

Sustainability in Mind: A Word Association Test Analysis

Emrah Hiğde¹, Ahmet Volkan Yüzüak², Zekiye Merve Öcal²

¹Department of Science Education, Aydın Adnan Menderes University, Türkiye

²Department of Science Education, Bartın University, Türkiye

Correspondence: Emrah Hiğde, Department of Science Education, Aydın Adnan Menderes University, Türkiye.
Email: emrah.higde@adu.edu.tr

Received: December 31, 2025

Accepted: February 26, 2026

Online Published: March 4, 2026

doi:10.11114/jets.v14i3.8339

URL: <https://doi.org/10.11114/jets.v14i3.8339>

Abstract

In the scope of this study, the cognitive structures of the science teacher candidates in the context in sustainable education were investigated through Word Association Test (WAT). The study group was composed of 70 third-year science teacher candidates. Their understanding of the concepts in terms of personal behavior ("recycling," "saving," "being responsible") was closely related to sustainability. Relatively few connections were made to more expansive and integrative concepts like "ecosystem," "ecological literacy," and "sustainable development." The findings demonstrated that rather than being a cohesive network, the conceptual frameworks of the participants were made up of broken clusters. A lack of integration between higher order thinking and environmental awareness was shown by the poor correlation between "responsible behavior" and "problem-solving skills." It was therefore recommended that teacher education programs emphasize holistic and interdisciplinary approaches that promote systems thinking, critical reflection, and problem-solving rather than focusing solely on behavior-oriented aspects of sustainability.

Keywords: cognitive structures, conceptual knowledge, sustainable education, teacher training, WAT

1. Introduction

The environment is a multidimensional living space with sociological, biological, economic, physical, chemical, and cultural aspects, where all living beings interact throughout their lives. Unlike other living beings, humans have disrupted the natural balance, leading to various dangers today, such as the drying up of rivers, deforestation, pollution of water resources, climate change, toxic waste, loss of biodiversity, and acid rain. It is well known that the fundamental source of these problems lies in human behaviors. Therefore, in recent years, the moral relationships between people and the environment have also started to be questioned (Dönmez & Gülen, 2023; Nacaroglu, O. & Bozdağ, T. (2020; Ariyati E, Susilo H, Suwono H, Rohman F (2023). The primary way to reduce environmental problems is through education. In this context, the concept of education for sustainable development (ESD) has emerged as a necessity to address increasing sustainability issues. Environmental education aims to develop characteristics in individuals such as sensitivity to the environment, ethical understanding, correct values, positive attitudes, interest, awareness, and a sense of responsibility (Dönmez & Gülen, 2023). This process encompasses not only the learning of ecological knowledge but also the development of attitudes towards the environment and the transformation of these attitudes into behavior. For effective environmental education, the use of out-of-school learning environments, such as school gardens, science centers, museums, and natural settings, plays a complementary role in addition to classroom learning (Topal & Keleş, 2024). Such nature-based learning approaches help individuals understand nature holistically and promote its conservation through direct interaction. At this point, the role of teachers, who will educate the future generations, is critically important. Only teachers who possess this competence can educate students about energy and environmental awareness. Therefore, teachers need to have environmental awareness to serve as role models for their students (Güngör, Yücel, Özer & Özkan, 2022). To design an effective environmental education program, it is essential first to understand individuals' existing perceptions and cognitive structures regarding the environment and environmental issues (Güngör, Yücel, Özer & Özkan, 2022). Cognitive structure is expressed as a network or schema that defines the relationships between concepts in individuals' minds. However, studies in the literature have shown that both students and teacher candidates generally have insufficient, superficial knowledge levels regarding environmental issues, often containing misconceptions (Kiryak, Candas & Özmen, 2021). It has been determined that the perceptions of teacher candidates regarding environmental issues generally focus more on everyday life experiences rather than scientific facts, and their knowledge is fragmented, lacking

connections (Çatak & Kahyaoğlu, 2019). This situation hinders environmental education from being effectively carried out at the desired level (Fehér, Czékman, Chrappán, Lakatos & Markóczi-Revák, 2023). Various evaluation techniques revealed the way people think, the relationships between thoughts and possible misconceptions. The Word Association Test (WAT) has been preferred when a quick analysis of conceptual relations among the mind of a few respondents was required (Çatak & Kahyaoğlu, 2019). In the WAT, respondents give the first words that come to their minds in relation to a stimulus concept. The number, variety and quality of their responses can reveal a great deal about how deeply and accurately they have thought about that idea (Kiryak, Candas & Özmen, 2021). After the test, writing a sentence related to the crucial concept better analyzes the feelings and thought of the subjects. Hence, the WAT is considered an appropriate method for examining perceptions and mental constructs of complex issues such as the environment and environmental concerns (Güngör, Yücel, Özer & Özkan, 2022).

