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The Interdisciplinary Approaches in Climate Change-Based Education: Bibliometric Analysis and Literature Review

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ABSTRACT

An interdisciplinary approach to climate change-based education is a growing field, but previous research has been limited in mapping trends, gaps, and directions for comprehensive research development. Therefore, this study aims to visualize research trends of interdisciplinary approaches in climate change-based education during the period 2020–2025, identify research gaps, and explore potential innovations and development strategies. This study uses a bibliometric approach and a systematic literature review, drawing on data from the Scopus database. A total of 609 articles were identified at the initial stage of the search, then selected and filtered, leaving 130 that met the criteria for analysis. Data analysis was conducted using VOSviewer and Microsoft Excel 2021. The analysis shows a significant increase in publications over the last six years, with six main keyword clusters. The dominant keywords include "interdisciplinary in education", "climate change-based education", and "climate change". In addition, temporal analysis reveals that topics such as education for sustainable development, strategic approaches, case studies, and prevention and control are emerging themes that have high potential for further research. This research provides a comprehensive mapping of research trends and directions, as well as identifies areas that are still underexplored, serving as a basis for the development of more effective interdisciplinary learning strategies in climate change-based education in the future.

Keywords: Climate change, Interdisciplinary, Education, Bibliometric

Introduction

In this era of fast-paced globalization, educational challenges are increasingly complex. Advances in information technology, changes in social values, and global issues such as environmental sustainability. Education is one of the main pillars of sustainable development, contributing directly to the development of high-quality human resources. In the global context, international education must adapt to the various dynamics triggered by globalization, the Industrial Revolution 4.0, climate change, and other social and economic challenges (Organisation for Economic Co-operation and Development, 2023). Curriculum changes are one way to adapt education to developments in science and technology. These changes have sparked differences of opinion among various education actors, including teachers. In the context of standards-based curriculum reform, education leaders face adaptive challenges when encouraging teachers to adopt a technically written curriculum (Limiansi et al., 2023; Pak et al., 2020).

On the other hand, climate change, as a global issue, further underscores the urgency of education's role. The real impact of climate change can be seen in the increasing frequency and intensity of natural disasters. Data from *the World Meteorological Organization* shows that over the past two decades, the number of weather-related disasters increased by 83% compared to the period 1980–1999, impacting more than 4 billion people globally and causing economic losses of up to US$ 2.97 trillion (Natur et al., 2022). Climate change has emerged as one of the environmental degradation phenomena that affects almost every aspect of life and threatens human existence both at the local, national, and global levels (Priadi & Fatria, 2024). Some impacts of climate change include ozone depletion, rising temperatures driven by increased atmospheric greenhouse gas concentrations, rising sea levels, and melting glaciers in high mountains and polar regions. Moreover, it will significantly contribute to a variety of other impacts that affect every aspect of life and environmental systems (Hayatulah & Mahasari, 2023; Junarto, 2023; Paulo et al., 2020; Susilawati, 2021).

To address the complexity of educational challenges, a holistic learning approach that integrates various perspectives is needed. The interdisciplinary approach becomes relevant because it combines knowledge and methods from various disciplines to solve problems comprehensively. Through collaboration and the exchange of ideas among experts, this approach results in a deeper understanding, as seen in climate change studies that involve multiple scientific fields (Assya'bani & Sabda, 2024). An interdisciplinary approach is a learning method that combines various disciplines to understand problems in a broader, more in-depth, and contextual way (Klaassen, 2018; Liao & Wang, 2020; Liu, 2025). In the scope of general education, Liu (2025) emphasizes that an interdisciplinary approach can be achieved by combining subjects such as English and science or art to help students gain a broader and more thorough understanding of a problem. Overall, the interdisciplinary approach is seen as a comprehensive and transformative learning strategy because it emphasizes cross-field integration while developing cognitive and affective competencies relevant to the challenges of the 21st century.

