
	Junior	54	74.65
	Senior	36	73.38
	Total	**148**	

Table 17. Pre-service mathematics teachers' matching of SD and indicators by academic year

Academic-Year Differences in Matching Sustainable Development and Indicators

Table 18 shows dimensions of the SD and indicators matching scale, outlining the test values for pre-service mathematics teachers' understanding of the alignment between SD concepts and related indicators. The analysis found no statistically significant differences in scores across academic years, indicating a consistent level of understanding among participants, regardless of their academic progression.

This lack of variation suggests that sustainability awareness remains stable throughout teacher training, potentially reflecting a uniform curriculum structure or consistent exposure to sustainability-related topics. While this consistency may be beneficial in ensuring foundational sustainability knowledge, it also underscores the need for continuous curriculum assessment and enhancement to ensure progressive learning and deeper engagement with sustainability issues.

Future research should explore factors contributing to this uniformity, including teaching methods, content delivery strategies, and the availability of experiential learning opportunities. Investigating

how practical engagement with sustainability concepts (e.g.project-based learning, case studies, and interdisciplinary approaches) affects student understanding could provide insights into ways to enhance sustainability education within teacher training programs.

Strengthening curriculum design to incorporate more dynamic, applied learning experiences will help pre-service mathematics teachers develop a more integrated and practical understanding of sustainability. That will make it possible that teachers are well-prepared to embed these concepts effectively in their future teaching practices.

Test	Ecological dimension	Social dimension	Economical dimension	Scale for matching SD and development indicators
Chi-Square	0.67	0.67	0.11	0.41
df	3	3	3	3
p	0.88	0.88	0.99	0.94

Table 18. Dimensions of the SD and indicators matching scale

Academic-Year Effects on Perceptions of SDG Achievement

Table 19 presents the distribution of pre-service mathematics teachers' perceptions of SDG achievement across academic years, aiming to assess whether perceptions of sustainability progress vary throughout teacher training. This analysis provides valuable insights into how awareness and understanding of sustainable development evolve as students advance in their academic journey.

Examining these differences is crucial for evaluating the effectiveness of the curriculum in shaping students' sustainability perspectives. If significant variations exist across academic years, this may indicate that exposure to sustainability concepts increases with academic progression. Conversely, a lack of differences could suggest a consistent, but potentially static, approach to sustainability education throughout the program.

The findings from this analysis will contribute to a better understanding of the relationship between academic progression and sustainability perceptions. This will offer guidance on how teaching strategies and curriculum design can be refined to enhance sustainability literacy. Identifying potential gaps or areas for improvement can help ensure that pre-service mathematics teachers develop a well-rounded, informed perspective on SDG achievements, equipping them to integrate sustainability more effectively into their future teaching practices.

Survey dimension	Class	N	Mean

Ecological dimension	Freshman	14	57.29
	Sophomore	44	79.55
	Junior	55	65.71
	Senior	35	88.86
	Total	**148**	
Social dimension	Freshman	14	63.11
	Sophomore	44	75.08
	Junior	54	67.74
	Senior	34	84.88
	Total	**146**	
Economical dimension	Freshman	14	58.68
	Sophomore	44	72.88
	Junior	53	67.97
	Senior	34	86.90
	Total	**145**	
Development with Sustainable Development Matching Indicators Scale	Freshman	14	63.57
	Sophomore	44	76.93
	Junior	53	70.02
	Senior	34	76.44
	Total	**145**	
Level of achievement of Sustainable Development Goals	Freshman	14	58.57
	Sophomore	44	79.01
	Junior	55	65.96
	Senior	35	88.61
	Total	**148**	

Table 19. Pre-service mathematics teachers' SDG achievement opinions by academic year

Academic Progression and Perceptions of SDG Achievement

The analysis of pre-service mathematics teachers' perceptions of SDG achievement reveals that seniors demonstrate the highest awareness across the social, economic, and ecological dimensions. As shown in Table 19, SDG awareness scores increase progressively from the freshman to senior years, suggesting a positive correlation between academic progression and sustainability awareness.

