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Sustainable Ecology Scale: Development Study for Secondary School Students

Kevser Arslan[1]*, Aslı Görgülü Arı[1], Behiye Akçay[2]

[1]Department of Mathematics and Science Education, Yıldız Technical University, Istanbul, Turkey
[2]Department of Science Education, İstanbul University-Cerrahpaşa, Istanbul, Turkey

*Corresponding author: arslankevser96@gmail.com

ABSTRACT This study aimed to develop a valid and reliable Sustainable Ecology Scale for secondary school students. The exploratory sequential design, a type of design within mixed-methods research, was employed. The study sample consisted of 500 secondary school students from various grade levels. To construct the draft version of the scale, a 96-item question pool was generated based on predefined learning objectives. In the initial phase, the draft scale was reviewed by expert evaluators, resulting in a reduction to 69 items. Following a pilot study, necessary adjustments were made, and the final version was implemented in the main study. The collected data were analyzed using statistical software, and both exploratory factor analysis and confirmatory factor analysis were conducted to ensure construct validity. The scale's reliability was assessed through Cronbach's alpha internal consistency coefficient, while item analyses, item-total correlation values, and factor correlations were examined. The results of CFA confirmed a three-factor structure, with fit indices indicating an acceptable to excellent model fit. As a result, a five-point Likert-type Sustainable Ecology Scale consisting of 32 items was developed, demonstrating a high internal consistency (Cronbach's alpha = 0.934). The findings indicate that the developed scale is a valid and reliable measurement tool suitable for assessing sustainable ecology awareness among secondary school students.

Keywords: Environment, Sustainability, Ecology, Literacy, Scale development, Secondary school

1. INTRODUCTION

With the rapid advancement of technology and industrialization in the 21st century, human activities have increasingly had detrimental effects on the environment, accelerating ecological degradation (Dere & Çinkaya, 2023). These anthropogenic impacts have placed the planet on a trajectory toward irreversible environmental destruction (Arora, 2018; Galli et al., 2012; Mızık & Yiğit Avdan, 2020; San-Francisco et al., 2020). The unsustainable exploitation of natural resources, coupled with an imbalance between consumption and conservation efforts, has contributed to resource depletion and ecosystem degradation.

These challenges have led to significant ecological crises, including climate change and biodiversity loss. (Görgülü-Arı, 2019; Prabawani et al., 2017). These environmental disruptions have led to the degradation of critical ecosystems, affecting essential natural elements such as soil, forests, freshwater bodies, marine environments, and air quality (Yoleri, 2012). Moreover, the unsustainable consumption of resources and unchecked environmental destruction pose a significant threat not only to human societies but also to biodiversity and the broader ecological balance (Akyüz, 2015).

Given the increasing urgency of these global environmental issues, there is a growing need for comprehensive strategies to mitigate anthropogenic impacts and promote sustainable resource management. Addressing these challenges requires interdisciplinary efforts that integrate scientific, technological, and policy-driven approaches to ensure environmental sustainability for future generations.

In recent years, growing concerns over environmental degradation, climate change, and socioeconomic issues and inequalities have brought the concept of sustainability to the forefront of global discussions (Arık, 2019; Belen, 2020). As an internationally recognized framework, sustainability encompasses multiple dimensions that require a comprehensive and interdisciplinary approach (Akgül & Aydoğdu, 2020; Gürlük, 2010). The widely accepted definition of sustainability Underlines the

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importance of meeting present demands while safeguarding future generations' opportunities (Pitelis, 2013). Among its core dimensions, environmental sustainability remains the most critical, as it directly influences ecological balance and long-term resource availability (Harris, 2000; Stokas et al., 2016; Soubbotina, 2004).

The increasing prominence of sustainability within environmental discourse is primarily driven by pressing global challenges, including pollution, depletion of natural resources, climate change, rising poverty levels, and the escalating rate of resource consumption (Çakır, 2023; Keleş, 2014; Yıldız, 2011). Key elements of environmental sustainability include biodiversity conservation, soil fertility, air and water quality, and the overall well-being of ecosystems (Kaypak, 2011; Tetik, 2023). Effective ecosystem and biodiversity management strategies are essential to ensuring the conservation and responsible use of natural resources. Addressing environmental risks necessitates the development of proactive solutions that enhance ecological awareness and promote sustainable behaviors (Chhokar et al., 2004).

Within this context, waste management and fostering attitudes toward sustainable consumption play a vital role in ecological conservation efforts (De Andrade Guerra et al., 2018). Zamora Polo and Sánchez Martín (2019) emphasize the importance of establishing structural frameworks that support sustainability and holistic ecological perspectives, enabling societies to coexist in harmony with nature. The interconnectedness of sustainability and ecology underscores their inseparability, as both concepts collectively contribute to long-term environmental stewardship. Long-term ecological well-being depends on the early integration of sustainable behaviors into daily life. Consequently, the integration of sustainability and ecology gives rise to the concept of sustainable ecology, which serves as a foundational paradigm for fostering environmental resilience and sustainable development.

The increasing impact of human activities on the environment necessitates educating the next generation to develop solutions that mitigate ecological degradation and prevent potential, irreversible environmental destruction. Societies that successfully implement sustainability practices rely heavily on education as the primary means of fostering environmental consciousness and responsibility (Okyay et al., 2021; Van Poeck et al., 2018). Hopkins and McKeown (2002) emphasize that education serves as the fundamental pillar for achieving sustainability, while McKeown (2014) defines sustainability education as an approach that cultivates the attitudes, knowledge, and skills required for a sustainable future. Within this framework, environmental education, recognized as the cornerstone of sustainability, plays a crucial role in raising environmentally responsible and ecologically aware individuals (Gülay & Öznacar, 2010).

Individuals play a central role in maintaining ecological balance, achieving sustainability goals, and safeguarding environmental systems. Since anthropogenic activities are the primary drivers of ecological disruption, corrective measures must also be led by individuals. In this regard, fostering awareness of sustainable ecology from an early age is essential, particularly among younger generations (Muldoon et al., 2019). Sustainable ecological competencies should be developed and internalized as a way of life through structured educational programs, particularly at the primary and secondary education levels. To achieve this, topics such as responsible resource consumption, pollution mitigation, biodiversity conservation, and recycling must be effectively integrated into the curriculum (De Andrade Guerra et al., 2018; Kaygısız, 2020).

Enhancing students' ecological awareness and fostering environmental sensitivity can only be accomplished through a well-structured and impactful sustainable ecology education. Gathering feedback from learners is critical for tailoring educational approaches to individual needs and ensuring the effectiveness of instructional strategies. By incorporating such feedback, sustainable ecology education can be refined to meet the desired learning outcomes. Moreover, assessing students' pre-existing knowledge of sustainability-related topics is instrumental in designing targeted and impactful educational interventions.