Environmental education plays an important role in encouraging creativity, critical thinking, problem-solving, and interdisciplinary learning as part of the educational revolution (Fitriyah, 2023). Its integration into the learning process helps students develop an attitude of caring for the environment through hands-on experience, thereby becoming more active, creative, innovative, and independent in addressing environmental problems (Yanti *et al.*, 2020). In addition, the environment is an important factor in 21st-century learning, fostering awareness of survival (Fitriyah, 2023). Climate change is a major threat to the sustainability of life on earth. Global warming, characterized by an increase in earth's average temperature, triggers various disasters, damages ecosystems, and threatens the lives of humans and other creatures. Global carbon emissions reached 36.8 billion tonnes in 2022, with the energy and transport sectors as the largest contributors (Chad, 2023). The impact is felt globally, but

developing countries are most vulnerable due to limited resources and risks to food security and economic growth (IPCC, 2023).

Education at all levels of schooling is essential to address the challenges of climate change and create a better environment in the future (Luthfia, 2025). Teaching about climate change requires educators to prepare thoroughly, given the magnitude of the challenges facing the planet. Many educators find it difficult to teach climate change due to limited understanding of the scientific principles involved and the perception of controversy or threats to personal beliefs, which are often erroneous (Plutzer, 2018). Integrating interdisciplinary or intradisciplinary approaches from various sources of knowledge, such as the social and natural sciences, is a complex yet crucial endeavor in climate change research and the development of climate change action strategies (Luthfia, 2025).

Educators and researchers recognize that the approach to climate change differs from that for other environmental issues because of its complex and uncertain nature. In addition, climate change is closely linked to group values and identities, which often provoke a defensive response from society. This is an additional challenge in learning, especially for educators who face different age groups. In fact, some teachers are worried about parents' reactions and are hesitant to teach climate change (Monroe et al. , 2019).

Amid this complexity, an interdisciplinary approach to climate change education has been widely discussed in various studies. However, previous studies still exhibit several significant limitations. Most studies tend to focus on implementing concepts in specific contexts using qualitative approaches or local case studies, so the results cannot be generalized widely. In addition, there are inconsistencies in the findings regarding the effectiveness of interdisciplinary approaches in improving students' science literacy and environmental awareness, as well as limitations in the scope of the samples and the analysis methods used. This condition indicates that existing research remains partial and does not provide a comprehensive picture of the development of this field. On the other hand, to date, there are still limitations to comprehensively mapping research using a bibliometric approach in interdisciplinary climate change-based education. In fact, bibliometric studies have an important role in identifying publication trends, collaboration patterns, scientific structures, and research gaps that have not been widely explored. The absence of bibliometric mapping ultimately leads to a fragmented research landscape, where studies develop separately without clear integration across topics, methods, or research foci.

The problem of climate change is a complex and multidimensional issue, as it can be viewed from various perspectives, including physics related to energy, biology related to ecosystems, chemistry related to pollution, and cultural aspects that reflect people's lifestyles. Therefore, learning about climate change becomes appropriate when implemented through an interdisciplinary approach. Based on this urgency, this research was carried out by mapping the trend of scientific studies regarding the implementation of interdisciplinary approaches in climate change-based education over the past six years (2020–2025). In particular, the main objectives of this study are: (1) to visualize research trends related to interdisciplinary approaches in climate change-based education during the period; and (2) to explore the potential for new research innovations and identify strategies that can be applied to integrate interdisciplinary approaches in those contexts. In this case, bibliometric research is important for providing a systematic, structured picture of the development of research in this field. Through bibliometric analysis, this study not only maps the trends and distribution of publications but also identifies relationships among topics, research clusters, and understudied areas. Thus, this study is expected to fill existing gaps, clarify the direction of future research, serve as a basis for the development of more effective interdisciplinary learning strategies in climate change-based education, and provide inspiration and benefits to researchers in related fields.

