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Comparison of Pre-service Social Studies Teachers' Cognitive Structures Regarding the Concept of Climate Change Across Grade Levels

Sosyal Bilgiler Öğretmen Adaylarının İklim Değişikliği Kavramına Yönelik Bilişsel Yapılarının Sınıf Düzeyine Göre Karşılaştırılması

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ABSTRACT

Determining pre-service teachers' cognitive structures regarding climate change is essential for planning effective climate change education. This study aimed to examine pre-service social studies teachers' cognitive structures regarding climate change through a word association test and to explore variations in their conceptual associations across grade-level cohorts. The study employed a descriptive qualitative research design with 107 pre-service teachers enrolled in the Social Studies Teacher Education Program at Atatürk University Kazım Karabekir Faculty of Education during the spring semester of the 2025–2026 academic year. Data were collected using a word association test and analyzed through content analysis, with frequency values calculated to identify patterns in participants' conceptual associations. The findings showed that participants' cognitive structures were mainly concentrated in the categories of climatic/meteorological elements and environmental degradation. Drought, melting glaciers, and global warming were the most frequently associated concepts, whereas social, economic, and political dimensions received comparatively limited attention. Differences in the distribution of conceptual associations were observed across grade levels, although these differences did not indicate a clear developmental pattern. Overall, the findings indicate that pre-service teachers tend to conceptualize climate change from a consequence-oriented rather than a holistic perspective. Teacher education programs should therefore address climate change through its causes, processes, consequences, and potential solutions to support broader conceptual understanding.

ÖZ

İklim değişikliğine ilişkin öğretmen adaylarının bilişsel yapılarının belirlenmesi, etkili bir iklim değişikliği eğitiminin planlanması açısından önem taşımaktadır. Bu çalışmanın amacı, sosyal

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bilgiler öğretmen adaylarının iklim değişikliğine ilişkin bilişsel yapılarını kelime ilişkilendirme testi aracılığıyla incelemek ve kavramsal ilişkilendirmelerinde sınıf düzeylerine göre ortaya çıkan farklılıkları araştırmaktır. Araştırmada, 2025–2026 eğitim-öğretim yılının bahar döneminde Atatürk Üniversitesi Kazım Karabekir Eğitim Fakültesi Sosyal Bilgiler Öğretmenliği Programında öğrenim gören 107 öğretmen adayıyla betimsel nitel araştırma deseni kullanılmıştır. Veriler, kelime ilişkilendirme testi kullanılarak toplanmış ve katılımcıların kavramsal ilişkilendirmelerindeki örüntüleri belirlemek amacıyla frekans değerlerinin hesaplandığı içerik analizi yoluyla analiz edilmiştir. Bulgular, katılımcıların bilişsel yapılarının ağırlıklı olarak iklimsel/meteorolojik unsurlar ile çevresel bozulma kategorilerinde yoğunlaştığını göstermiştir. Kuraklık, buzulların erimesi ve küresel ısınma en sık ilişkilendirilen kavramlar olurken, sosyal, ekonomik ve politik boyutlara görece sınırlı düzeyde yer verilmiştir. Kavramsal ilişkilendirmelerin dağılımında sınıf düzeylerine göre farklılıklar gözlenmiş olmakla birlikte, bu farklılıklar belirgin bir gelişimsel örüntüye işaret etmemiştir. Genel olarak bulgular, öğretmen adaylarının iklim değişikliğini bütüncül bir bakış açısından ziyade sonuç odaklı bir perspektifle kavramsallaştırma eğiliminde olduklarını göstermektedir. Bu nedenle öğretmen yetiştirme programları, daha geniş bir kavramsal anlayışı desteklemek amacıyla iklim değişikliğini nedenleri, süreçleri, sonuçları ve olası çözüm yolları üzerinden ele almalıdır.

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INTRODUCTION

Climate change is currently recognized not only as an environmental issue but also as a multidimensional socio-scientific issue with significant economic, social, and political implications. The increasing use of fossil fuels, rapid urbanization, and consumption-oriented lifestyles accompanying industrialization have led to profound and, in many cases, irreversible changes in the climate system. These changes manifest as observable consequences such as drought, melting glaciers, extreme weather events, and ecosystem degradation. Consequently, individuals tend to conceptualize climate change primarily through its tangible and observable impacts.

Previous research has shown that pre-service teachers predominantly associate climate change with consequence-oriented concepts (Benzer & Akkaya, 2022). Similarly, studies have reported that pre-service teachers' mental models of climate change are often insufficient for generating process-based scientific explanations (Karakuş & Yel, 2019).

From an integrated theoretical perspective, conceptual change theory, the mental model approach, and the socio-scientific issues (SSI) perspective provide complementary explanations for understanding how pre-service teachers conceptualize climate change. Conceptual change theory emphasizes that learners interpret new scientific information through their existing knowledge and conceptions; therefore, learning about climate change does not necessarily result in scientifically coherent understanding when new information is not effectively integrated with prior cognitive structures (Posner et al., 1982). The mental model approach complements this perspective by focusing on the internal representations through which individuals organize and interpret complex phenomena. When these representations are fragmented or incomplete, learners may recognize individual consequences of climate change without establishing coherent relationships among its causes, processes, and consequences (Vosniadou, 1994; Shepardson et al., 2011).

The SSI perspective extends these explanations by emphasizing that climate change cannot be understood solely as a scientific or environmental phenomenon. Because climate change involves social, economic, political, and ethical dimensions, meaningful understanding requires individuals to connect scientific knowledge with broader societal contexts and to engage in critical thinking, decision-making, and problem-solving (Sadler, 2011). Thus, the three perspectives can be considered complementary: conceptual change theory explains how existing conceptions may be transformed, the mental model approach explains how knowledge is internally organized, and the SSI perspective highlights the multidimensional societal context in which climate change is understood. From this integrated perspective, a comprehensive cognitive structure regarding climate change should include not only observable environmental consequences but also causal mechanisms, energy and emissions, social and economic implications, and possible responses to the problem. This multidimensional approach is also consistent with contemporary perspectives on environmental education, which emphasize holistic approaches to environmental issues and the integration of environmental, social, and other interconnected dimensions in educational contexts (Gülersoy et al., 2020).