1.1 Importance of Study

Teachers are crucial to the development of environmentally positive future citizens. Their knowledge, attitudes and perceptions towards environmental matters have a direct effect on the nature of education received by students. Hence, it is important to acquire a better understanding of science teacher candidates' pre-existing cognitive structures relating to key concepts such as environment and sustainability for the development of more effective teacher education programs (Dönmez & Gülen, 2023). Revealing the mental models of pre-service science teachers regarding sustainable education, this study is likely to have a significant impact on policy, curriculum development, and teacher education programme design. In addition, even though the literature contains numerous studies investigating students' concepts of environmental phenomena, events and issues, there is a significant dearth of research with regard to how students might conceptualize the environment as a whole and on the evolution of pre-service teachers' mental models. In this scope, the current study could contribute to addressing a significant gap in the literature (Kiryak, Candas & Özmen, 2021).

1.2 Rationale of the Study

In both Turkey and worldwide, research in the area of environmental education has predominantly been on assessment of attitudes and behavior, while comprehensive research on the cognitive structure of science teacher candidates concerning core environmental issues is quite scarce (Dönmez & Gülen, 2023). Especially, there is lack of knowledge relating to how contemporary approaches constituting the umbrella term of sustainable education such as "ecological literacy", "zero waste", and "climate change education" are perceived by pre-service teachers (Çatak & Kahyaoğlu, 2019). Existing studies suggest that often pre-service teachers' understanding in these domains are fragmented or cursory. With this purpose, the study intends to unearth the conceptual linkages and misconceptions underneath superficial knowledge using the Word Association Test, a data collection instrument that enables qualitative and comprehensive analysis. When doing so, it will generate practical information about what should be focused on more strongly during teacher education and about the nurturing of conceptual change (Güngör, Yücel, Özer & Özkan, 2022).

1.3 Purpose of the Study

In this study, it was aimed to reveal the cognitive structures of the pre-service science teachers about the concepts related with the sustainable education (i.e. In this context, the study attempts to explore which concepts were more dominant in students' cognitive structure, the nature of the relationships among these concepts, and possible gaps in students' understanding).

1.4 Research Questions

1. What are the cognitive structures of pre-service science teachers concerning fundamental concepts related to "sustainable education"?
2. Under which conceptual themes do pre-service teachers' associations cluster?
3. What insights does the Word Association Test provide in revealing possible deficiencies and conceptual connections in pre-service teachers' cognitive structures regarding sustainable education?

2. Method

2.1 Research Model

This study was designed as descriptive research employing a survey model. Descriptive survey models aim to portray an existing situation as it currently exists or as it existed in the past, without manipulating variables (Karasar, 1999). In this study, the survey design was preferred to systematically examine pre-service teachers' cognitive structures regarding the selected key concepts. The research process was structured to ensure transparency and replicability, and detailed procedural steps are explained below.

2.2 Study Group

The study group consisted of 70 third-year pre-service teachers enrolled in the Department of Science Education at a public university during the 2024–2025 academic year. Participants were selected using convenience sampling, as they were readily accessible to the researchers.

All participants had completed foundational coursework in science content and pedagogy prior to the implementation of the study, ensuring a comparable academic background relevant to the research topic. Participation was voluntary, and informed consent was obtained from all individuals. Demographic information (e.g., gender distribution and age range) was collected to provide contextual clarity and enhance the transparency and validity of the study. These characteristics are reported to allow for a clearer understanding of the sample structure and to support the interpretability of the findings.

2.3 Data Collection Tool

The Word Association Test (WAT) was employed as the primary data collection instrument. The WAT is widely used to reveal participants' cognitive structures and the relationships they establish between concepts.

For the development of the instrument, 18 key concepts were identified through a review of the relevant literature and the science education curriculum. The selection process aimed to ensure content relevance and conceptual representativeness. The finalized list of key concepts is presented in Table 1.

During the implementation process, participants were asked to write the words that came to their minds in response to each key concept within a specified time limit. Standardized instructions were provided to ensure consistency in administration. The collected data were then systematically analyzed in accordance with the research objectives.

Table 1. Key concepts utilized in the Word Association Test (WAT)

Environmental Education	Environmental Knowledge	Responsible Behavior
Ecological Literacy	Climate Change Education	Global Awareness
Green School	Nature Education	Participatory Education
Environmentally Friendly Behavior	Lifelong Learning	Problem-Solving Skills
Sustainability in Education	Eco-School Programs	Sustainable Attitudes
Sustainable Future	Sustainable Goals	Environmental Behavior

Before the implementation, the pre-service science teachers were provided with explanations regarding the Word Association Test (WAT) to be administered. For each concept, the participants were given one minute. An example of the page layout is presented below:

Environmental education	
Environmental education	
Environmental education	
Environmental education	
Environmental education	
Related sentence	

2.4 Data Analysis

To evaluate the results of the Word Association Test (WAT), the key concepts were examined, and a frequency table was generated. In constructing the concept network that illustrates the relationships among concepts within the cognitive structure, the cut-off point technique was employed (Bahar, Johnstone & Sutcliffe, 1999).