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Methods

The method used in this study is a literature review with a bibliometric approach. This review of the bibliometric literature is based on explicit, systematic methods (Garza-Reyes, 2015). Data were obtained from secondary sources on the Scopus website (https://www.scopus.com). Bibliometric analysis is the process of analyzing publications using mathematical or statistical approaches to identify the distribution, patterns, and developments of research in a particular field of study, which can also illustrate its impact, where its operation involves searching for relationships between various unique keywords (Indriyanti et al., 2023; Musyarrafah & Muqarramah, 2021; Yani & Soebagyo, 2023). Bibliometric analysis visualizes the interconnectedness of research concepts, and the gaps identified between these keywords can inform future studies (Astuti et al., 2023). Meanwhile, the literature review serves as a basis for expanding knowledge and formulating new ideas based on existing findings, taking into account implications, limitations, suggestions, future research directions, and scientific progress (Source et al., 2023).

The bibliometric analysis in this study follows five stages developed by Tranfield et al. (2003): keyword determination, keyword search, improvement of initial search results, compilation of statistical data, and data analysis (Indriyanti et al., 2023; Sustainable et al., 2023). At the search stage, the author uses a systematically designed combination of *search strings*: *("interdisciplinary approach in education" OR "climate change education") AND ("climate change" OR "interdisciplinary climate change" OR "interdisciplinary education")*. The search was conducted across the *title*, *abstract*, and *keywords fields* to ensure relevant and comprehensive coverage of the literature. Data collection will take place in October 2025. A total of 609 articles were identified in the initial stages of the search. Furthermore, the search results are filtered using several criteria, namely: (1) only research articles (*Research Articles*); (2) does not include literature review articles or bibliometric studies; (3) has open access (*Open Access*); (4) written in English; and (5) issued in the range of 2020 to 2025. Based on these criteria, a total of 130 documents were obtained. The data is then downloaded as a *.csv* file. Data processing is carried out using Microsoft Excel 2021 and *VOSviewer* software for bibliometric analysis and visualization. The visual mapping generated by *VOSviewer* is further analyzed to identify patterns of relationships between keywords. In addition, article data compiled in Microsoft Excel is systematically selected based on title, abstract, and overall context to ensure alignment with the research focus, an interdisciplinary approach to climate change education, before further synthesis. The systematic literature review in this study comprises five stages, as shown in Figure 1.

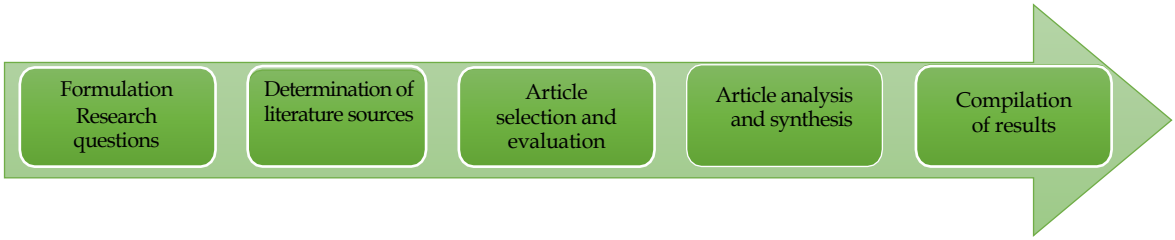

Figure 1. Stages of systematic literature review research (Day et al., 2018)