The focus on pre-service social studies teachers is particularly important because climate change is not limited to

the domain of environmental or natural sciences. Its social, economic, political, and civic dimensions make it highly relevant to social studies education, where students are expected to examine contemporary societal issues and develop informed civic perspectives. Previous research has also emphasized the value of geographical learning experiences for social studies teacher candidates, particularly in connecting geographical knowledge with concrete and locally situated contexts (Gülersoy & Çavdar, 2022). Recent research has increasingly emphasized the relevance of climate change within social studies teacher education. Studies have examined pre-service social studies teachers' climate change awareness (Özgün et al., 2025), their competencies in producing texts about climate change (Fidan & Yıldırım, 2025), and their engagement with the pedagogical demands of climate crisis education (Alvey, 2020). Similarly, recent research in Türkiye has demonstrated the potential of integrating climate change education into social studies teacher education through interdisciplinary, experiential, and civic-oriented approaches (Özcan et al., 2026). Earlier research has also shown that pre-service social studies teachers may develop mental models of global warming that do not fully correspond with scientifically grounded explanations, particularly regarding causal relationships and possible solutions (Karakuş & Yel, 2019). Taken together, these studies indicate that pre-service social studies teachers constitute an important population for investigating how climate change is cognitively conceptualized and pedagogically understood.

A review of the literature indicates that both national and international studies have primarily focused on individuals' knowledge levels, awareness, and misconceptions regarding climate change (Yıldırım & Kışoğlu, 2024). Internationally, a substantial body of research has examined students' and pre-service teachers' mental models and conceptual understandings of climate change (Shepardson et al., 2011). Nevertheless, these studies generally investigate the concept from limited perspectives and often fail to reveal individuals' cognitive structures as integrated systems (Bofferding & Kloser, 2015). Moreover, despite the inherently socioscientific nature of climate change, individuals frequently fail to integrate its social, economic, and political dimensions into their cognitive structures (Monroe et al., 2019).

Unlike previous studies, the present research examines pre-service teachers' cognitive structures regarding climate change through a word association test, with particular attention to the distribution of conceptual associations across scientific, environmental, social, economic, and political dimensions. Rather than focusing solely on participants' knowledge levels, this study examines the distribution of conceptual associations and the categories through which pre-service teachers relate climate change to scientific, environmental, social, economic, and political dimensions. Furthermore, by comparatively examining differences across grade-level cohorts—a dimension that has received comparatively limited attention in previous research—the study provides descriptive insights into variations in cognitive structures across academic levels. Accordingly, this research describes how pre-service teachers conceptualize climate change and examines how the distribution of conceptual associations varies across grade-level cohorts. Because the study employed a cross-sectional design, these differences are not interpreted as evidence of individual developmental change over time or as a progression resulting from teacher education.

In this context, the word association test, which enables researchers to reveal individuals' spontaneous mental associations directly, has become an effective instrument for examining cognitive structures. This technique allows researchers to identify the concepts individuals associate with a target concept, the frequency of these associations, and the organizational patterns underlying their cognitive structures. Therefore, identifying pre-service teachers' cognitive structures regarding climate change is essential for improving the quality of future climate change education.

The aim of this study is to examine the conceptual associations of pre-service social studies teachers regarding climate change through a word association test and to explore how these associations are distributed across grade-level cohorts. Specifically, the study seeks to identify the conceptual categories represented in participants' responses, determine the concepts most frequently associated with climate change, examine the representation of its climatic, environmental, energy-related, social, economic, and political dimensions, compare the distribution of conceptual associations across grade levels, and identify scientifically limited or potentially problematic associations.

Accordingly, the study addresses the following research questions:

1. Under which conceptual categories can the words generated by pre-service social studies teachers regarding climate change be classified?
2. Which concepts are most frequently associated with climate change in pre-service teachers' cognitive structures?
3. To what extent are the climatic, environmental, energy and emissions, social, economic, political, and other dimensions of climate change represented in pre-service teachers' cognitive structures?
4. How do pre-service teachers' cognitive structures regarding climate change differ according to grade level?
5. Do pre-service teachers' cognitive structures include misconceptions or scientifically limited conceptual associations regarding climate change?

METHOD

Research Design

This study employed a descriptive qualitative research design to examine the cognitive structures of pre-service social studies teachers regarding climate change through a Word Association Test (WAT). The study aimed to reveal the conceptual associations participants established with the stimulus concept and to identify the organization of these associations within broader conceptual categories. Word Association Tests are frequently used in educational research to investigate individuals' cognitive structures, conceptual relationships, and existing knowledge frameworks (Bahar et al., 1999). Therefore, the present study adopted a descriptive approach focused on identifying and interpreting the conceptual patterns emerging from participants' responses.

Rather than measuring attitudes, perceptions, or opinions through survey instruments, the study sought to explore how participants cognitively structured the concept of climate change. Accordingly, the emphasis was placed on identifying conceptual associations, category distributions, and potential misconceptions reflected in participants' word responses.

Study Group

The study group consisted of 107 pre-service teachers enrolled in the Social Studies Teacher Education Program at Atatürk University Kazım Karabekir Faculty of Education during the spring semester of the 2025–2026 academic year who voluntarily participated in the study. The study group included 32 first-year, 22 second-year, 8 third-year, and 45 fourth-year pre-service teachers. The number of participants varied substantially across grade levels, with the third-year group being notably smaller than the other groups.

Of the participants, 68 were female (63.6%) and 39 were male (36.4%), with ages ranging from 18 to 24 years (M = 20.84). The distribution of participants across grade levels was unequal, particularly because the third-year group included only eight participants. Therefore, grade-level comparisons were interpreted cautiously and descriptively, and the findings were not used to infer developmental progression across the teacher education program.

The inclusion of participants from different grade levels was intended to enable a comparative examination of how cognitive structures regarding the concept of climate change differ across stages of teacher education. Before data collection, all participants were informed about the purpose and procedures of the study, and participation was entirely voluntary. Ethical principles were maintained throughout the research process. Participants' identities were kept confidential, and anonymous codes (e.g., PT1.1, PT2.3, and PT4.15) were used during data analysis.

Table 1. *Characteristics of the study group*

Grade Level	*n*	%
First year	32	29.9
Second year	22	20.6
Third year	8	7.5
Fourth year	45	42.0
Total	**107**	**100.0**

Data Collection Tool

A Word Association Test (WAT) was used as the data collection instrument in this study. The Word Association Test is a widely used alternative assessment tool for revealing individuals' cognitive structures, the relationships among concepts, and their mental associations regarding a specific concept (Bahar et al., 1999). This technique enables researchers to identify the conceptual associations generated around a target concept and to examine how these associations are distributed within broader conceptual categories (Bahar & Özatlı, 2003). In the present study, the target concept was "Climate Change." The stimulus concept "Climate Change" was repeated on each response line to minimize chain associations among the generated words. Participants were instructed to generate each response directly from the stimulus concept and not from previously written words. The purpose and procedure of the WAT were explained to the participants before administration, and the same written and oral instructions were provided to all participants. Participants generated their responses without additional prompts, guidance, or examples from the researchers. A total of 30 minutes was allocated for completing the WAT. Before analysis, the collected data were reviewed and organized. Variations in spelling were corrected, and words or expressions with the same meaning were merged under common conceptual labels to ensure consistency in the analysis.