3. Findings

Below, frequency values of each of the top 20 association words which correspond to the concepts are presented in Table 2. The cell values show that the number of a given association was preferred to use for each concept.

Table 2. Frequency Table Containing Key Concepts and Associated Words

Associations	Environmental Education	Eco-School Programs	Responsible Behavior	Global Awareness	Participatory Education	Problem-Solving Skills	Sustainable Attitudes	Sustainable Future	Sustainable Goals	Environmental Behavior
Education	6	9	0	3	4	5	0	0	2	4
Awareness	5	0	10	4	0	0	4	0	0	3
Nature	4	0	0	0	0	0	0	0	3	2
Recycling	2	1	3	0	0	1	1	4	3	6
Environment	5	3	1	0	0	0	0	1	1	5
Consciousness	3	0	5	0	15	0	2	0	2	1
School	12	4	0	0	3	0	1	1	0	0
Responsibility	0	0	9	4	1	0	1	0	0	2
Saving	1	0	7	0	0	0	8	9	1	0
Student	2	1	0	0	2	0	0	1	0	0
Environmental	1	3	2	2	0	0	0	0	1	0
Human	1	0	3	1	1	0	1	1	0	0
Future	0	0	0	0	0	1	0	4	6	0
Teacher	6	0	1	0	0	0	0	0	0	0
Global Warming	0	1	0	3	0	0	0	0	1	0
Behavior	0	0	1	0	0	1	5	0	0	0
Ecosystem	0	1	0	0	0	1	0	0	0	0
Conscious	1	2	2	0	0	0	1	0	0	1
Lesson	1	11	0	0	2	0	0	0	0	0
Clean Environment	0	0	0	2	0	0	3	1	4	0

When Table 2 is examined, frequency distribution of the most used association words of the key concepts can be seen. Based on this table, it can be understood that the concept of environmental education is associated with educational institutions and their components. The words of “teacher,” “school,” and “lesson” with the concepts of “environmental education”, “eco-school programs represent the high value of frequency, which shows that institutional frameworks and pedagogical perspectives take place. Moreover, the concept of “global awareness” is seen closely related to the “awareness” indicates that participants have the environmental sensitivity as globally. From there, multidimensional effect of environmental education triggers the changes and challenges in knowledge, attitudes and behaviors.

However, when it comes to everyday life experiences, sustainability related themes play dominant roles in associations. Especially, the words such as “saving” and “recycling” represents high value of goals considering sustainable future. This issue shows that sustainability and sustainable attitudes and behaviors are usually related to individual behaviors. On the other hand, association words with low frequency levels such as “nature,” “behavior,” and “ecosystem” indicates that participants may not consider the ecological terms in the scope of environmental education. This emphasizes that educational programs are needed not just because of cognitive understanding but also construct the value-based learning structures. Below, in Figure 1, frequency matrix of the key concepts with shared association words is presented.

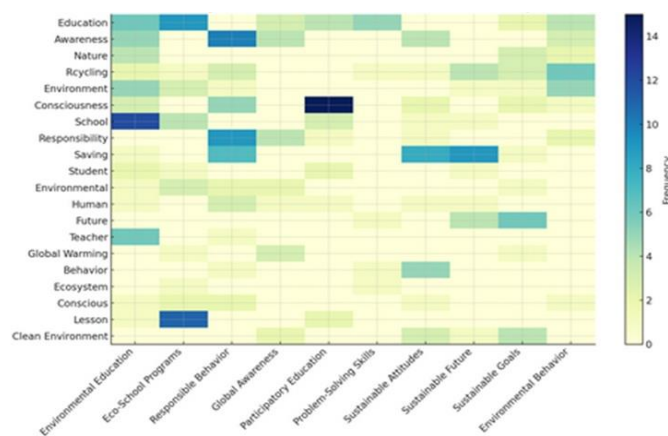


Figure 1. Heatmap of the Frequency Matrix for Shared Association Words

In Figure 1, concepts related to environmental education are represented in educational context. Most frequently used words such as “education,” “school,” “teacher,” and “awareness” shows that environmental education is usually considering as formal learning environments based on the thoughts of the participants. Moreover, preferred words such as “responsible behavior” and “sustainable attitudes” consistent with expressions of individual reflections based on the actions. Additionally, associations such as “saving” and “recycling” also support that issue. This situation describes that environmental issues and environmental sensitivity may be affected by personal experiences and responsibilities. On the other hand, concepts such as “ecosystem,” “environmentally friendly,” “sustainable development,” and “green school” have relatively low frequency which represent the systematic dimensions of the environmental concepts. In this context, perceptions of environmental education are concentrated at the individual level as practical, while more holistic approaches remain less prominent. In addition to these, overall findings support that environmental education should change the behavioral and conceptual understanding of the human-nature relationship. In Table 3, most used ten association words presented.