The Sustainable Ecology Scale, developed within the scope of this study, makes a unique contribution to the field of environmental education as a validated tool for assessing the ecological competencies of secondary school students. Unlike many tools that focus on environmental attitude or awareness scales, it combines cognitive, affective, and behavioral components. An important aspect of the scale's originality is its alignment with global sustainability agendas that draw on both environmental education goals and ecological literacy frameworks. The inclusion of items derived from curriculum-based learning outcomes makes the scale a curriculum-responsive diagnostic tool that educators can use directly to monitor and improve sustainability-related teaching. It also fills a gap in the literature by introducing the concept of 'sustainable ecology' as a holistic construct that bridges consciousness and sustainable living practices. Finally, strong reliability indices, combined with a robust validation process that utilizes both exploratory and confirmatory factor analyses on separate samples, enhance the scale's utility for international comparative studies, national educational evaluations, and targeted intervention programs. In summary, the present scale is a novel and versatile tool for educators who wish to assess and promote ecological literacy and sustainability in secondary school students.

The three-factor structure of the Sustainable Ecology Scale was designed to encompass cognitive, affective, and behavioral aspects based on environmental and sustainability education. The cognitive dimension corresponds to students' knowledge and understanding of ecological processes, sustainability principles, and environmental challenges. This dimension evaluates how effectively students can define ecological problems and comprehend the logic behind sustainable solutions. The Affective Dimension encompasses students' emotional reactions, environmental concerns, and value-based orientation toward sustainability and is critical in shaping the components of taking responsibility and environmental values. This factor reflects an internalized concern for nature and ethical attitudes toward ecological conservation, indicating the value-based orientation of the student. It emphasizes the development of attitudes and values that support sustainability and protect the natural environment. The last dimension, the behavioral dimension, reflects sustainability-related actions such as recycling, resource conservation, or participation in environmental initiatives. This dimension serves to transform individuals' ecological knowledge and values into actions. Therefore, it bridges the gap between intention and behavior in sustainability education. These three dimensions collectively provide a holistic model of sustainable ecological literacy that aligns with the principles of sustainable living. This construct provides an integrated assessment of how students think (cognitive), feel (affective), and behave (behavioral) regarding sustainability, thereby addressing all key learning domains in environmental education theory. In light of this need, the development of an assessment tool for sustainable ecology is expected to make a significant contribution to the field, providing educators and researchers with a standardized measure to evaluate students' ecological knowledge, attitudes, and competencies. Accordingly, this study aimed to develop a "Sustainable Ecology Scale" for middle school students. The research focused on answering the following fundamental questions:

1. Does the developed "Sustainable Ecology Scale" provide valid results?
2. Does the developed "Sustainable Ecology Scale" provide reliable results?

2. METHOD

2.1 Research Model

This study employed an exploratory sequential design, a type of design within the mixed-methods research approach. The exploratory sequential design involves an initial qualitative phase followed by a subsequent quantitative phase. In this process, qualitative data are collected, analyzed, and then integrated into the quantitative stage to refine and validate measurement instruments. This approach enables a more profound and thorough understanding of research problems by first exploring concepts qualitatively and then testing them quantitatively (Creswell & Creswell, 2021).

Following this methodological framework, the research process commenced with the qualitative phase, during which a preliminary question pool was developed through a thorough review of the literature. The collected qualitative data were shaped by the results of the measurement tool, which were then structured into a draft form. In the quantitative phase, this draft instrument was administered to an appropriate sample to assess its validity and reliability. Statistical analyses, including validity and reliability coefficient calculations, were carried out to ensure the psychometric robustness of the tool. The step-by-step process of the study's exploratory sequential mixed-method design is illustrated in Figure 1.

Figure 1 illustrates the step-by-step process of the study conducted within the framework of the exploratory sequential mixed-method design. In the first phase, qualitative data were collected and analyzed, resulting in the development of an initial item pool for the measurement

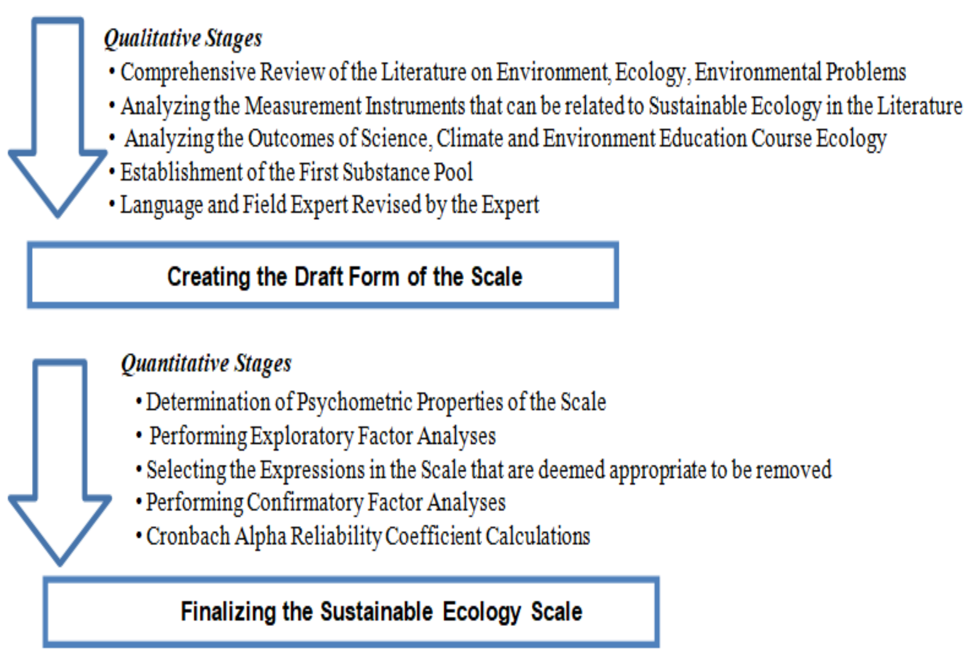

Figure 1 Method design steps of the study

tool, which was grounded in an extensive review of the literature. Following this, the draft version of the measurement instrument was constructed.

During the quantitative phase, the preliminary version of the tool was administered to the participants, and quantitative data were subsequently collected. The dataset obtained from the students was transferred to a statistical software program for analysis. Item analysis procedures were conducted to evaluate the psychometric properties of the instrument. Additionally, the reliability of the tool was assessed using Cronbach's alpha internal consistency coefficient to determine its internal reliability and consistency.

2.2 Participants

This study employed an exploratory sequential design, a type of design within the study. The study group consisted of 500 secondary school students, with an equal number of participants from each grade level, who were enrolled in a public secondary school in Istanbul during the 2022–2023 academic year. The participants were selected using convenience sampling, a non-random sampling method that allows for practical and efficient data collection by selecting individuals who are readily accessible to the researcher (Fraenkel & Wallen, 2011; Yıldırım & Şimşek, 2018). This approach was chosen to enhance the feasibility and efficiency of the research process, facilitating easier access to the target student population. The demographic characteristics and attributes of the participating students are presented in Table 1.

Table 1 presents the demographic distribution and characteristics of the secondary school students who participated in the study. Among the 500 students, 289 were female, and 211 were male, with participants evenly distributed across all grade levels. Special attention was given to ensuring that the number of students included from each grade level was balanced.