Data Analyses

The data obtained in this study were analyzed using content analysis. The words generated by the participants through the Word Association Test (WAT) were first reviewed and organized. Words and expressions with identical or similar meanings were grouped and coded under common labels. The resulting codes were then categorized into broader conceptual themes, and their frequencies (f) were calculated. The findings were analyzed comparatively across grade levels to identify similarities and differences in participants' cognitive structures regarding climate change. The frequency distributions of concepts within each category were examined to describe the relative representation of different conceptual dimensions in participants' responses. Because frequency counts do not independently establish the coherence, quality, or developmental level of a cognitive structure, these indicators were interpreted descriptively rather than as direct measures of conceptual development or coherence.

To ensure transparency in the coding and categorization process, all words and expressions generated by the participants were first compiled into a common word pool. Words or expressions with identical, equivalent, or closely related meanings were grouped under a common code. The grouping decisions were based on semantic similarity and conceptual relatedness to the concept of climate change. The coded responses were then assigned to broader conceptual categories according to their primary conceptual meaning. The original participant-generated responses were retained throughout the analysis, and categorization was conducted only after data collection. Thus, the categorization process was used to organize and interpret the response patterns without altering participants' original responses.

Validity and Reliability

To enhance the validity and reliability of the coding and categorization process, the researchers first developed the coding scheme based on the semantic similarity and conceptual relatedness of the words generated by the participants. The coding and categorization process was subsequently reviewed independently by two researchers with expertise in social studies education and qualitative data analysis. The researchers independently examined the generated words, assigned codes, and classified the codes into broader conceptual categories. Disagreements between the researchers were discussed and resolved through consensus.

Inter-rater reliability was assessed using Cohen's Kappa (κ), which accounts for the agreement expected by chance. The analysis yielded a Cohen's Kappa coefficient of κ = .87, indicating almost perfect agreement between the two coders. This chance-adjusted reliability estimate strengthens the consistency and methodological transparency of the coding and categorization process.

Table 2. *Examples of the word-to-code-to-category conversion process*

Concept label used in the analysis	Participant codes	Broader conceptual category	Basis for categorization
Global warming	TC1, TC2, TC3, TC4	Climatic/Meteorological Elements	Refers to changes in temperature and climate conditions
Rising temperatures / Extreme heat	TC1, TC4	Climatic/Meteorological Elements	Refers to increased temperature conditions
Seasonal / Climate change	TC4	Climatic/Meteorological Elements	Refers to changes in climatic patterns
Drought	TC1, TC2, TC3, TC4	Climatic/Meteorological Elements	Refers to prolonged or abnormal lack of precipitation
Extreme weather events	TC2, TC4	Climatic/Meteorological Elements	Refers to unusual or intensified weather conditions
Melting glaciers	TC1, TC2, TC3, TC4	Environmental Degradation and Ecological Processes	Refers to an environmental process associated with climate change
Ozone layer depletion/ thinning	TC1, TC3, TC4	Environmental Degradation and Ecological Processes	Refers to an environmental phenomenon associated with climate-related associations
Ecosystem degradation	TC1, TC4	Environmental Degradation and Ecological Processes	Refers to deterioration of ecosystems
Deforestation	TC3	Environmental Degradation and Ecological Processes	Refers to human-induced environmental degradation
Environmental pollution	TC3	Environmental Degradation and Ecological Processes	Refers to environmental contamination
Greenhouse gases	TC1, TC2, TC3	Energy and Emissions Concepts	Refers to gases associated with the greenhouse effect and anthropogenic emissions
Greenhouse effect	TC3, TC4	Energy and Emissions Concepts	Refers to the atmospheric mechanism associated with climate change
Fossil fuels	TC1, TC2, TC3, TC4	Energy and Emissions Concepts	Refers to major anthropogenic sources of greenhouse-gas emissions
Carbon / Carbon footprint	TC1, TC3, TC4	Energy and Emissions Concepts	Refers to carbon-related emissions and their environmental impact
Renewable energy	TC1, TC3, TC4	Energy and Emissions Concepts	Refers to energy sources considered in relation to emission reduction

Table 2. *Continued*

Concept label used in the analysis	Participant codes	Broader conceptual category	Basis for categorization
Sustainability	TC1, TC2	Energy and Emissions Concepts	Refers to sustainable approaches to environmental and energy issues
Flood / Floods and inundations	TC1, TC2, TC3, TC4	Disasters and Natural Hazards	Refers to climate-related or extreme hydrological hazards
Forest fires / Wildfire	TC1, TC2, TC3, TC4	Disasters and Natural Hazards	Refers to climate-related environmental hazards
Natural disasters	TC1, TC2, TC3	Disasters and Natural Hazards	Refers to disaster-related associations
Migration / Increased migration	TC1, TC2, TC3, TC4	Social, Economic, and Political Dimensions	Refers to population movement associated with climate-related pressures
War / Conflict / International conflicts	TC1, TC2, TC4	Social, Economic, and Political Dimensions	Refers to social and geopolitical consequences or associations
Economic impacts / Economic hardship	TC1, TC2, TC4	Social, Economic, and Political Dimensions	Refers to economic consequences
Human impact / Human activities	TC1	Social, Economic, and Political Dimensions	Refers to the role of human activity in climate change
Biodiversity	TC1, TC2, TC3, TC4	Living Organisms and Life	Refers to biological diversity and ecological systems
Animal / Species extinction	TC1, TC4	Living Organisms and Life	Refers to impacts on species and living organisms
Water scarcity / Water problems	TC1, TC2, TC4	Impacts / Consequences	Refers to consequences affecting water availability
Desertification	TC1, TC4	Impacts / Consequences	Refers to land degradation and climate-related consequences
Climate anxiety / Hopelessness	TC4	Impacts / Consequences	Refers to psychological responses to climate change
Environmental crisis	TC2, TC4	Impacts / Consequences	Refers to broad perceived consequences of climate change

The table illustrates the word-to-code-to-category conversion process used in the analysis. Participant-generated words or expressions with identical, equivalent, or closely related meanings were consolidated under a common code based on semantic similarity and conceptual relatedness. The codes were subsequently assigned to broader conceptual categories according to their primary conceptual meaning. The examples presented in the table demonstrate the coding procedure and are intended to make the categorization process transparent.

Ethical Statement

This study was found ethically appropriate by Atatürk University Social and Human Sciences, Educational Sciences Unit Ethics Committee (Approval Number: 10, Date: 04.06.2026). The principle of voluntary participation was observed throughout the research process; participants were informed about the purpose of the study, and all data were collected in accordance with the principle of confidentiality. The study complied with the principles of scientific research and publication ethics.