Table 3. Total Frequencies and Number of Related Concepts for the Ten Most Frequently Associated Words

Association Words	Total Frequency	Number of Related Concepts
Education	200	75
Awareness	182	60
Nature	151	57
Recycling	132	52
Environment	131	53
Consciousness	115	61
School	105	46
Responsibility	81	47
Saving	77	46
Student	64	38

Table 3 shows that, in terms of both intensity and variety, the linkages formed around environmental education and sustainability tend to cluster around particular themes. With a total frequency of 200 and connections to 75 different ideas, "education" stands out as the most prominent association term, underscoring its significance as a crucial point of reference in procedures meant to increase environmental consciousness. In a similar vein, the large networks and high total frequencies linked to "awareness" and "nature" imply that environmental perception is influenced by emotional and value-based ties to the natural world in addition to cognitive processes. From there, it can be understood that environmental education plays important role in developing environmental awareness and values.

Conversely, while concepts like "recycling," "environment," "awareness," and "school" have high overall frequencies, there aren't many related concepts. This implies that although these concepts are commonly used in the context of environmental education, they are still limited to certain subject areas. Practice-oriented concepts like "recycling" and "saving," for example, are embedded inside a more limited network of connections, suggesting that environmental education is highly focused on practical behaviors, even while there is little conceptual variation in how these behaviors are handled. As a result, it is evidently necessary to broaden the scope of environmental education and create more complex networks of connections around preexisting ideas.

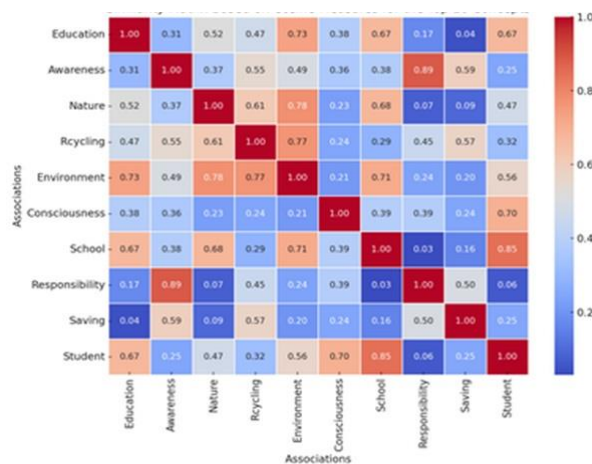


Figure 2. Similarity Matrix Based on Cosine Measures for the Top 10 Concepts

The degree of correlation between environmental education categories is quantitatively shown in Figure 2. The correlation values on the scale, which range from 0 to 1, are determined by the ideas' conceptual closeness or frequency of co-occurrence. The map's general structure shows that certain environmental education-related topics have far stronger relationships than others. For example, "Environmental Education" exhibits strong correlations with "Participatory Education" (0.61) and "Eco-School Programs" (0.66), suggesting that environmental education is primarily seen and carried out through organized initiatives that prioritize student involvement. On the other hand, certain ideas show rather weak correlations. For instance, there is extremely little correlation (0.05) between "Responsible Behavior" and "Problem-Solving Skills." Likewise, there are few links between "Global Awareness" and "Sustainable Future" or "Participatory Education." This implies that people's knowledge of the world tends to stay limited to their own consciousness or attitude levels and hasn't yet been fully integrated with higher-order abilities like critical problem-solving or systemic thinking.

In conclusion, this map shows that certain environmental education idea clusters are closely connected, but they do not create a completely integrated structure; instead, they form segmented groups. As a result, one may argue that environmental education ought to evolve toward a framework that is more transdisciplinary, integrated, and intellectually balanced.

Table 4. Concepts Most Frequently Associated with Specific Associations

Association	Most Frequently Associated Concepts	Frequency
School	Environmental education	12
Nature	Green school	10
Awareness	Responsible behavior	10
Education	Eco-school programs	9
Recycling	Environmentally friendly behaviors	9
Environment	Nature education	9
Responsibility	Responsible behavior	9
Continuity	Sustainability in education	9
Environmental awareness	Ecological literacy	8
Earth	Global awareness	6

A study of the results shows that pre-service teachers have a strong and significant association between certain answer phrases and environmental themes. The subject themes with which links pertaining to environmental education most commonly coincide are depicted in Table 4. The idea that learning processes pertaining to the environment mostly take place through formal educational institutions is reinforced by the term "school" being most frequently associated with "environmental education." Similarly, the strong correlation between "Education" and "Eco-School Programs" implies that institutional programs are employed to organize and carry out environmentally conscious actions. These findings show that environmental education is intimately associated with institutionalized, organized, and structured learning processes in pre-service teachers' mental representations.