To establish the validity and reliability of the measurement tool, the sample was divided into two groups. Three hundred (300) students participated in the exploratory factor analysis (EFA), while two hundred (200) students contributed to the confirmatory factor analysis (CFA). According to existing methodological guidelines, an ideal sample size for factor analysis should be three to five times the number of items in the scale (Bryman & Cramer, 2001; Sönmez & Alacapınar, 2016).

Additionally, the literature suggests that a sample size of 300 is generally adequate for exploratory factor analysis (EFA), although smaller samples may pose certain limitations (Tabachnick & Fidell, 2019; DeVellis, 2017). For confirmatory factor analysis (CFA), a minimum sample size of 150 or more is recommended to ensure statistical robustness (Muthén & Muthén, 2002). In line with these recommendations, 300 students were included in the EFA phase, while 200 students participated in the CFA phase of this scale development study.

Table 1 Qualifications of the research group

	Exploratory Factor Analysis	Confirmatory Factor Analysis	Total
Gender			
Female Student	168	121	289
Male Student	132	79	211
Class Level			
5	68	45	113
6	75	52	127
7	77	52	129
8	80	51	131
Total	300	200	500

2.3 Research Process and Planning

The research methodology and study design were shaped and drawn from a thorough examination of the literature. Drawing upon existing scale development studies (Acar Güvendir & Özer Özkan, 2022; Benek & Akçay, 2019; Carpenter, 2018; De Vellis & Thorpe, 2021; Sangwan et al., 2021; Tzafilkou et al., 2022; Wang et al., 2022; Zhou, 2019), the step-by-step stages of the scale development process are illustrated in Figure 2.

Figure 2 illustrates the stages of the research conducted to develop the Sustainable Ecology Scale. The process began with an extensive literature review to identify the necessity of a Sustainable Ecology Scale. A comprehensive

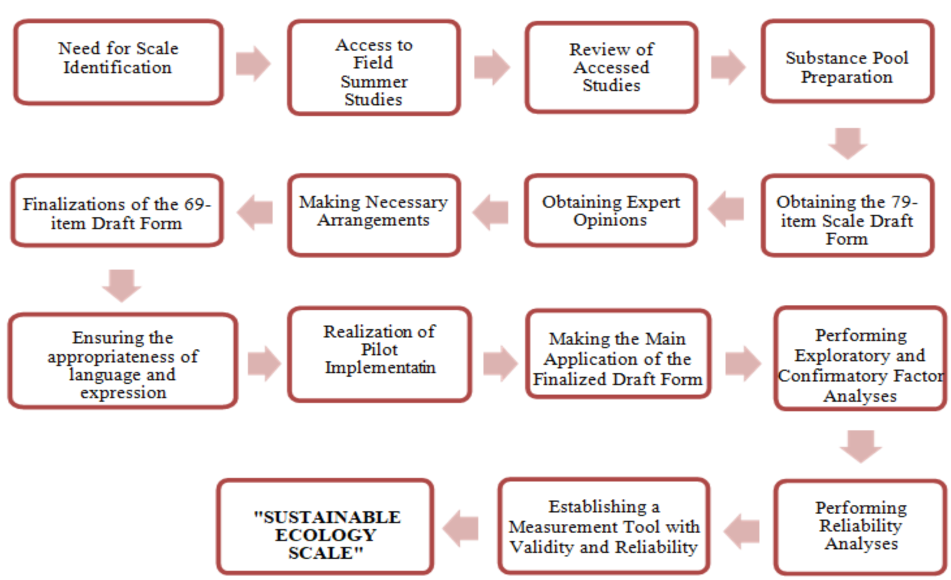

Figure 2 Stages of the development of the sustainable ecology scale

examination of articles, theses, and dissertations related to environment, ecology, and sustainability was conducted, alongside an evaluation of existing measurement tools in the field. Additionally, secondary school textbooks were analyzed, with specific attention given to the environment, ecology, and climate change-related learning outcomes embedded in science and environmental education curricula. The key learning outcomes that should be included in the scale were identified. However, based on expert and researcher evaluations, additional items that were deemed important for students' ecological literacy were incorporated into the scale.

The scale content was developed based on the learning outcomes from science and environmental education courses, as well as expert-generated items. To construct a robust item pool, three field experts contributed by formulating items derived both from the literature and original research insights. The question pool was structured to assess students' cognitive, emotional, and behavioral dimensions of ecological awareness. Consequently, an initial pool of 96 items was generated. In the subsequent revision stage, this number was refined to 79 items after careful evaluation by the researchers.

To ensure content validity, the Content Validity Ratio was calculated using Lawshe's (1975) method, a widely accepted and practical approach for assessing content validity (Ayre & Scally, 2014). Items with overlapping meanings or those deemed insufficiently aligned with the research objectives were removed from the draft version. Consequently, a 79-item preliminary scale was formulated.

Next, the draft scale was evaluated by eight field specialists, including a social studies educator, an environmental scientist, two measurement and evaluation experts, two science educators, and two science teachers. A professional judgment form was used to assess the appropriateness of each item systematically. Experts were solicited to indicate whether the relevance of each item was appropriate or inappropriate. For items deemed inappropriate, they were required to provide justifications, suggestions, or corrections. Based on expert feedback, 10 items were eliminated, resulting in a revised draft of 69 items.

The refined scale was then subjected to linguistic and content review by two language experts to ensure clarity, coherence, and appropriateness of wording. Redundant, ambiguous, or improperly worded items were revised or removed, and final refinements were made. The scale was structured using a five-point Likert format, and a brief yet concise instruction explaining the purpose and guidelines for administration was added to the draft form.

For initial validation, the 69-item draft scale underwent a pilot study with 20 students to assess its applicability and comprehensibility. After this preliminary stage, the scale was finalized for large-scale implementation. In the final phase, exploratory factor analysis and confirmatory factor analysis were conducted to evaluate the psychometric properties of the scale, ensuring its validity and reliability for measuring sustainable ecology awareness among students.

2.4 Data Collection Process

During the second semester of the 2022–2023 academic year, secondary school students participated in the study by completing the scale form in person. Data collection was conducted using the 69-item draft version of the scale. Prior to administering the form, students were provided with detailed instructions and explanations regarding the study's purpose and the proper procedure for completing the form. This step ensured that participants clearly understood the items and responded accurately, thereby enhancing the reliability of the collected data.

2.5 Data Analyses

A quantitative data analysis approach was employed in this study. The gathered data were analyzed employing SPSS and LISREL statistical software. In the initial stage, the dataset was carefully examined, and incomplete or blank responses were excluded from further analysis. The remaining valid responses were processed using SPSS 22.0 to conduct statistical analyses. This systematic approach ensured the accuracy and reliability of the data used for further evaluations.

At the preliminary stage of the analysis, the dataset was reviewed to assess whether it followed a normal distribution. Given that the sample size exceeded 50 participants, the Kolmogorov-Smirnov test was conducted to assess normality (Seçer, 2017). As suggested in the literature (Büyüköztürk, 2019; İlhan et al., 2013; Tabachnick & Fidell, 2019), before conducting factor analysis, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity tests were conducted to assess the appropriateness of the data for factor analysis. Following these preliminary tests, exploratory factor analysis was initiated.