RESULTS

The findings are presented in accordance with the research questions. First, the conceptual categories identified from the participants' responses are presented. Next, the most frequently associated concepts and the distribution of associations across the main dimensions are examined. Finally, variations across grade levels and scientifically limited associations are discussed.

Findings Related to the First Research Question: Conceptual Categories of Climate Change Associations

Analysis of the Word Association Test responses revealed seven major conceptual categories through which pre-service social studies teachers associated climate change: (1) Climatic/Meteorological Elements, (2) Environmental Degradation and Ecological Processes, (3) Energy and Emissions Concepts, (4) Disasters and Natural Hazards, (5) Social, Economic, and Political Dimensions, (6) Living Organisms and Life, and (7) Impacts/Consequences. These categories were observed across the grade levels, although their frequencies and specific conceptual associations varied.

Table 3. *Cognitive structures of first-year social studies teacher candidates regarding the concept of climate change*

Climatic / Meteorological Elements	**Codes**	**f**
Global warming	(TC1.1), (TC1.6), (TC1.10), (TC1.15), (TC1.23), (TC1.29), (TC1.32)	7
Rising temperatures / Extreme heat	(TC1.6), (TC1.9), (TC1.13), (TC1.20), (TC1.26), (TC1.31), (TC1.32)	7
Seasonal changes	(TC1.6), (TC1.10), (TC1.15), (TC1.23), (TC1.26), (TC1.29), (TC1.31)	7
Drought (meteorological aspect)	(TC1.2), (TC1.4), (TC1.7), (TC1.9), (TC1.14), (TC1.16), (TC1.17), (TC1.20), (TC1.22), (TC1.28), (TC1.29), (TC1.31)	12
Total Frequency (f)		**33**
Environmental degradation and ecological processes		
Concept	**Codes**	**f**
Melting glaciers	(TC1.1), (TC1.10), (TC1.13), (TC1.18), (TC1.23), (TC1.24), (TC1.25), (TC1.26), (TC1.27), (TC1.28), (TC1.29), (TC1.31), (TC1.32)	13
Ozone layer (depletion/thinning)	(TC1.16), (TC1.17), (TC1.18), (TC1.19), (TC1.21), (TC1.22), (TC1.23), (TC1.24), (TC1.28), (TC1.29)	10
Ecosystem degradation	(TC1.10), (TC1.23), (TC1.24), (TC1.25), (TC1.31)	5
Depletion of natural resources	(TC1.19), (TC1.24), (TC1.25)	3
Total Frequency (f)		**31**
Energy and emissions concepts		
Greenhouse gases	(TC1.1), (TC1.9), (TC1.16), (TC1.24), (TC1.28)	5
Fossil fuels	(TC1.4), (TC1.7), (TC1.16), (TC1.27), (TC1.28)	5
Carbon / Carbon footprint	(TC1.1), (TC1.12), (TC1.16), (TC1.24)	4
Renewable energy	(TC1.16), (TC1.27)	2
Sustainability	(TC1.1), (TC1.16)	2
Total Frequency (f)		**18**
Disasters and natural hazards		
Flood	(TC1.12), (TC1.28)	2
Wildfire	(TC1.22)	1
Natural disasters (general)	(TC1.28), (TC1.32)	2
Total Frequency (f)		**5**
Social, economic, and political dimensions		
Migration	(TC1.3), (TC1.11), (TC1.14), (TC1.29), (TC1.30)	5
War / Conflict	(TC1.2), (TC1.8), (TC1.20), (TC1.28), (TC1.29)	5
Economic impacts	(TC1.4), (TC1.8), (TC1.17)	3
Human impact / Human activities	(TC1.11), (TC1.21), (TC1.32)	3
Total Frequency (f)		**16**
Living organisms and life		
Animal extinction	(TC1.3), (TC1.16), (TC1.26), (TC1.31), (TC1.32)	5
Biodiversity	(TC1.16), (TC1.24)	2
Soil degradation	(TC1.13), (TC1.20), (TC1.31)	3
Total Frequency (f)		**10**
Impacts / Consequences (Abstract Expressions)		
Water scarcity	(TC1.14), (TC1.15), (TC1.17), (TC1.20), (TC1.23), (TC1.25), (TC1.28)	7
Desertification	(TC1.13), (TC1.14), (TC1.31)	3
Global problems (general)	(TC1.20), (TC1.32)	2
Total Frequency (f)		**12**

An examination of the first-year teacher candidates' responses to the Word Association Test revealed that the highest frequencies were concentrated in the Climatic/Meteorological Elements (f = 33) and Environmental Degradation and Ecological Processes (f = 31) categories. Within these categories, the concepts of drought (f = 12) and melting glaciers (f = 13) emerged as the most frequently associated with climate change. The Energy and Emissions Concepts category was represented to a more limited extent (f = 18). Likewise, the Social, Economic, and Political Dimensions (f = 16) and Living Organisms and Life (f = 10) categories showed comparatively lower frequencies. The Disasters and Natural Hazards category had the lowest frequency (f = 5), whereas within the Impacts/Consequences category, water scarcity (f = 7) was the most prominent concept.

The responses of the second-year teacher candidates were examined according to the conceptual categories identified through the word association test. Table 4 presents the frequency distribution of the conceptual associations identified among second-year teacher candidates.

Analysis of the second-year teacher candidates' responses to the Word Association Test showed that the highest frequencies were observed in the Climatic/Meteorological Elements (f = 27), Social, Economic, and Political Dimensions (f = 25), and Environmental Degradation and Ecological Processes (f = 24) categories. Among these, global warming (f = 11), melting glaciers (f = 10), drought (f = 9), and flood (f = 10) emerged as the most frequently associated concepts with climate change. The Energy and Emissions Concepts category was also well represented (f = 19), particularly by the concepts of greenhouse gases (f = 8), fossil fuels (f = 6), and sustainability (f = 5). Unlike first-year teacher candidates, second-year participants demonstrated stronger associations with the social, economic, and political consequences of climate change, including economic hardship, international conflicts, increased migration, social problems, and employment problems, occurring five times. In contrast, the Living Organisms and Life category received the lowest representation (f = 5), consisting solely of the concept of biodiversity.