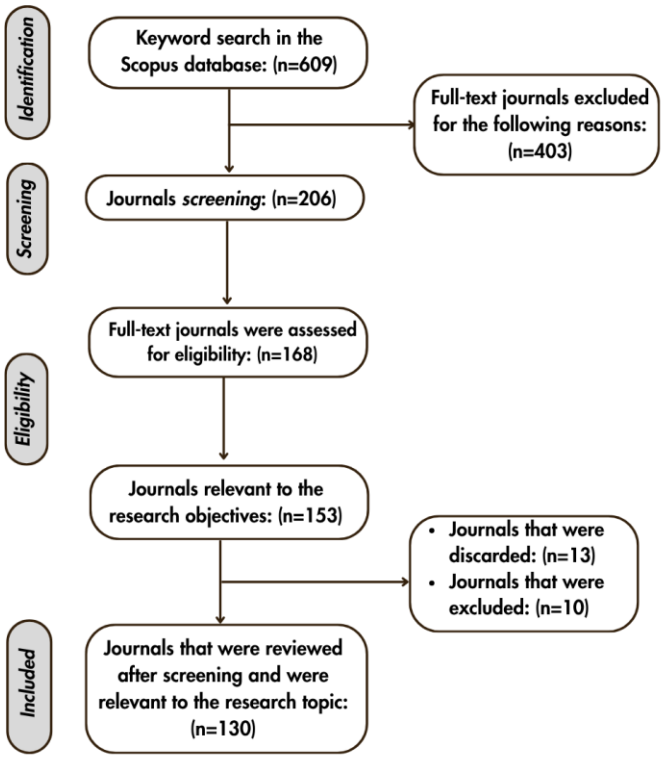

Figure 2. PRISMA diagram

Results and Discussion

Visualization of research trends on interdisciplinary approaches in climate change-based education over 6 years (2020-2025)

Based on a bibliometric analysis, 10 articles with the highest citations or that were often cited in other studies were identified. These 10 articles are shown in Table 1. The articles with the highest citations are mostly from 2023, and most are from the journal Sustainability Switzerland. The article with the highest citations is *"Scientific novelty beyond the experiment,"* by Hallsworth et al. (2023). This article argues that scientific innovation comes not only from practical experiments but also from theoretical thinking and deep imagination. They highlight how theory-based and experimental studies complement each other and how the approach has helped scientists from the past and present make important discoveries.

Table 1. 10 Articles with the highest number of citations

Author	Title	Journal	Quotes
(Hallsworth *et al.*, 2023)	Scientific novelty beyond the experiment	*Microbial Biotechnology*	45
(Raman *et al.*, 2024)	Exploring Sustainable Development Goal Research Trajectories in Small Island Developing States	*Sustainability Switzerland*	19
(Brandt *et al.*, 2024)	Climate change and mental health: Position paper of the European Psychiatric Association	*European Psychiatry*	14
(Levy *et al.*, 2023)	Implementing climate literacy in schools — what to teach our teachers?	*Climatic Change*	9
(Scarpa & Casu, 2024)	Genomics and Bioinformatics in One Health: Transdisciplinary Approaches for Health Promotion and Disease Prevention	*International Journal of Environmental Research and Public Health*	8
(Lokmic-Tomkins) *et al.*, 2024)	Integrating planetary health education into tertiary curricula: a practical toolbox for implementation	*Frontiers in Medicine*	8
(Zhang *et al.*, 2023)	Exploring the Main Determinants of National Park Community Management: Evidence from Bibliometric Analysis	*Forests*	7
(Horne *et al.*, 2024)	Alignment among environmental programs in higher education: What Food-Energy-Water Nexus concepts are covered in introductory courses?	*Journal of Geoscience Education*	6
Choudhury, M. (2023)	Disaster Education in the Context of Postsecondary Education: A Systematic Literature Review	*Natural Hazards Review*	5
Maccanti, M. (2023)	Learning-by-Doing Methodology towards Urban Decarbonisation: An Application in Valletta (Malta)	*Sustainability Switzerland*	5

Meanwhile, from Figure 3, a trend in article publication rates regarding interdisciplinary approaches in climate change-based education is evident, with a consistent increase until the end of 2025. Research on this topic shows a strong trend in 2025, with the number of publications reaching 30 in one year. In contrast, 2020 had the fewest articles, with only 11 articles. The average number of publications on interdisciplinary approaches to climate change-based education over the past 6 years is 17. This indicates that climate change is no longer seen as a single domain but as a complex problem that requires integrating various disciplines. These findings align with the constructivist learning concept, which emphasizes integrating knowledge from various perspectives to build meaningful understanding and construct knowledge from experience (Kartika et al., 2022). In addition, this trend is consistent with previous research showing that climate change education is a major focus in 21st-century education. Education is often considered to have an important role in raising awareness.