Varimax rotation was applied during factor analysis, as this method is commonly used to produce a more precise distinction among factors by maximizing variance (Can, 2022). Varimax rotation was specifically chosen to enhance the interpretability of item distributions across factors. Upon completion of EFA, confirmatory factor analysis (CFA) was conducted to validate the factor structure and sub-dimensions identified in the exploratory analysis. The verification of the scale structure through CFA serves as critical evidence supporting the validity of the scale's construct (Yaşlıoğlu, 2017).

For the CFA, the dataset obtained from the second sample group was transferred to LISREL, where confirmatory factor analysis was performed. Therefore, this analysis confirmed the factor loadings and fit indices, ensuring the structural integrity of the scale. "Moreover, the reliability of the scale was assessed using Cronbach's alpha internal consistency coefficient, which was calculated for both the overall scale and its sub-dimensions."

To further evaluate the discriminative power of the scale items, item-total correlation values were calculated to determine the effectiveness of each item in measuring the intended construct. The dataset was then ranked based on total scores, and 27% upper and 27% lower subgroups were formed from the 300-participant sample, resulting in two subgroups of 81 participants each for further comparative analysis.

2.6 Ethical Process of the Research

The secondary school students who participated in the study were provided with detailed explanations regarding the research methodology and the intended use of their responses. To ensure participant confidentiality, student names and surnames were anonymized, and a coding system was implemented to protect their identities.

As part of the ethical procedures, all necessary legal permissions were obtained from both the Ethics Committee of the university where the researchers are affiliated and the Ministry of National Education. The ethical approval for this scale adaptation study was granted by the Yıldız Technical University – Social and Human Sciences Research Ethics Committee on February 2, 2023, under approval number 2023.02.

3. RESULT

This section outlines the findings from the validity and reliability analyses of the Sustainable Ecology Scale, which was developed within the scope of this study. Before proceeding with factor analysis, the dataset was assessed for normality distribution, as meeting this assumption is a prerequisite for conducting valid factor analysis. To evaluate normality, a normality distribution test was conducted, and the results are presented in Table 2.

Table 2 presents the results of the normality distribution test for the draft version of the Sustainable Ecology Scale." An examination of the normality test findings revealed no statistically significant difference ($p > 0.05$), indicating that the dataset followed a normal distribution. Additionally, the skewness and kurtosis values were within the acceptable range of -1.96 to +1.96 (skewness: -0.180; kurtosis: -0.132), further confirming the normality of the data (Can, 2022). Moreover, the mean, median, and mode values (mean: 3.51; median: 3.57) were found to be reasonably similar, supporting the assumption of normality. To assess the suitability of the dataset for factor analysis, the results of the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity are presented in Table 3.

Table 2 Normality test results

Kolmogorov-Smirnov			Shapiro-Wilk		
Statistic	Degrees of Freedom	p Significance	Statistic	Degrees of Freedom	p Significance
0.041	300	0.200*	0.992	300	0.086

Table 3 KMO and Barlett's test results

KMO Coefficient	0.914	
Barlett Test Results	Chi-square Value	4270.388
	Degrees of Freedom	496
	Significance (Sig.)	0.000

Table 3 displays the results of the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity for the dataset. The KMO value was 0.914, indicating a high level of sampling adequacy. Bartlett's test yielded a chi-square value of 4270.388 with 496 degrees of freedom ($p < 0.001$), confirming that the dataset was suitable for exploratory factor analysis (EFA). These results demonstrate that the dataset meets the necessary statistical assumptions for conducting factor analysis.

Following the Varimax rotation procedure during the exploratory factor analysis (EFA), certain items were removed based on their factor loadings. Table 4 presents the eigenvalue statistics obtained from the rotated component matrix, which reflects the final factor structure after removing low-loading items.

Table 4 Explained variance and eigenvalues of the scale

Factors	Total	Variance Explained	Cumulative (%)
1	5.58	17.44	17.44
2	4.75	14.87	32.31
3	4.67	14.60	46.92

Table 4 presents the total variance explained and percentage values of 37 items (2, 5, 6, 7, 9, 14, 18, 19, 20, 21, 25, 28, 30, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 52, 53, 54, 57, 64, 66, 68, 69) following the preliminary factor analysis. After conducting the initial factor analysis, the scale was refined to include 32 items grouped under three factors that collectively explained 46.92% of the total variance. Additionally, the variance contributions of each factor were determined as follows: 17.44%, 14.87%, and 14.60%, respectively.

As a result of the Varimax rotation applied during the exploratory factor analysis (EFA) process, the remaining items within the scale were renumbered to reflect the revised factor structure. Table 5 presents the common factor variances corresponding to the final retained items.

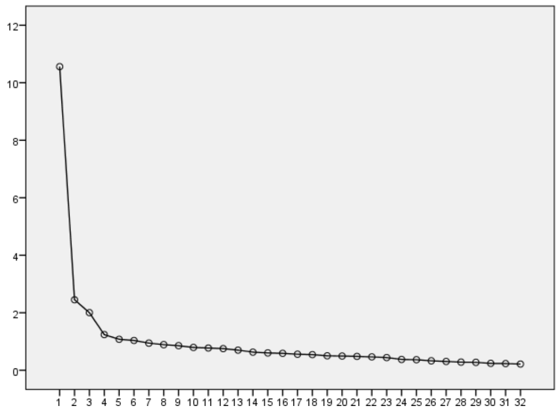

Figure 3 Scree-plot graph

Table 5 Common factor variance values of scale items after rotation

Item No	Initial Values	Factor Variance	Item No	Initial Values	Factor Variance
I1	1.00	0.445	I17	1.00	0.426
I2	1.00	0.437	I18	1.00	0.450
I3	1.00	0.512	I19	1.00	0.523
I4	1.00	0.491	I20	1.00	0.443
I5	1.00	0.411	I21	1.00	0.390
I6	1.00	0.508	I22	1.00	0.408
I7	1.00	0.434	I23	1.00	0.617
I8	1.00	0.382	I24	1.00	0.626
I9	1.00	0.399	I25	1.00	0.637
I10	1.00	0.429	I26	1.00	0.551
I11	1.00	0.478	I27	1.00	0.517
I12	1.00	0.424	I28	1.00	0.460
I13	1.00	0.444	I29	1.00	0.561
I14	1.00	0.466	I30	1.00	0.461
I15	1.00	0.455	I31	1.00	0.380
I16	1.00	0.487	I32	1.00	0.362

Table 6 Factor loadings of scale items and factors

Items No	Factor Loadings		
	1	2	3
I1	0.657		
I2	0.636		
I3	0.630		
I4	0.623		
I5	0.605		
I6	0.600		
I7	0.595		
I8	0.586		
I9	0.584		
I10	0.582		
I11	0.567		
I12	0.543		
I13		0.660	
I14		0.616	
I15		0.614	
I16		0.611	
I17		0.598	
I18		0.573	
I19		0.555	
I20		0.552	
I21		0.524	
I22		0.503	
I23			0.744
I24			0.695
I25			0.689
I26			0.673
I27			0.626
I28			0.595
I29			0.582
I30			0.553
I31			0.503
I32			0.475

Table 5 displays the common factor variance values of the retained items in the scale following the rotation process applied during the exploratory factor analysis (EFA). An analysis of these values indicates that the common factor variance values of the items range between 0.362 and 0.637, with all values exceeding the 0.30 threshold, confirming their adequacy for inclusion in the scale.