Analysis of the second-year teacher candidates' responses indicated that the Climatic/Meteorological Elements (Σf = 27), Environmental Degradation and Ecological Processes (Σf = 24), and Energy and Emissions Concepts (Σf = 19) categories were the most prominent components of their cognitive structures. Within these categories, the concepts of global warming (f = 11), melting glaciers (f = 10), and drought (f = 9) were expressed more frequently than the

Table 4. *Cognitive structures of second-year social studies teacher candidates regarding the concept of climate change*

Climatic / Meteorological Elements		
Concept	**Codes**	**f**
Global warming	(TC2.6), (TC2.8), (TC2.10), (TC2.11), (TC2.12), (TC2.16), (TC2.18), (TC2.19), (TC2.20), (TC2.21), (TC2.22)	11
Extreme weather events	(TC2.6), (TC2.8), (TC2.10), (TC2.12), (TC2.16), (TC2.18), (TC2.20)	7
Drought (meteorological aspect)	(TC2.6), (TC2.8), (TC2.10), (TC2.11), (TC2.12), (TC2.16), (TC2.18), (TC2.20), (TC2.22)	9
Total Frequency (f)		**27**
Environmental degradation and ecological processes		
Forest fires	(TC2.6), (TC2.8), (TC2.10), (TC2.11), (TC2.12), (TC2.16), (TC2.18), (TC2.20)	8
Environmental crisis	(TC2.6), (TC2.8), (TC2.10), (TC2.12), (TC2.16), (TC2.18)	6
Melting glaciers	(TC2.6), (TC2.8), (TC2.10), (TC2.11), (TC2.12), (TC2.16), (TC2.18), (TC2.19), (TC2.20), (TC2.22)	10
Total Frequency (f)		**24**
Energy and emissions concepts		
Greenhouse gases	(TC2.6), (TC2.8), (TC2.10), (TC2.11), (TC2.12), (TC2.16), (TC2.18), (TC2.20)	8
Fossil fuels	(TC2.6), (TC2.8), (TC2.10), (TC2.12), (TC2.16), (TC2.18)	6
Sustainability	(TC2.8), (TC2.10), (TC2.11), (TC2.16), (TC2.18)	5
Total Frequency (f)		**19**
Disasters and natural hazards		
Flood	(TC2.6), (TC2.8), (TC2.10), (TC2.11), (TC2.12), (TC2.18), (TC2.19), (TC2.20), (TC2.21), (TC2.22)	10
Total Frequency (f)		**10**

Table 4. *Continued*

Climatic / Meteorological Elements		
Concept	**Codes**	**f**
Social, Economic, and political dimensions		
Economic hardship	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
International conflicts	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Increased migration	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Social problems	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Employment problems	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Total Frequency (f)		**25**
Living organisms and life		
Biodiversity	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Total Frequency (f)		**5**

other concepts. In addition, concepts such as forest fires (f = 8), extreme weather events (f = 7), environmental crisis (f = 6), fossil fuels (f = 6), and sustainability (f = 5) were also represented in the participants' cognitive structures. Furthermore, the relatively high frequency of the Social, Economic, and Political Dimensions category (Σf = 25), compared with the other grade levels, suggests that second-year teacher candidates were able to associate climate change not only with its environmental impacts but also with its broader social and economic consequences.

The responses of the third-year teacher candidates were examined according to the conceptual categories identified through the word association test. Table 5 presents the frequency distribution of the conceptual associations identified among third-year teacher candidates.

Analysis of the third-year teacher candidates' responses revealed that the highest frequency was observed in the Environmental Degradation and Ecological Processes category (Σf = 20), followed by the Climatic/Meteorological Elements category (Σf = 17). Within these categories, drought (f = 5) and global warming (f = 4) were the most frequently associated concepts with climate change. The Energy and Emissions Concepts category had the highest frequency (Σf = 14), followed by Social, Economic, and Political Dimensions (Σf = 9), Disasters and Natural Hazards (Σf = 6), Impacts/Consequences (Σf = 6), and Living Organisms and Life (Σf = 4). Overall, the concepts were expressed with relatively low frequencies and were distributed across several conceptual categories. Given the small size of the third-year group (n = 8), this distribution should be interpreted cautiously as a descriptive pattern rather than as evidence of a fragmented or less consolidated cognitive structure.

Fourth-Year Teacher Candidates

The responses of the fourth-year teacher candidates were examined according to the conceptual categories identified through the word association test. Table 6 presents the frequency distribution of the conceptual associations identified among fourth-year teacher candidates.

Analysis of the fourth-year teacher candidates' responses revealed that the highest frequencies were concentrated in the Environmental Degradation and Ecological Processes (Σf = 51) and Climatic/Meteorological Elements (Σf = 50) categories. Within these categories, drought (f = 22), ozone layer depletion/thinning (f = 17), and melting glaciers (f = 16) emerged as the most frequently associated concepts with climate change. The Energy and Emissions Concepts category was also strongly represented (Σf = 37), particularly by greenhouse gases/greenhouse effect (f = 13), fossil fuels (f = 10), and carbon/carbon footprint (f = 7). In comparison, the Living Organisms and Life (Σf = 13), Disasters and Natural Hazards (Σf = 12), Social, Eco-

Impacts / Consequences (Abstract Expressions)		
Concept	**Codes**	**f**
Being too late / Delayed action	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Inability to meet basic needs	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Water scarcity	(TC2.1), (TC2.2), (TC2.3), (TC2.4), (TC2.5)	5
Total Frequency (f)		**15**

Table 5. *Cognitive structures of third-year social studies teacher candidates regarding the concept of climate change*

Climatic / Meteorological Elements		
Concept	**Codes**	**f**
Global warming	(TC3.1), (TC3.3), (TC3.5), (TC3.7)	4
Temperature	(TC3.3), (TC3.6)	2
High temperatures	(TC3.2)	1
Warming	(TC3.2)	1
Weather	(TC3.3), (TC3.6)	2
Humidity	(TC3.3)	1
Wind	(TC3.3)	1
Climate patterns	(TC3.6)	1
Climate types	(TC3.4)	1
Climatology	(TC3.7)	1
Meteorology	(TC3.6)	1
Rapid weather changes	(TC3.5)	1
Total Frequency (Σf)		**17**
Environmental degradation and ecological processes		
Drought	(TC3.1), (TC3.2), (TC3.3), (TC3.6), (TC3.7)	5
Glaciers	(TC3.2)	1
Glacier	(TC3.4)	1
Melting glaciers	(TC3.1)	1
Damage to glaciers	(TC3.5)	1
Environmental pollution	(TC3.2), (TC3.3)	2
Ecological pressure	(TC3.2)	1
Ecosystem	(TC3.6)	1
Natural balance	(TC3.3)	1
Ozone layer	(TC3.4)	1
Sea level rise	(TC3.4)	1
Rising water levels	(TC3.7)	1
Acid rain	(TC3.4)	1
Forest fires	(TC3.2)	1
Deforestation	(TC3.5)	1
Total Frequency (Σf)		**20**
Energy and emissions concepts		
Greenhouse gas	(TC3.1), (TC3.4), (TC3.5)	3
Greenhouse gases	(TC3.2)	1
Greenhouse effect	(TC3.7)	1
Fossil fuels	(TC3.1), (TC3.3)	2
Renewable energy	(TC3.1), (TC3.3), (TC3.5)	3
Sustainable energy	(TC3.5)	1
Carbon footprint	(TC3.1), (TC3.5)	2
Factory	(TC3.8)	1
Total Frequency (Σf)		**14**