In addition to these, relationships shows that the personal attitudes such as "responsibility" and "awareness" overlap with "responsible behavior," supporting that ethical and value-based perceptions enhance the environmental consciousness. However, there also exists a link between environmental consciousness and others. For example, the connection between "ecological literacy" and "environmental awareness" indicates that environmental education consists of cognitive and conceptual particles besides behavioral ones. Associations among the concepts of "nature" with "green school" and "continuity" with "sustainability in education" emphasizes that sustainability can be explained by not only educational system but also physical environmental.

Finally, the correlations between "world" and "global awareness" show that participants generally consider the environmental concerns as both locally and globally. When taken as a whole, these indicate that environmental education consists of a complex structure that emerges from personal habits to global awareness. On the below, observations and explanations regarding the association words displayed in Table 5.

Table 5. Observations and Explanations Regarding Association Words

Association	Total frequency	Observation/Explanation
Education	200	Participants frequently emphasized the importance of education in addressing environmental issues.
Awareness	182	The concept of awareness played a central role in acquiring and disseminating environmental consciousness.
Nature	151	The relationship with nature was often highlighted as a foundation for positive environmental attitudes.
Recycling	132	Recycling emerged as a concrete indicator of individual responsibility.
Environment	131	The term environment stood out as a common intersection point among all concepts.

Data obtained from the analysis shows that thoughts of the participants are mainly based on environmental educational issues, as shown in Table 5. The term "education" was used 200 times makes it abundantly evident that participants consider education as a key element for solving environmental problems. When table 5 is examined, it can be understood that there exists an emphasis on education, which represents behavioral change in a positive way and increasing in the level of environmental awareness. Similarly, the high frequency of the term "awareness" indicates the strong associations between educational processes and environmental consciousness. This supports that widespread belief that both ignorance and lack of awareness contribute to environmental issues. Moreover, concepts such as "nature," "recycling," and "environment" elaborates the responses to environmental problems have the effect on practical and emotional level. Finally, the word "environment," which emerges 131 times, shows the importance of environmental education by existing at the intersection of all these conceptual areas. Overall, these findings represent the environmental education composed of not only transferring knowledge but also raising awareness, enhancing values, and transforming attitudes leading beneficial ones.

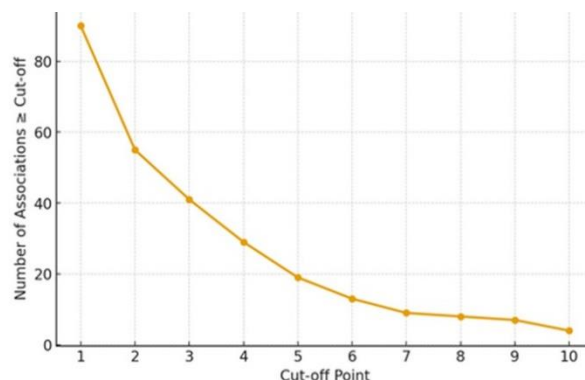


Figure 3. Cut-off Point Distribution Graph

In the context of environmental education, Figure 3 shows the distribution of relevant phrases based on their overall frequency. The distribution shows how the intensity of relationships clearly differs from one another. The first few association terms—education, awareness, and nature, for instance—occur often, suggesting that these ideas are fundamental to the mental models of the participants. This implies that some ideas become more prominent and offer a crucial foundation for environmental education. The graph's trend indicates that while most concepts are dispersed among lower and closer frequency ranges, a few numbers dominate with extremely high frequencies. This pattern suggests that while a significant number of subsidiary or supporting ideas also exist around these axes, society conceptions of environmental education center around a few primary axes. In the end, the graphical data show that although the conceptual framework of environmental education is broad and rich, some ideas are used more frequently than others in the formation of meaning. With only a few words dispersed over a large conceptual network, the distribution shows that associated terms often display considerable conceptual variety. This implies that some linkages are more prevalent or central in brain structures related to environmental awareness. The “Common Associative Concept Network” is presented in Figure 4, the “Frequency-Based Common Associative Concept Network” in Figure 5.