Table 6 displays the factor distributions of all remaining items in the scale, along with the corresponding factor loadings derived from the EFA results. These values provide insight into the contribution of each item to its respective factor, supporting the structural validity of the scale.

Table 6 presents the distribution of the retained items within the scale, following the exploratory factor analysis (EFA), along with their respective factor loadings. After completing the exploratory component analysis, the final version of the scale retained 32 items, confirming a three-factor structure. An analysis of the factor loadings indicates that the values range between 0.744 and 0.475, demonstrating strong item contributions to their respective factors. The factor loadings for each dimension were as follows.

Factor 1: Loadings ranged from 0.657 to 0.543
Factor 2: Loadings ranged from 0.660 to 0.503
Factor 3: Loadings ranged from 0.744 to 0.475

These results provide evidence for the structural validity of the scale, confirming the robustness of its factor composition. Figure 3 illustrates the scree plot, which represents the factor distribution obtained from the exploratory factor analysis (EFA).

An examination of Figure 3 reveals a precise breakpoint in the eigenvalue plot, indicating that the factors beyond the third point have a minimal contribution with a relatively uniform distribution (Seçer, 2018). This finding confirms that the scale is well-aligned with a three-factor structure."To further validate the scale, a confirmatory factor analysis (CFA) was conducted to confirm the structure identified through exploratory factor analysis (EFA). The t-values obtained from the CFA are presented in Figure 4, providing statistical evidence that supports the construct validity of the scale."

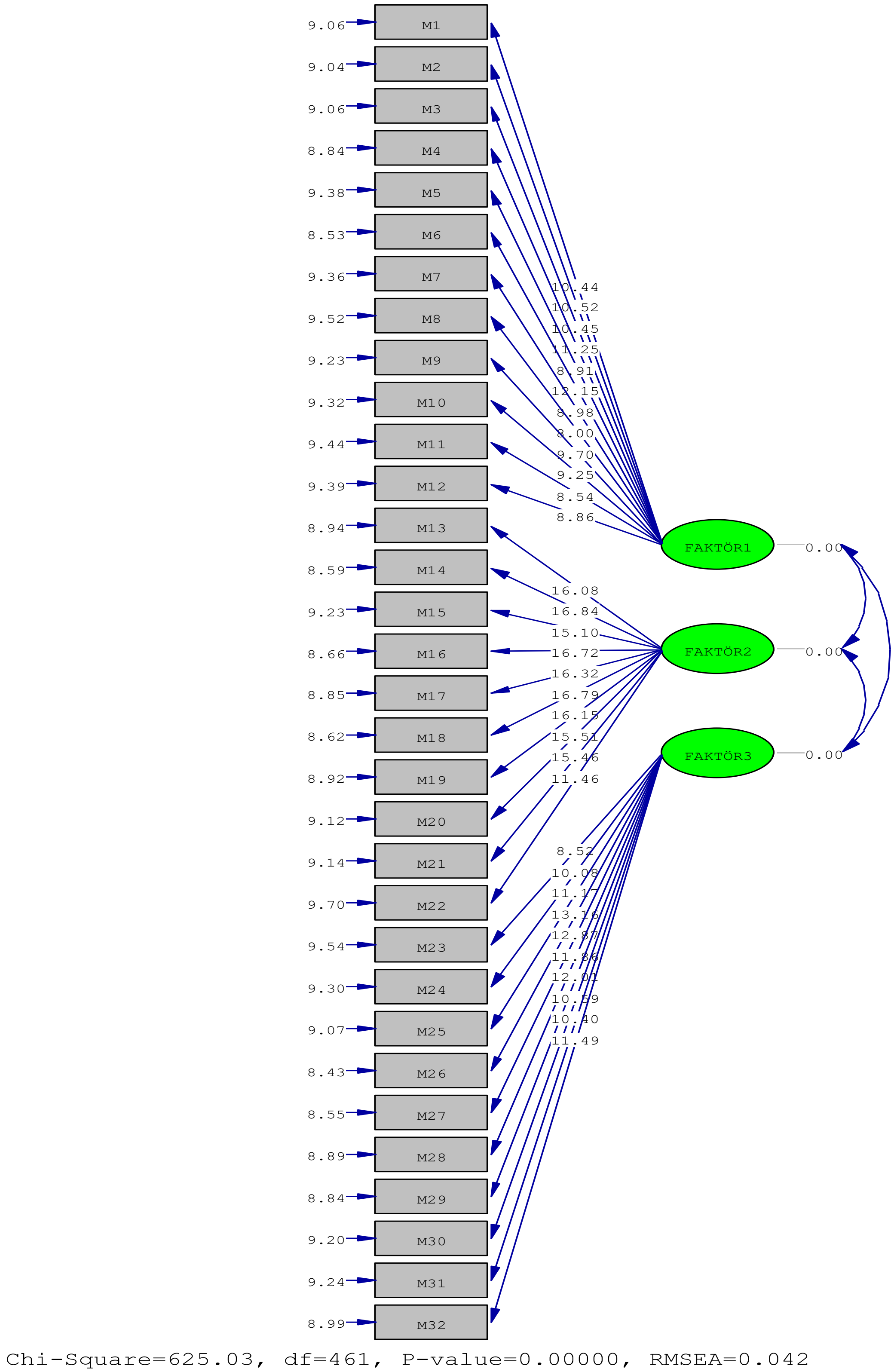

Figure 4 Confirmatory factor analysis t-values road map

Figure 4 presents the t-values obtained from the confirmatory factor analysis (CFA), conducted to validate the three-factor structure identified through exploratory factor analysis (EFA). No red arrows were observed in the figure, indicating that all factor loadings are statistically significant.