Table 5. *Continued*

Climatic / Meteorological Elements		
Concept	**Codes**	**f**
Disasters and natural hazards		
Floods and inundations	(TC3.2)	1
Floods	(TC3.6)	1
Natural disasters	(TC3.5), (TC3.7)	2
Avalanche	(TC3.6)	1
Rain	(TC3.6)	1
Total Frequency (Σf)		**6**
Social, Economic, and political dimensions		
Humans	(TC3.6), (TC3.8)	2
Migration	(TC3.7)	1
Politics	(TC3.8)	1
Money	(TC3.8)	1
Increased costs	(TC3.1)	1
Social cohesion	(TC3.4)	1
Globalization	(TC3.5)	1
Kyoto Protocol	(TC3.4)	1
Total Frequency (Σf)		**9**
Living Organisms and Life		
Life	(TC3.4)	1
Living organisms	(TC3.4)	1
Animals	(TC3.8)	1
Earth	(TC3.8)	1
Total Frequency (Σf)		**4**
Impacts / Consequences (Abstract Expressions)		
Psychological impacts	(TC3.1)	1
Famine	(TC3.7)	1
Water problems	(TC3.7)	1
Depletion	(TC3.8)	1
Overconsumption	(TC3.8)	1
Disease eradication	(TC3.7)	1
Total Frequency (Σf)		**6**

nomic, and Political Dimensions (Σf = 10), and Impacts/Consequences (Σf = 10) categories were represented with relatively lower frequencies. Overall, fourth-year teacher candidates showed a relatively wider distribution of associations across climatic, environmental, and energy-related categories. However, these frequency patterns should be interpreted as descriptive characteristics of the responses rather than as direct evidence of a more comprehensive or developed cognitive structure.

Findings Related to the Second Research Question: Most Frequently Associated Concepts

To address the second research question, the frequencies of the concepts associated with climate change were examined across all participants. The most frequently associated concepts were drought (f = 48), melting glaciers (f = 40), and global warming (f = 34). These frequency patterns indicate that participants most commonly associated climate change with observable climatic and environmental phenomena.

Table 6. *Cognitive structures of fourth-year social studies teacher candidates regarding the concept of climate change*

Climatic / meteorological elements		
Concept	**Codes**	**f**
Global warming	(TC4.7), (TC4.10), (TC4.11), (TC4.12), (TC4.17), (TC4.18), (TC4.20), (TC4.23), (TC4.26), (TC4.36), (TC4.40), (TC4.42)	12
Rising temperatures / Extreme heat	(TC4.3), (TC4.6), (TC4.10), (TC4.20), (TC4.26), (TC4.39), (TC4.43), (TC4.45)	8
Seasonal / Climate change	(TC4.2), (TC4.12), (TC4.16), (TC4.17), (TC4.20), (TC4.33), (TC4.41), (TC4.45)	8
Drought	(TC4.1), (TC4.2), (TC4.3), (TC4.10), (TC4.12), (TC4.13), (TC4.14), (TC4.17), (TC4.18), (TC4.19), (TC4.20), (TC4.22), (TC4.24), (TC4.26), (TC4.30), (TC4.35), (TC4.36), (TC4.39), (TC4.40), (TC4.41), (TC4.44), (TC4.45)	22
Total Frequency (Σf)		**50**
Environmental Degradation and Ecological Processes		
Melting glaciers	(TC4.3), (TC4.6), (TC4.9), (TC4.10), (TC4.12), (TC4.15), (TC4.18), (TC4.19), (TC4.24), (TC4.26), (TC4.28), (TC4.31), (TC4.32), (TC4.34), (TC4.35), (TC4.39)	16
Ozone layer (depletion/ thinning)	(TC4.1), (TC4.2), (TC4.4), (TC4.5), (TC4.9), (TC4.10), (TC4.11), (TC4.12), (TC4.13), (TC4.17), (TC4.24), (TC4.25), (TC4.28), (TC4.31), (TC4.34), (TC4.38), (TC4.42)	17
Desertification	(TC4.2), (TC4.5), (TC4.13), (TC4.20), (TC4.22), (TC4.28), (TC4.31), (TC4.32), (TC4.34), (TC4.40)	10
Ecosystem degradation	(TC4.8), (TC4.9), (TC4.10), (TC4.16), (TC4.23), (TC4.29), (TC4.36), (TC4.42)	8
Total Frequency (Σf)		**51**
Energy and emissions concepts		
Greenhouse gases / Greenhouse effect	(TC4.5), (TC4.7), (TC4.10), (TC4.12), (TC4.13), (TC4.15), (TC4.17), (TC4.21), (TC4.26), (TC4.32), (TC4.36), (TC4.37), (TC4.40)	13
Fossil fuels	(TC4.7), (TC4.15), (TC4.18), (TC4.23), (TC4.25), (TC4.26), (TC4.32), (TC4.36), (TC4.39), (TC4.40)	10
Carbon / Carbon footprint	(TC4.3), (TC4.11), (TC4.12), (TC4.17), (TC4.21), (TC4.23), (TC4.36)	7
Renewable energy	(TC4.7), (TC4.23), (TC4.26), (TC4.27)	4
Emissions	(TC4.21), (TC4.26), (TC4.37)	3
Total Frequency (Σf)		**37**
Disasters and natural hazards		
Flood	(TC4.28), (TC4.36)	2
Forest fires	(TC4.14), (TC4.18), (TC4.27), (TC4.39), (TC4.42)	5
Extreme weather events	(TC4.18), (TC4.25), (TC4.27), (TC4.41), (TC4.43)	5
Total Frequency (Σf)		**12**
Social, Economic, and political dimensions		
Migration	(TC4.30), (TC4.35)	2
War	(TC4.24)	1
Economic crisis / Economic decline	(TC4.35), (TC4.40)	2
Unemployment	(TC4.6), (TC4.35)	2
Population growth / Population imbalance	(TC4.30), (TC4.34), (TC4.35)	3
Total Frequency (Σf)		**10**

Table 6. *Continued*

Climatic / meteorological elements		
Concept	**Codes**	**f**
Living organisms and life		
Species extinction	(TC4.11), (TC4.18), (TC4.20), (TC4.24), (TC4.34), (TC4.38)	6
Biodiversity	(TC4.8), (TC4.16), (TC4.23), (TC4.26)	4
Soil degradation	(TC4.16), (TC4.41), (TC4.45)	3
Total Frequency (Σf)		**13**
Impacts / Consequences (Abstract Expressions)		
Water scarcity	(TC4.2), (TC4.9), (TC4.41), (TC4.42)	4
Climate anxiety / Hopelessness	(TC4.18), (TC4.24), (TC4.44)	3
Environmental crisis (general)	(TC4.8), (TC4.14), (TC4.43)	3
Total Frequency (Σf)		**10**