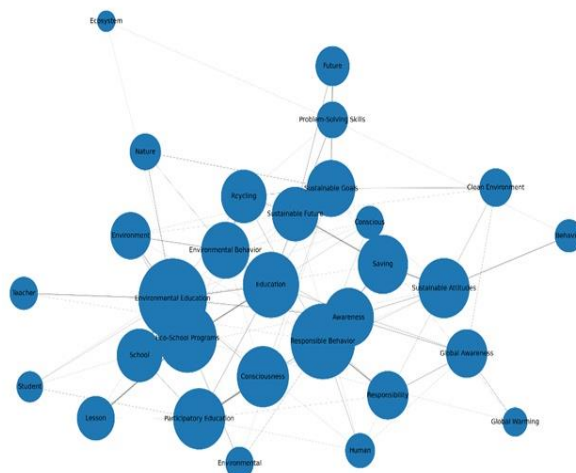


Figure 4. Common Associative Concept Network

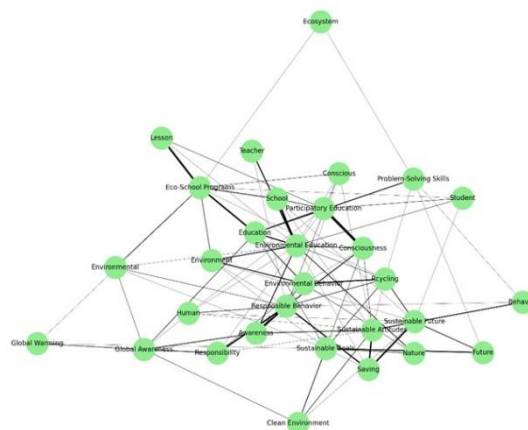


Figure 5. Frequency-Based Common Associative Concept Network

Figure 6 shows the idea network labeled with peripheral associative terms, which is used to display the relationship structures and cognitive representations of environmental concepts. The conceptual linkage network resulting from participant associations has been represented within the context of environmental education. In this case, conceptual closeness and co-occurrence frequency impacted the thickness of links and the gaps between ideas. The distribution of the illustration demonstrates how some concepts are placed in the center and develop into significant nodes in the network. Concepts that have formed stronger linkages with other words, such as sustainability in education, ecological literacy, environmental education, and responsible conduct, are among the main components of the conceptual map.

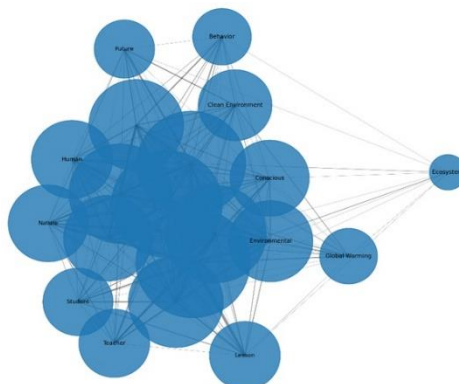


Figure 6. Concept Network Labeled with Peripheral Associative Words

Associations between concepts such as awareness, consciousness, responsibility, and environmental awareness shows the strong constitutions by bigger clusters. Similarly, the role of formal education enhances environmental sustainability, which reflects the effect of education, teachers, schools, and environmental education on sustainability concepts. In addition to these, thoughts of the participants directly related to the environmental components, such as nature, recycling, and conservation, which are placed in the outer regions of the figure, represents that these elements are action oriented. This general structure indicates that environmental education concept is composed of not only behavioral aspects but also cognitive aspects.



Figure 7. General Associative Word Cloud

Figure 7 illustrates the links among participants in the context of environmental education and highlights the issues that were expressed more frequently. A qualitative analytical tool that visually depicts the conceptual relevance levels is provided by the visualization, in which the size of the words is determined by their frequency. The most important ideas are recycling, education, awareness, and nature. These claims suggest that the development of environmental awareness is mostly influenced by behavioral and cognitive processes. The word "education" suggests that people view education as a crucial instrument for increasing environmental consciousness. The prevalence of awareness and consciousness serves as another evidence of the importance of internalized knowledge and sensitivity in forming environmental attitudes. The idea that human acts are crucial for environmental sustainability is also reflected in the use of concepts like recycling, responsibility, and conservation. Furthermore, the use of words like "nature," "environment," "student," and "school" highlights both the anticipated good link with nature and the connection between environmental education and formal educational institutions. Overall, the word cloud emphasizes the complexity of environmental education by showcasing the major ideas ingrained in participants' conceptualizations of environmental challenges. The "Frequency-Based Thematic Concept Network" developed from the data is shown in Figure 8. The dense links and thematic clusters that have emerged between particular themes are displayed by the diagram's center locations and colored thick interconnections.