An analysis of the t-values reveals that they range between 8.52 and 16.89 for the overall scale, indicating

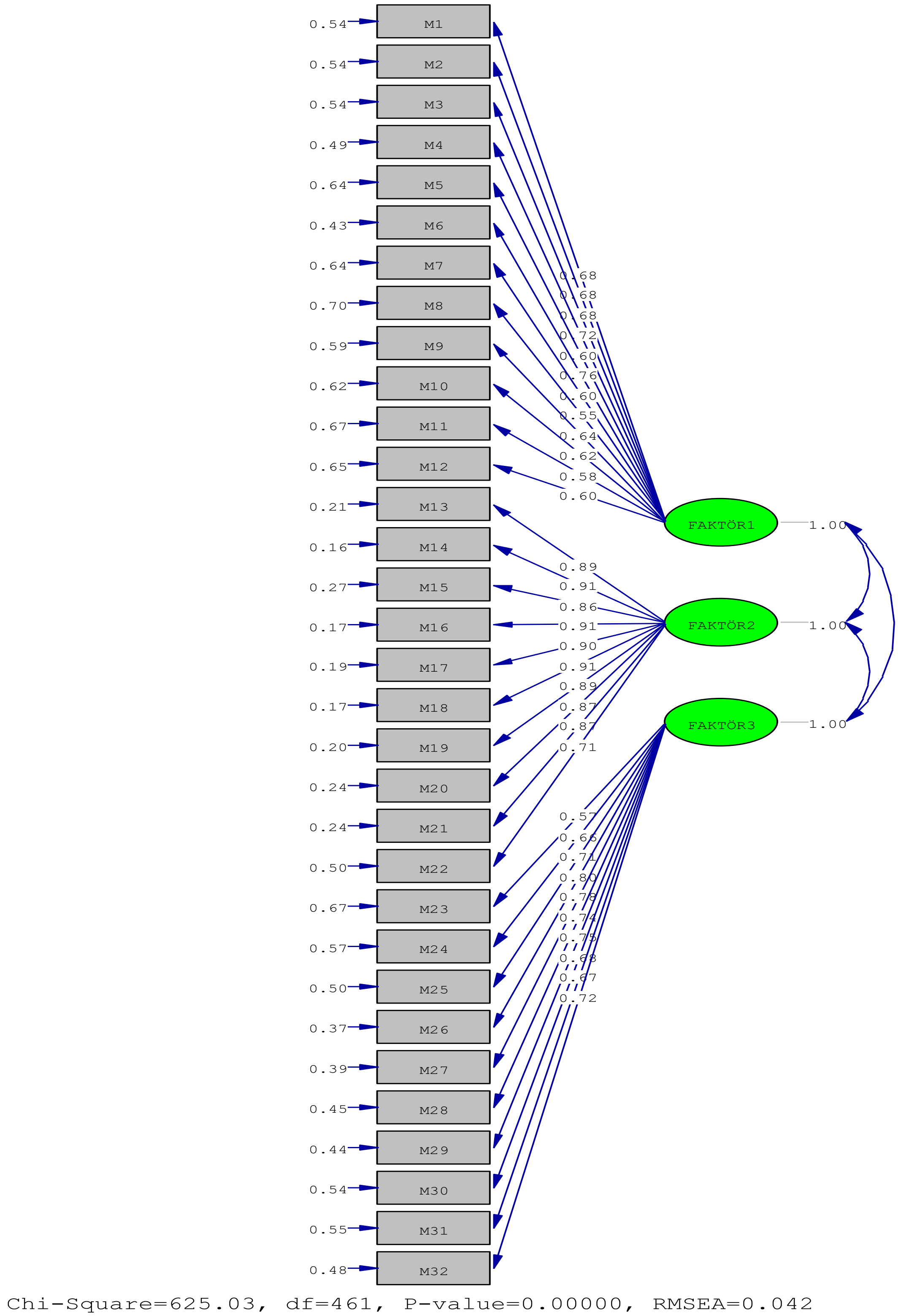

Figure 5 Map confirmatory factor analysis item loadings road map

statistical significance. The distribution of t-values for each factor shows that Factor 1 ranges from 8.00 to 11.25, Factor 2 from 11.46 to 11.84, and Factor 3 from 8.52 to 13.16. These results provide strong statistical evidence in support of the validity of the three-factor structure of the scale. Furthermore, the factor loadings derived from the confirmatory factor analysis (CFA) are presented in Figure 5.

Figure 5 presents the factor loadings of the scale items obtained from the confirmatory factor analysis (CFA). The item loadings in the scale range between 0.57 and 0.91, indicating strong contributions to their respective factors.

Specifically, the loadings for Factor 1 range from 0.55 to 0.76, for Factor 2 from 0.71 to 0.91, and Factor 3 from 0.57 to 0.80. These values confirm the structural robustness of the scale and support its validity.

Following the CFA, the model fit indices were analyzed to evaluate the goodness of fit of the three-factor model, in line with the criteria outlined in the literature (Seçer, 2018). Table 7 presents the results of the CFA model fit indices.

Table 7 presents the fit index values derived from the confirmatory factor analysis (CFA). The fit indices indicate that the scale exhibits either an excellent or acceptable fit, confirming the validity of its structural composition. The values of χ^2/df, NNFI, IFI, CFI, AGFI, PNFI, PGFI, RFI, SRMR, RMSEA, and RMR demonstrate a good to excellent fit, supporting the overall model fit of the scale. In line with standard reporting conventions, p-values displayed as 0.00000 in LISREL output were reported as p< .001, acknowledging that such values represent extremely small probabilities but are not exactly zero (APA, 2020; Greenland et al., 2016; Jöreskog et al., 2016; Wasserstein & Lazar, 2016). For instance, the chi-square result was reported as $\chi^2(461) = 625.03$, $p < .001$, and the RMSEA = 0.042 was considered indicative of an acceptable model fit (Hu & Bentler, 1999).

To further evaluate the reliability of the scale, Cronbach's alpha internal consistency coefficients were computed for both the overall scale and its sub-factors. The reliability coefficients derived from this analysis are shown in Table 8.

Table 8 presents the reliability index values computed for the overall scale and its sub-dimensions. The Cronbach's alpha reliability coefficient for the entire scale was determined to be 0.930, signifying a high level of internal coherence. The reliability coefficients for the sub-factors were also found to be strong, with the cognitive dimension at 0.881, the behavioral dimension at 0.872, and the affective dimension at 0.807. These values confirm the reliability and consistency of the scale across its components.

To further assess the discriminative power of the scale items, item-total correlation values were calculated, examining the ability of each item to measure the intended construct. Additionally, t-values were analyzed to determine the differences in item scores between the 27% upper and lower groups, providing further evidence of the scale's validity.

Table 9 presents the results of the item analysis, including mean scores, standard deviations, item-total correlations, and item t-values.

An analysis of Table 9 reveals the item-total correlation values and t-values indicating differences in item scores

Table 7 CFA model fit index values obtained from the scale

Model Fit Indices	Conclusion	Interpretation
χ^2 / sd	1.35	Acceptable Fit
NNFI	0.96	Acceptable Fit
IFI	096	Acceptable Fit
CFI	0.96	Acceptable Fit
GFI	0.84 (0.85)	Acceptable Fit
NFI	0.87 (0.90)	Acceptable Fit
AGFI	0.81	Acceptable Fit
RMSEA	0.042	Acceptable Fit
PNFI	0.81	Acceptable Fit
RMR	0.11	Acceptable Fit
SRMR	0.057 (0.050)	Acceptable Fit
PGFI	0.73	Acceptable Fit
RFI	0.86	Acceptable Fit
RMR	0.057	Acceptable Fit

Factor Name	Article Number	Cronbach Alpha Values Coefficient (α)
Cognitive	12	0.881
Behavioral	10	0.872
Affective	10	0.856
Total	32	0.934