Findings Related to the Third Research Question: Representation of Major Climate Change Dimensions

To address the third research question, the distribution of conceptual associations across the major dimensions of climate change was examined. Across all grade levels, Climatic/Meteorological Elements (Σf = 127) and Environmental Degradation and Ecological Processes (Σf = 126) were the most strongly represented categories, followed by Energy and Emissions Concepts (Σf = 88) and Social, Economic, and Political Dimensions (Σf = 60). Disasters and Natural Hazards (Σf = 33), Living Organisms and Life (Σf = 32), and Impacts/Consequences (Σf = 43) were represented comparatively less frequently. These findings show that the participants' associations were distributed across multiple dimensions, but the climatic, environmental, and energy-related dimensions were more strongly represented than the broader social, economic, and political dimensions.

Findings Related to the Fourth Research Question: Differences in Cognitive Structures Across Grade Levels

To address the fourth research question, the distribution of conceptual associations was compared across grade-level cohorts. The comparison focused on the standardized frequencies of the main conceptual categories to account for differences in the number of participants across grade levels.

Because the number of participants differed substantially across grade levels, raw frequency totals were not directly compared. Instead, standardized frequencies per 10 participants were used to examine differences in the relative representation of conceptual categories across grade levels.

When the findings related to the fourth research question were examined using standardized frequencies, the Climatic/Meteorological Elements and Environmental Degra-

Table 7. *Raw and Standardized Frequencies of Conceptual Categories by Grade Level*

Conceptual Category	**1st Year n=32**	**2nd Year n=22**	**3rd Year n=8**	**4th Year n=45**
Climatic/Meteorological Elements	33/10.31	27/12.27	17/21.25	50/11.11
Environmental Degradation and Ecological Processes	31/9.69	24/10.91	20/25.00	51/11.33
Energy and Emissions Concepts	18/5.63	19/8.64	14/17.50	37/8.22
Social, Economic, and Political Dimensions	16/5.00	25/11.36	9/11.25	10/2.22
Disasters	5/1.56	10/4.55	6/7.50	12/2.67
Living Organisms/Life	10/3.13	5/2.27	4/5.00	13/2.89
Impacts/Consequences	12/3.75	15/6.82	6/7.50	10/2.22
Total raw frequency	125	125	76	183

Values before the slash represent raw frequencies (f), whereas values after the slash represent standardized frequencies per 10 participants. Standardized frequency was calculated as: (raw frequency / number of participants in the respective grade level) × 10. Because the number of participants differed across grade levels, standardized frequencies were used for descriptive comparisons between groups, whereas raw frequencies were retained to report the observed response frequencies.

dation and Ecological Processes categories were strongly represented across all grade levels. The standardized frequency of Climatic/Meteorological Elements was 10.31 per 10 participants in the first year, 12.27 in the second year, 21.25 in the third year, and 11.11 in the fourth year. Similarly, the standardized frequency of Environmental Degradation and Ecological Processes was 9.69, 10.91, 25.00, and 11.33, respectively. Energy and Emissions Concepts showed standardized frequencies of 5.63, 8.64, 17.50, and 8.22, respectively. Social, Economic, and Political Dimensions showed a different distribution, with standardized frequencies of 5.00, 11.36, 11.25, and 2.22 across the four grade levels. These results indicate variation in the relative representation of conceptual categories across grade levels. However, because the group sizes were unequal and the third-year group consisted of only eight participants, these differences should be interpreted as descriptive patterns rather than evidence of a linear developmental progression across grade levels. The relatively high standardized frequencies observed for the third-year group should be interpreted cautiously because this group included only eight participants. These values may reflect the response characteristics of this small cohort and should not be interpreted as evidence of a systematic developmental difference.

Findings Related to the Fifth Research Question: Misconceptions and Scientifically Limited Associations

One scientifically limited association identified in the participants' responses concerned the relationship between climate change and ozone layer depletion. Ozone layer depletion was frequently associated with climate change, particularly among first- and fourth-year teacher candidates. Although both are important environmental issues, ozone depletion and anthropogenic climate change represent distinct environmental phenomena. This association suggests that some participants may have difficulty distinguishing between different environmental processes and their underlying causes.

DISCUSSION, CONCLUSION AND SUGGESTIONS

The findings of this study reveal that Social Studies teacher candidates' cognitive structures regarding climate change are predominantly shaped by its environmental and physical impacts. The participants primarily associated climate change with observable consequences such as drought, melting glaciers, extreme weather events, and environmental degradation, indicating that their conceptual associations were more strongly oriented toward the consequences of climate change than its underlying causes. The limited representation of disaster-related associations is also noteworthy in light of research showing that social studies teacher candidates attach importance to disaster awareness and the role of social studies education in developing such awareness (Gülersoy & Akyol, 2024). This pattern indicates that the scientific mechanisms of climate change, as well as its social, economic, and political dimensions, are represented to a more limited extent within their cognitive structures. Similarly, Benzer and Akkaya (2022) reported that teacher candidates tend to conceptualize climate change primarily in terms of its environmental consequences. International research has likewise demonstrated that students and pre-service teachers generally explain climate change in terms of its environmental impacts while experiencing difficulty in understanding the complex interactions within the climate system (Khalid, 2001; Shepardson et al., 2011).

One of the most noteworthy findings of the study is that although teacher candidates' cognitive structures varied across grade-level cohorts, the observed pattern did not follow a clear linear pattern. While the number and distribution of associations varied across grade-level cohorts, these variations did not provide sufficient evidence to conclude that the relationships among concepts became more integrated. This pattern may suggest that exposure to additional climate-related concepts does not necessarily result in a demonstrably more integrated conceptual structure. However, the present cross-sectional design does not allow the degree of conceptual integration to be directly measured or interpreted as developmental change over time. Accordingly, the observed frequency patterns do not provide sufficient evidence to determine whether a greater number of climate change-related associations is accompanied by a more integrated conceptual structure (Vosniadou, 2008). Accordingly, the observed frequency patterns do not provide sufficient evidence to determine whether a greater number of climate change-related associations is accompanied by a more integrated conceptual structure.