For instance, scores in the SDG Social Dimension rise from 57.29 among freshmen to 88.86 among seniors, while the SDG Economic Dimension follows a similar pattern, increasing from 63.11 to

84.88. This trend indicates that continued exposure to coursework, sustainability discussions, and teacher training experiences contributes to enhanced awareness and understanding of sustainable development over time.

Conversely, the lower scores observed among freshmen may reflect insufficient sustainability education during the early years of teacher training. This highlights the need for earlier integration of sustainability concepts within the curriculum to confirm that students develop a strong foundation in sustainable development from the beginning of their academic journey.

These findings emphasize the importance of progressive curriculum design that systematically reinforces sustainability education across all academic levels. By incorporating sustainability principles earlier in teacher training, education programs can foster deeper engagement with sustainability issues, equipping future mathematics teachers with the knowledge and skills to effectively integrate SDG concepts into their classrooms.

Academic-Year Analysis of SDG Achievement

Table 20 presents the SD dimensions and indicators matching scale. The data reveal significant disparities in SDG attainment perceptions among pre-service mathematics teachers, particularly by academic year. The results indicate that academic progression plays a key role in shaping students' views on sustainability achievements.

Statistical analysis revealed a p-value of 0.028 for the SDG Social Dimension and 0.038 for the overall scale, both of which fall below the 0.05 significance level. This finding suggests that academic year significantly influences how pre-service mathematics teachers perceive SDG achievement, with students at different academic levels demonstrating varying assessments of sustainability progress.

These differences may stem from variations in exposure to sustainability-related coursework, the depth of engagement with SDG topics, and the integration of sustainability discussions in teacher education programs. As students advance through their academic years, their increased exposure to sustainability education, research, and classroom discussions likely enhances their understanding and shapes their perceptions of SDG progress.

These findings highlight the importance of structuring sustainability education progressively across all academic years to ensure that students develop a well-rounded and informed perspective on sustainable development. By integrating comprehensive sustainability learning opportunities throughout teacher training programs, institutions can better prepare pre-service teachers to effectively incorporate SDG principles into their future teaching practices.

Test	SDG social dimension	SDG eco-nomical di-mension	SDG ecological dimension	Revitalizing the global partnership for the SDGs	Level of achievement of SDGs
Chi-Square	9.13	4.43	6.17	1.75	8.40
df	3	3	3	3	3
p	0.028	0.218	0.104	0.625	0.038

Table 20. SD dimensions and indicators matching scale

The analysis revealed that senior pre-service mathematics teachers demonstrated higher awareness of the SDGs compared to students in earlier academic years. This finding is consistent with studies conducted in Spain (Leiva-Brondo et al., 2022) and Italy (Smaniotto et al., 2020), which similarly reported greater sustainability awareness among senior students. The increased awareness observed in senior students may be attributed to cumulative academic experiences, deeper coursework, and greater exposure to sustainability topics throughout their training.

However, some researchers, such as Kirby et al. (2021), caution against viewing academic progression or age alone as a reliable predictor of sustainability knowledge. Other factors, including the quality of educational content, engagement in sustainability-related activities, and personal motivation, likely play significant roles in shaping students' awareness and understanding of the SDGs.

These findings highlight the need for teacher education programs to adopt a structured, progressive approach to sustainability education, ensuring that students at all academic levels receive meaningful engagement with sustainability concepts. By enhancing course content, integrating sustainability-focused activities, and fostering student motivation, institutions can cultivate a more comprehensive and well-rounded understanding of sustainable development among future mathematics educators.

Implications for Teacher Education and Sustainability Integration

Studies have demonstrated that incorporating sustainability into teacher training significantly enhances educators' ability to integrate environmental topics into their teaching (Suralin, 2023; Karim et al., 2021). Given the findings of this study and the critical role of sustainability awareness in mathematics education, universities offering teacher training programs should consider the following strategic recommendations:

- **Integrating real-world sustainability challenges into mathematics instruction:** Teacher education programs should incorporate sustainability-focused mathematical applications such as climate change modeling, statistical analysis of sustainability data, and resource management optimization. These topics can be embedded within mathematical reasoning and pedagogy courses, ensuring that future educators are equipped to connect sustainability concepts with core mathematics curricula.
- **Mandating sustainability training in teacher education programs:** Universities should consider requiring formal sustainability training for pre-service teachers. This could be achieved through dedicated ESD courses, interdisciplinary workshops, and sustainability-oriented pedagogical seminars. Each institution can develop its own tailored approach to effectively integrate sustainability into teacher training.
- **Establishing a national framework for sustainability education in Türkiye:** A structured, national model for integrating sustainability into mathematics teacher education could help standardize sustainability instruction across universities. A unified framework would ensure that all pre-service mathematics teachers receive consistent and systematic training, enabling them to effectively incorporate sustainability concepts into their future classrooms.

CONCLUSION

This study examined pre-service mathematics teachers' awareness of SDGs and ESD, focusing on how gender, academic level, and environmental club membership influence sustainability perceptions. While the findings indicate a general awareness of sustainability, they also reveal an uneven distribution of knowledge across different dimensions.

As a response to RQ1, the primary sources of information about sustainable development for pre-service math teachers in Türkiye are found to be educational and digital platforms. According to the study, more than half of the participants cited the internet as their primary source of SDG information, with university lectures coming in second. It was found that their awareness was only slightly shaped by traditional media, like newspapers and television. A similar trend was noted in relation to ESD, where 39.7% of respondents cited the internet as their primary source. There is a notable lack of structured exposure through formal education. On the other hand, a sizable percentage (38.5%) stated that they had no prior knowledge of ESD. These results demonstrate how pre-service teachers depend on internet resources for sustainability knowledge.

As a response to RQ2, pre-service math teachers in Türkiye showed uneven alignment with the three pillars of sustainable development, despite having a basic understanding of ESD. Social sustainability (e.g., quality education, gender equality) appears to be well understood, whereas ecological (e.g., climate action, clean water) and economic sustainability (e.g., responsible consumption, economic growth) receive less emphasis. This imbalance highlights the need for teacher education programs to strengthen instruction on environmental and economic sustainability to ensure a more comprehensive understanding.

Results showed gender differences were minimal. While male participants scored slightly higher on perceptions of ESD applicability, female participants tended to be more optimistic about social and economic sustainability accomplishments and more aware of ESD practices in schools. Even though overall gender differences were not statistically significant, It was found that male and female awareness levels are generally comparable.

From freshman to senior years, there was a progressive increase in academic awareness of the SDGs and perceptions of their accomplishment. Seniors showed the greatest awareness of social, ecological, and economic aspects. This suggests that more academic exposure enhances understanding of sustainability. This trend demonstrated how exposure to academic materials and discussions shapes awareness and was statistically significant for both the SDG social dimension and overall achievement perceptions.

Members of environmental clubs, especially female participants, reported greater awareness and more positive attitudes toward sustainability than non-members. However, these differences were not statistically significant because of the small sample size. Nevertheless, the results imply that extracurricular activities can improve sustainability consciousness and strengthen links between ESD and sustainable development principles.

Recommendations for Strengthening Sustainability Education

Based on the findings, the following recommendations are proposed to enhance the integration of sustainability within mathematics teacher education:

- **Early Integration of Sustainability Concepts:** Sustainability education should be embedded in the early years of teacher training rather than being introduced in later academic years.
- **Real-Life Applications in Mathematics Instruction:** Mathematics courses should include real-world data analysis, case studies, and problem-solving exercises that connect mathematical concepts with sustainability challenges.
- **Development of National Frameworks:** Governments should establish clear national policies for sustainability education in teacher training programs to ensure a standardized and systematic approach across universities.
- **Enhancing Digital Literacy:** Teacher training should equip future educators with critical digital literacy skills to help them evaluate and apply sustainability-related information from electronic sources in an informed manner.

In conclusion, while pre-service mathematics teachers in Türkiye exhibit moderate awareness of SDGs, their knowledge remains fragmented and is strongly influenced by their academic level. A structured and multidimensional approach to sustainability education is essential to bridging these gaps. Strengthening sustainability training within teacher education will empower future educators to integrate mathematics and sustainability effectively. A well trained teachers are expected to

prepare students to engage with global challenges through analytical and sustainability-oriented thinking.

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