Table 9 Item analysis results of the scale

Item	Group	Mean	Standard Deviation	Item Total Correlation	t-Value	Significance (p)
I1	Top	5.0000	.00000	0.460	33.372	.000
	Lower	1.8765	.84236			
I2	Top	5.0000	.00000	0.503	31.290	.000
	Lower	2.1235	.82739			
I3	Top	5.0000	.00000	0.631	22.265	.000
	Lower	2.0494	1.19270			
I4	Top	5.0000	.00000	0.586	42.429	.000
	Lower	1.6296	.71492			
I5	Top	5.0000	.00000	0.498	33.882	.000
	Lower	1.8642	.83296			
I6	Top	5.0000	.00000	0.624	36.005	.000
	Lower	1.8765	.78075			
I7	Top	4.9012	.30021	0.501	34.980	.000
	Lower	2.0123	.67996			

Table 9 Item analysis results of the scale (*Continued*)

Item	Group	Mean	Standard Deviation	Item Total Correlation	t-Value	Significance (p)
I8	Top	5.0000	.00000	0.443	65.397	.000
	Lower	1.4074	.49441			
I9	Top	4.8395	.36935	0.490	35.830	.000
	Lower	1.7407	.68516			
I10	Top	5.0000	.00000	0.556	40.483	.000
	Lower	1.6914	.73556			
I11	Top	5.0000	.00000	0.612	42.372	.000
	Lower	2.0247	.63197			
I12	Top	4.8519	.35746	0.560	30.876	.000
	Lower	2.0617	.73051			
I13	Top	4.8519	.35746	0.411	41.460	.000
	Lower	1.6543	.59499			
I14	Top	5.0000	.00000	0.548	37.566	.000
	Lower	2.0123	.71578			
I15	Top	5.0000	.00000	0.518	41.664	.000
	Lower	1.8272	.68539			
I16	Top	5.0000	.00000	0.516	37.851	.000
	Lower	2.0864	.69278			
I17	Top	5.0000	.00000	0.563	34.288	.000
	Lower	2.1111	.75829			
I18	Top	5.0000	.00000	0.524	31.035	.000
	Lower	2.1975	.81271			
I19	Top	5.0000	.00000	0.604	36.663	.000
	Lower	1.9259	.75462			
I20	Top	5.0000	.00000	0.539	32.769	.000
	Lower	2.1358	.78666			
I21	Top	5.0000	.00000	0.533	31.520	.000
	Lower	2.1358	.81782			
I22	Top	5.0000	.00000	0.571	31.973	.000
	Lower	2.1852	.79232			
I23	Top	4.9383	.24216	0.517	34.924	.000
	Lower	1.9753	.72414			
I24	Top	4.9506	.21802	0.575	43.930	.000
	Lower	1.7778	.61237			
I25	Top	5.0000	.00000	0.603	59.079	.000
	Lower	1.5926	.51908			
I26	Top	5.0000	.00000	0.521	47.114	.000
	Lower	1.7654	.61789			
I27	Top	5.0000	.00000	0.512	56.117	.000
	Lower	1.7284	.52470			
I28	Top	5.0000	.00000	0.556	40.784	.000
	Lower	1.8395	.69744			
I29	Top	5.0000	.00000	0.515	37.948	.000
	Lower	1.9012	.73493			
I30	Top	5.0000	.00000	0.498	33.896	.000
	Lower	2.0617	.78016			
I31	Top	5.0000	.00000	0.485	36.681	.000
	Lower	2.0123	.73304			
I32	Top	5.0000	.00000	0.514	32.963	.000
	Lower	2.1975	.76518			

between the upper and lower 27% groups, along with the mean and standard deviation values for each item on the scale. The item-total correlation values for all items exceed 0.30, ranging from 0.411 to 0.631, indicating that each item makes a significant contribution to the overall scale. Furthermore, a significant difference was observed between the means of the lower and upper groups for all scale items ($p = 0.000 < 0.05$), further validating the discriminative validity of the scale.

Table 10 Correlation values between the factors in the scale

		F1	F2	F3
F1	r	1	0.558**	0.640**
	p		0.00	0.00
F2	r	0.558**	1	0.616**
	p	0.00		0.00
F3	r	0.640**	0.616**	1
	p	0.00	0.00	

**p<0.01,r=Pearson Correlation Coefficient

The Pearson correlation coefficient values, which indicate the relationships between the factors within the scale, are presented in Table 10.

When Table 10 is examined, the Pearson correlation coefficient values, which express the relationship between the factors and sub-factors in the scale, are observed. It is seen that there is a positive and significant relationship between the first factor and the second factor of the scale ($r=0.558$; $p<0.01$), between the first factor and the third factor ($r=0.640$; $p<0.01$), and between the second factor and the third factor ($r=0.616$ $p<0.01$).

4. DISCUSSION

An analysis of Table 10 reveals the Pearson correlation coefficients, which express the relationships between the sub-factors of the scale. The findings indicate a strong positive correlation between the first and second factors ($r = 0.558$), the first and third factors ($r = 0.640$), and the second and third factors ($r = 0.616$). These results support the structural coherence of the scale.

The Sustainable Ecology Scale was developed in this study to assess the ecological awareness and attitudes of secondary school students. Each stage of the scale development process was carefully executed by established methodological guidelines. The development of a valid and reliable measurement tool requires adherence to specific criteria that ensure the instrument's quality (Karakoç & Dönmez, 2014).

A comprehensive literature review guided the creation of the Sustainable Ecology Scale item pool. Studies relevant to the research topic were systematically reviewed and analyzed. Prior research in scale development has emphasized the importance of source scanning during the item generation phase. When writing scale items, clarity and comprehensibility were prioritized, and subjective rating expressions were avoided (Acar Güvendir & Özer Özkan, 2022; Şeker & Gençdoğan, 2014). Each item was designed to measure a single judgment, ensuring accuracy and precision. To enhance content validity, expert opinions were sought at multiple stages (Acar Güvendir & Özer Özkan, 2015; Gül & Sözbilir, 2015; Şahin & Boztunç Öztürk, 2018). Consulting subject-matter experts is a critical step in the scale development process (Yeşilyurt & Çapraz, 2018). Büyüköztürk (2019) identified expert evaluation as one of the most effective methods for ensuring content validity. In this study, expert opinions were obtained from eight field specialists, as recommended by Yurdugül (2005), who suggested that at least five experts should be involved in this process.

To ensure content validity, the Lawshe (1975) method was applied, and the Content Validity Ratio (CVR) was calculated (Ayre & Scally, 2014). A CVR value exceeding 0.750, as required for a sample of eight experts, confirmed that the scale met content validity standards. Additionally, the item pool was designed to be three times the final number of items included in the scale (Slavec & Drnovsek, 2012).

Before the main application, a pilot study was conducted to ensure that the participants reflected the target group (Erkuş, 2007). The pilot study was completed with 7th-grade students, who were deemed representative of the broader target group. The final main study included 300 participants, a sample size considered adequate for exploratory factor analysis (Comrey & Lee, 2013). Similar studies in the literature have also employed sample sizes of 300 or more (Çüm & Koç, 2013; Şahin & Boztunç Öztürk, 2018).