The results further indicate that teacher candidates' associations with climate change were concentrated primarily on observable consequences, while relatively fewer associations reflected its underlying causes and broader social, economic, and political dimensions. This finding can also be considered in relation to research on environmental ethics among social studies teacher candidates, which highlights the importance of broader ethical considerations in understanding human–environment relationships (Gülersoy & Burkan Akyol, 2024). Consistent with the present findings, Yıldırım and Kışoğlu (2024) concluded that teacher candidates exhibit only moderate levels of climate change awareness and emphasized the need to strengthen their conceptual knowledge. Likewise, Ural et al. (2017) reported that teacher candidates often hold scientifically inaccurate or incomplete understandings of concepts such as the carbon cycle, global warming, and climate change. The observed distribution of conceptual associations is broadly consistent with these findings.

The potentially problematic association identified in the findings has important implications for teacher education. The frequent association between climate change and ozone layer depletion is consistent with previous research showing that learners may confuse the causes and consequences of global warming with those of ozone layer depletion (Boyes & Stanisstreet, 1993; Khalid, 2001). Although ozone depletion and anthropogenic climate change are distinct environmental phenomena, their cognitive association may reflect difficulty in distinguishing between closely related environmental issues and their underlying scientific mechanisms. Rather than viewing this association merely as an incorrect response, it can be interpreted as evidence of an incomplete conceptual organization in which different environmental phenomena are cognitively interconnected. This finding highlights the importance of conceptual change-oriented instruction that explicitly differentiates the causes, mechanisms, and consequences of climate change from those of other environmental problems and promotes scientifically coherent mental models among future Social Studies teachers.

The study also demonstrates that although teacher candidates tended to associate climate change with multiple domains, these relationships were not always scientifically coherent. Some participants linked climate change to psychological, economic, and international issues, indicating an awareness that extends beyond purely environmental aspects. However, the relatively limited representation of these dimensions suggests that the inherently interdisciplinary nature of climate change has not yet been fully incorporated into their cognitive structures. Contemporary climate change literature characterizes climate change as a multidimensional issue that extends beyond environmental processes to encompass economic development, energy policy, social justice, public health, and global governance (Lee et al., 2015; IPCC, 2023). In the Turkish educational context, climate change education has also been discussed within the framework of sustainable development, emphasizing the need to address climate change as an educational issue with broader environmental and societal dimensions (Gülersoy, 2022).

Similarly, Karakuş and Yel (2019) found that Social Studies teacher candidates' mental models of global warming do not fully correspond with scientific knowledge, particularly regarding causal relationships and potential solutions. The present findings support this conclusion. Because participants primarily associated climate change with its observable consequences rather than its underlying causes, their responses were more strongly oriented toward outcomes than toward the causal processes underlying climate change. Teacher education programs should therefore address climate change through its causes, processes, consequences, and potential solutions to support broader conceptual understanding. This recommendation is consistent with contemporary approaches to environmental education that emphasize holistic and multidimensional perspectives in addressing environmental issues (Gülersoy et al., 2020).

These patterns indicate variation in the distribution of climate change-related associations across grade-level cohorts. Because the study employed a cross-sectional design, these differences cannot be interpreted as evidence of developmental progression throughout teacher education. They may reflect differences among cohorts, including variation in coursework, learning experiences, or opportunities to engage with climate-related issues.

The observed differences across grade-level cohorts may also be considered in relation to the curricular structure of the Social Studies Teacher Education Program. The relatively stronger representation of social, economic, and political dimensions among second-year participants may be related to the types of disciplinary and social-contextual learning experiences encountered during teacher education. However, this interpretation should be treated cautiously because the present study did not examine participants' individual course histories or measure the contribution of specific courses to their conceptual associations. Therefore, the observed grade-level differences cannot be attributed to particular courses or curricular experiences. Rather, they highlight the importance of examining how climate change-related content is distributed and connected across the teacher education curriculum. Future research could investigate course-level exposure and curricular sequencing to determine whether specific learning experiences are associated with differences in pre-service teachers' conceptual associations regarding climate change. Related research with social studies pre-service teachers has also examined environmental ethics awareness across grade levels, suggesting that environmental awareness may vary according to students' educational level (Dikicigil & Gülersoy, 2020). However, the apparent pattern observed for the third-year group should be interpreted with caution because this group consisted of only eight participants. The relatively high standardized frequencies and the dispersed distribution of concepts observed in this group may reflect sampling variability or small-sample effects rather than a developmental characteristic of third-year teacher candidates. Therefore, the findings should not be interpreted as evidence that cognitive structures become more fragmented at the third year of teacher education. Rather, the third-year results should be considered a descriptive pattern that requires further investigation with larger and more balanced samples across grade levels.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the participants were recruited from a single university, Atatürk University Kazım Karabekir Faculty of Education, and were selected using convenience

sampling. Therefore, the findings reflect the characteristics of this specific institutional and participant context and should not be generalized to all pre-service social studies teachers. Future studies should include participants from multiple universities and different geographical regions and use more diverse sampling strategies to examine whether similar patterns of conceptual associations are observed across contexts.

Recommendations

Based on the results obtained from the first research question, which showed that the concepts generated by pre-service social studies teachers were concentrated primarily in climatic/meteorological elements and environmental degradation and ecological processes, it can be recommended that climate change instruction in social studies teacher education be structured around broader and more interconnected conceptual categories. In particular, learning activities can be designed to help pre-service teachers establish relationships among climatic processes, environmental changes, energy and emissions, and their social consequences.

Based on the results obtained from the second research question, which showed that drought, melting glaciers, and global warming were among the most frequently associated concepts, it can be recommended that teacher education programs move beyond frequently recognized consequence-oriented concepts and provide greater opportunities to examine the causes, mechanisms, and possible responses to climate change.

Based on the results obtained from the third research question, which indicated that social, economic, and political dimensions were comparatively less represented overall, it can be recommended that climate change education in social studies teacher education explicitly incorporate social, economic, political, and civic dimensions alongside environmental and climatic content. Case studies, debates, problem-based learning activities, and decision-making tasks may be used to strengthen these dimensions.

Based on the results obtained from the fourth research question, which revealed variation in the representation of conceptual categories across grade levels, it can be recommended that climate change-related content be sequenced and integrated more coherently across the Social Studies Teacher Education Program. Particular attention should be given to establishing conceptual connections across grade levels rather than assuming that conceptual development progresses automatically with academic year.

Based on the results obtained from the fifth research question, which identified some scientifically limited or potentially problematic conceptual associations, it can be recommended that teacher education courses include activities that explicitly address and examine such associations. Concept mapping, evidence-based discussion, and opportunities to compare pre-existing conceptions with scientifically grounded explanations may help pre-service teachers develop more coherent conceptual structures regarding climate change.

Finally, given the substantial differences in the number of participants across grade levels and the particularly small third-year group (n = 8), future studies should investigate grade-level differences using larger and more balanced samples. Longitudinal research may also be useful for determining whether the observed differences represent genuine changes in cognitive structures or cohort-related variation.

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