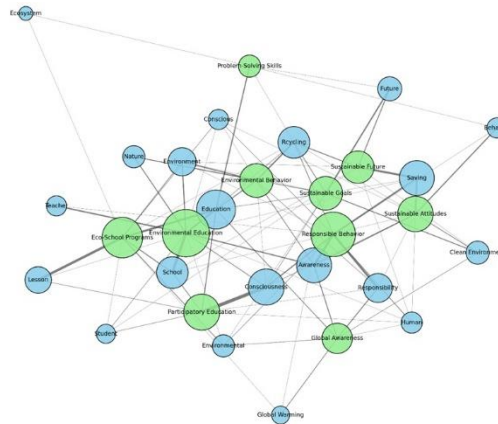


Figure 8. Frequency-Based Thematic Concept Network Visualization

An examination of Figure 8 demonstrates the relationships between the key concepts that are developing in the field of environmental education as well as the degree to which these concepts are interconnected. The red-highlighted nodes reflect the concepts included in the analysis, and the lines (edges) linking these nodes illustrate the associative linkages between the concepts. The high density of linkages in the visualization indicates that participants developed considerable cognitive coherence across environment-related topics. Because of their high degree of connectivity, ideas like education, awareness, the environment, recycling, consciousness, and responsibility stand out at the center of the network. Numerous aspects of environmental education, including conservation, nature, schools, behavior, and students, are reflected in these core principles. This distribution demonstrates how participants comprehend environmental issues such as human responsibility, harmony with nature, information transmission, and behavioral change holistically within their conceptual frameworks. In summary, the high density of the network structure highlights the strong semantic links made between concepts connected to environmental education, demonstrating both the conceptual richness and the implementation of an integrated strategy in environmental awareness-raising concepts.

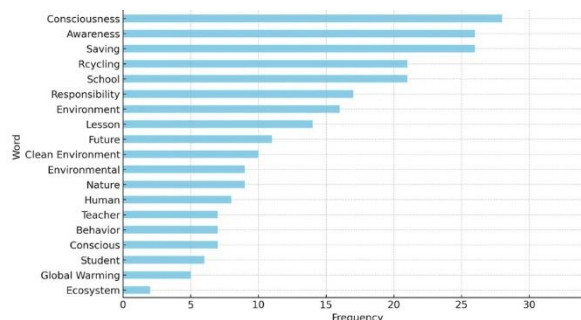


Figure 9. Associative Word Frequency Distribution Graph

The concept distribution presented in Figure 9 illustrates that a limited number of frequently cited ideas account for a substantial share of total connections, even though many additional ideas are mentioned less often. This indicates that

certain key concepts are more significant in cognitive frameworks relating to environmental education, while various secondary or supportive ideas contribute to the broader conceptual domain. Additionally, the data distribution exhibits a right skew and a long tail, suggesting that major concepts like education, awareness, and nature are central to the participants' collective cognitive structures. In contrast, other concepts are associated with more niche, individualized, or secondary responses. The large volume of low-frequency thoughts signifies a notable level of conceptual diversity, implying that individuals view environmental education from a multitude of angles.

4. Discussion & Conclusion

Pre-service science teachers' cognitive structures related to sustainable education and other terminologies in the Word Association Test (WAT) employed in this research are focused on a finite number of areas, and these are fragmented rather than unified. The strongest associations in their mind map are education, school, teacher, and lesson. This is taken to imply that education for the environment and for sustainability are fundamentally institutional and pedagogical endeavors conducted in the context of formal education system. The frequent coupling of environmental education with school and eco-school programs with education strengthens also this perception (Atabek-Yiğit, Balkan-Kıyıcı & Yavuz Topaloğlu, 2019). The theme of sustainability was mainly related to personal behaviour and attitudes, such as recycling, conservation, responsibility and awareness. In particular, the association of core constructs such as responsible behaviour and sustainable attitude with these practical implications suggests that the conception of sustainability is predominantly interpreted through its representative individual day-to-day actions rather than through societal or systemic notions (Uzun & İris, 2023). Holistic or systems-oriented concepts of environmental issues such as ecosystem, green school and sustainable development were of the relatively low frequency. Likewise, the lack of positive associations with contemporary and inclusive constructions such as ecosocial literacy suggests that pre-service teachers' conceptions of environmental education are still a work in progress (Ariyati, Susilo, Suwono & Rohman, 2023). The cosine similarity matrix and concept net reveal the cognitive structure as having clusters of closely related concepts with weak interconnectedness rather than the strong interconnectedness across all concepts. For instance, the very low correlation between responsible behavior and problem-solving skills indicates that environmental consciousness is not tightly tied to higher order cognitive skills. Although individual consciousness is high, this does not lead people to analyze or address complex environmental problems (Tecimer Altınel, Hamalosmanoğlu & Kızılay, 2022). These results align with most of the literature, which has largely suggested that pre-service teachers' understanding of environmental concerns were shallow, rote knowledge, and disjointed. In this research, the participants' capture on sustainability under the lens of popular and concrete actions like recycling and saving supports this superficial understanding. This suggests that the focus of environmental education is on practical behavior, rather than on understanding ecological, social and economic relations (Özata Yücel & Özkan, 2018). The prominence of education and school in the participants' cognitive maps is positive in terms of the role that they expect to play professionally in the future. After all, "teachers are pivotal in raising environmentally aware generations" (p. This, however, runs the risk of framing the environmental school subject as a 'lesson' with little relevance to real life. Comprehensive environmental education is a multi-faceted, lifelong process that takes place in various learning environments, not confined to the classroom (Kiryak, Candas & Özmen, 2021).