Following the administration of the scale, exploratory factor analysis (EFA) was conducted. The Varimax rotation method was employed, as it is commonly recommended for clarifying the factor structure (Can, 2022). Before proceeding with factor analysis, the Kaiser-Meyer-Olkin (KMO) test was performed to assess the suitability of the dataset (Yaşlıoğlu, 2017). The KMO value was 0.914, confirming that the dataset was adequate for factor analysis (Yıldız & Uzunsakal, 2018). Items with low factor loadings were removed, and the remaining factor loadings ranged between 0.475 and 0.744, which is considered acceptable for factor retention (Büyüköztürk, 2019). Additionally, when items showed loadings across multiple factors, the difference between them was ensured to be greater than 0.10 to prevent cross-loading issues (Yavuz, 2005).

The three-factor structure accounted for 46.91% of the total variance, meeting the acceptable threshold of 40–60% variance explanation in social sciences (Çokluk, Şekercioğlu & Büyüköztürk, 2021). Each factor contained at least three to five items with high factor loadings, as recommended in the literature (Bandalos & Finney, 2019; Beavers et al., 2013).

A high Cronbach's alpha coefficient indicates strong internal consistency among the scale items (Yıldız & Uzunsakal, 2018). The overall reliability coefficient for the scale was 0.934, exceeding 0.80, which is considered a high-reliability level (Kayış, 2018). Similar reliability assessments in the literature confirm the reliability of measurement tools through Cronbach's alpha analysis (Delice & Ergene, 2015; Gül & Sözbilir, 2015; Öztürk et al., 2015; Şahin & Boztunç Öztürk, 2018).

The scale's item-total correlation values exceeded 0.30, ranging from 0.411 to 0.631, demonstrating that the items are discriminative and contribute effectively to the overall measurement. High item-total correlations also indicate strong internal consistency (Büyüköztürk, 2019). A 27% upper-lower group t-test was conducted to assess the scale's ability to differentiate between participants with high and low levels of ecological awareness. A statistically significant difference ($p = 0.000 < 0.05$) in mean scores confirmed that the scale effectively distinguishes between different levels of sustainable ecological awareness (Can, 2022).

Confirmatory factor analysis (CFA) was conducted to validate the structure identified through exploratory factor analysis (EFA). CFA is widely used in social sciences for verifying scale structures (Yaşlıoğlu, 2017). Henson and Roberts (2006) emphasize that conducting EFA and CFA on separate samples enhances the validity and reliability of a measurement tool. In this study, 300 students participated in the exploratory factor analysis (EFA), while 200 students were included in the confirmatory factor analysis (CFA). The absence of red arrows in the t-value distribution plot further confirmed the robustness of the factor structure (Seçer, 2018). The factor loadings from CFA were all above 0.45, supporting the strength of the identified factors.

The fit indices obtained from CFA further confirmed the model fit, with values exceeding 0.90 and 0.95, indicating an ideal model fit (Candan, 2019; Karagöz, 2021; Kline, 2015; Schumacker & Lomax, 2010; Sümer, 2000).

The three-factor structure of the scale was named according to the common themes underlying the items. To enhance usability (Acar Güvendir & Yeşim Özkan, 2022), easily understandable and memorable factor names were chosen. The first factor was identified as Cognitive, the second as Behavioral, and the third as Affective, aligning with the theoretical foundations of environmental education. Consistent with Tavşancıl (2018), a five-point Likert scale was adopted, as this format is widely used in educational research.

The Sustainable Ecology Scale developed in this study differs from existing tools in that it addresses sustainability and ecological awareness more comprehensively. While previous scales have focused on related themes, such as the Sustainable Environmental Education Scale (Afacan & Güler, 2011), the Sustainable Environmental Awareness Scale (Atabek Yiğit & Balkan Kıyıcı, 2022), and the Sustainable Living Awareness Scale (Akgül & Aydoğdu, 2020), the current scale integrates sustainable living and ecological continuity. It provides a unique contribution to understanding students' approaches to sustainability and environmental responsibility.

The findings of this study confirm that the Sustainable Ecology Scale is a valid and reliable measurement tool. The final version comprises 32 items, structured into three dimensions, and utilizes a five-point Likert format. By assessing students' sustainable ecology levels, this tool can inform the development of educational programs designed to enhance ecological awareness and understanding. Additionally, future studies can investigate the relationship between students' sustainability scores and various demographic and behavioral variables. Comparative analyses between students at different educational levels can provide further insights into sustainable ecology education. Ultimately, the scale offers a valuable alternative measurement tool for researchers and educators working in the fields of sustainability, environmental education, and sustainable ecology.

5. CONCLUSION

In this study, a valid and reliable Sustainable Ecology Scale was developed for middle school students. During the scale development process, a literature review was conducted, and a question pool was created within the framework of the determined gains. The created question pool was presented to experts, and the pilot application was carried out after necessary checks were made. Exploratory and confirmatory analyses confirmed the scale's structural validity. As a result of the statistical analyses, a measurement tool with a three-factor structure (cognitive, behavioral, and affective dimensions) consisting of 32 items was developed. The Cronbach alpha internal consistency coefficient of the scale was obtained as $\alpha = 0.934$. In addition, confirmatory factor analysis revealed that the model was verified by showing excellent and good fit values. In this context, it was determined that the developed Sustainable Ecology Scale could be used as an alternative and reliable measurement tool for researchers and educators in the field of environmental and ecological education.

6. EDUCATIONAL IMPLICATIONS

The development of the Sustainable Ecology Scale has several important implications for educational policy and practice, particularly in the context of improving environmental and sustainability education at the secondary school level. Firstly, the present scale provides a research-based, psychometrically sound tool to systematically assess students' cognitive, affective, and behavioral orientations toward a sustainable ecology. Therefore, it enables educators to make data-driven decisions in curriculum design and reform, positively influencing students' environmental attitudes. On the other hand, by identifying gaps in students' ecological understanding and sustainability practices, the scale can guide the development of targeted teaching interventions such as project-based environmental learning, community eco-action programs, or interdisciplinary sustainability modules. These strategies can be tailored to the needs of specific groups of learners, thereby increasing curricular responsiveness and equity. Furthermore, the inclusion of this scale in national education assessments can support the progress towards goals aligned with the Education for Sustainable Development 2030 framework. It can serve as a reference tool for aligning school-based ecological education with international competencies and outcomes. Additionally, the scale is crucial for integrating ecological literacy as a formal learning objective in science and social studies curricula. With the results obtained using the scale, education makers can shape sustainability education through resource development at the national level. Finally, the multidimensional nature of the scale (encompassing cognitive, behavioral, and affective dimensions) highlights the need for holistic pedagogical approaches to environmental education. This suggests a shift from knowledge transfer to value-based and action-oriented learning models, encouraging students not only to understand environmental issues but also to internalize and act on them. The Sustainable Ecology Scale contributes not only to academic research but also to the advancement of evidence-based educational policies and the development of ecologically literate and sustainability-sensitive generations.

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