Among the most significant findings of this study is the structural fragmentation observed between environmental attitudes/behaviors and higher-order cognitive skills, particularly problem solving. In this study, "broken clusters" are operationally defined as concept groups that (a) show low associative frequency, (b) remain weakly connected to central sustainability nodes, and (c) do not form reciprocal or multi-directional links within the cognitive network. Network analysis revealed that while behavior-oriented concepts (e.g., recycling, conservation) formed relatively dense internal clusters, their linkage to higher-order constructs such as problem solving and critical thinking remained limited. Specifically, higher-order skills accounted for less than one-tenth of total associative links within the network and appeared in isolated or sparsely connected clusters. In contrast, behavior-based concepts represented a substantially higher proportion of total associations and displayed stronger intra-cluster density. This imbalance indicates a segmented rather than integrated cognitive structure. The low centrality and peripheral positioning of integrative constructs such as ecological literacy further support this interpretation. These concepts appeared either as single-node responses or as minimally connected elements, reflecting weak systemic integration. Similar trends have been identified in international research. For example, Fehér et al. (2023) reported that environmental education programs frequently emphasize pro-environmental behaviors but insufficiently develop systems thinking competencies. Likewise, Güngör et al. (2022) demonstrated that pre-service teachers' environmental knowledge structures are often experience-based rather than scientifically interconnected. However, compared with some international samples reporting moderate conceptual integration between sustainability, systems thinking, and problem solving, the present findings indicate a comparatively lower network density and a higher proportion of broken clusters. This suggests that although affective sensitivity and personal responsibility are well represented, epistemic depth and systemic reasoning remain underdeveloped. Overall, the cognitive structures of pre-service science teachers reveal strong moral engagement and behavioral awareness but limited

cross-cluster integration. The weak associative bridges between behavioral nodes and analytical constructs indicate a narrow systemic perspective and insufficient linkage to critical thinking capabilities. This pattern aligns with arguments presented by Dönmez and Gülen (2023), who emphasize that sustainable education requires not only behavioral adaptation but also conceptual restructuring of human–nature relations. In response to these findings, teacher education programs should move beyond predominantly behavior-focused themes and explicitly integrate systems-oriented and analytical dimensions, such as ecosystem functioning, sustainable development frameworks, climate change systems, circular economy principles, and ecological literacy. Instructional designs that incorporate case-based learning, project-based inquiry, and structured problem-centered teaching may help increase cross-cluster connectivity and reduce fragmentation within cognitive networks. Furthermore, experiential and place-based learning (e.g., ecological fieldwork, science center visits, applied sustainability projects) may strengthen both conceptual density and affective engagement, potentially transforming isolated clusters into more cohesive and multidimensional cognitive structures. Given the cross-sectional nature of this study, longitudinal research is needed to measure changes in cluster density, centrality indices, and associative integration over time. Future studies may also triangulate Word Association Test findings with semi-structured interviews, concept maps, and drawing analyses to quantify structural coherence more precisely. Cross-national and interdisciplinary comparative research would further contribute to benchmarking cognitive network integration in sustainable education contexts.

In view of the above-mentioned results and discussions, teacher education needs to move beyond behavioral themes, such as recycling and conservation, to focus on whole and depth issues such as ecosystem functioning, sustainable development, system implications of climate change, circular economy and ecological literacy. Regarding environmental education courses, more case studies, project work and problem-centred teaching should be added rather than simply transferring knowledge. This can help to capture the bonding element between pre-service teachers' view on responsible behavior and their problem-solving. They should be invited to engage with nature both physically and ontologically through direct, in situ experiences of ecological processes. Non-formal activities such as nature camps, visits to science centers, or hands-on experience in ecological farms also can help consolidate conceptual awareness and emotional ties with nature. The study was cross-sectional in nature. Longitudinal studies of how the cognitive structures of pre-service science teachers change over the course of university education and after they have entered the profession would be valuable for assessing the effectiveness of teacher education programs. Findings from WAT can be supported by other qualitative methodologies such as semi-structured interviews, concept maps, and drawings to provide a deeper and more detailed understanding of cognitive structures. Cross-comparative studies on the cognitive structures of pre-service teachers in sustainable education, not only in science education but also in other disciplines, can reveal interdisciplinary patterns and differences.

Acknowledgments

Not applicable.

Author contributions

Assoc. Prof. Dr. Emrah Hiçde, Assoc. Prof. Dr. Ahmet Volkan Yüzüak and Res. Assist. Zekiye Merve Öcal were responsible for study design, writing the original draft, data collection, and revision. All authors read and approved the final manuscript and contributed equally to the study.

Funding

This research received no specific grant from any funding agency in the public, commercial, or non-profit sectors.

Competing interests

The authors declare that they have no conflict of interest.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Redfame Publishing.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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