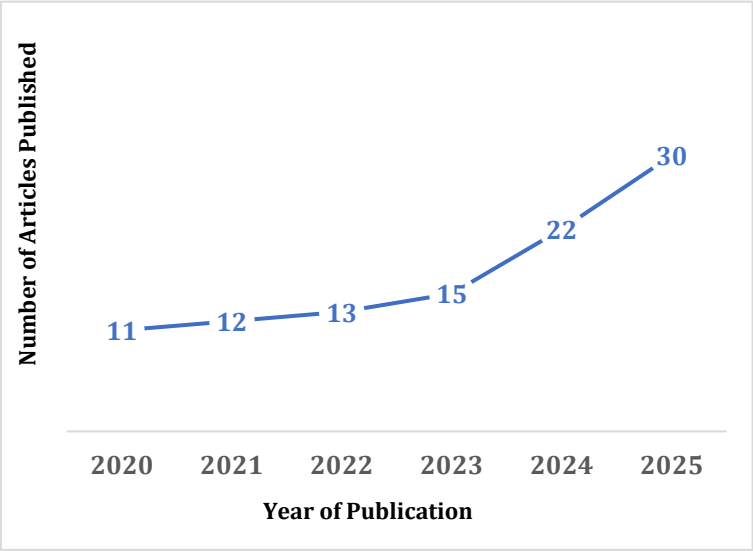

Figure 3. Development of article publications from 2020 to 2025

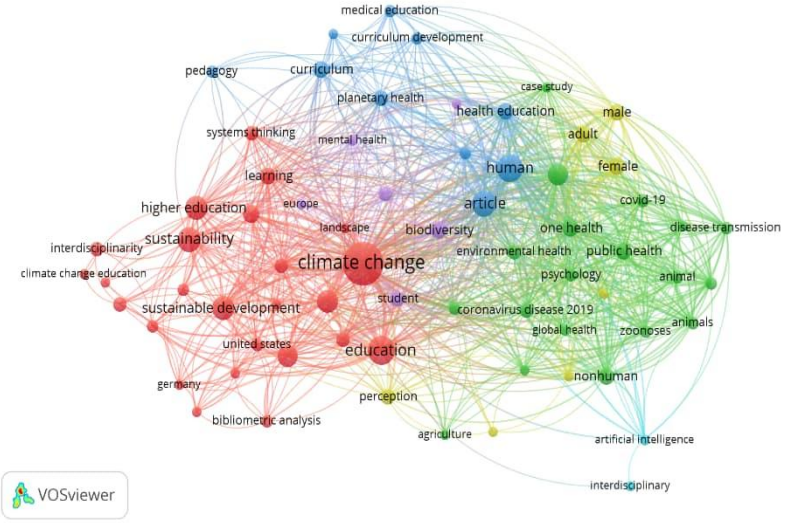

Figure 4. Mapping of publication keywords

The *VOSviewer* analysis results in the visualization shown in Figure 4 that illustrates the research keyword network. There are 6 clusters, 935 connections, and a link strength of 1758, enriching research on interdisciplinary approaches to climate change-based education. Each cluster is represented by circles and connecting lines of different colors, grouping topics based on their characteristics (Astuti et al., 2023), The size of the circle in the mapping indicates the frequency with which the keyword is mentioned. The larger the circle, the more often that keyword appears (Indriyanti et al., 2023).

These findings align with previous bibliometric research showing that keyword network visualization can reveal scientific structures, relationships between concepts, and the development of research themes in a systematic manner. A study by Donthu (2020) confirms that the co-occurrence analysis *of* keywords in *VOSviewer* is effective for identifying dominant themes and emerging research areas. In addition, according to Aria & Cuccurullo (2017) bibliometric mapping not only helps group research topics but also provides an overview of the direction of scientific development and potential collaboration between fields. In the context of climate change education, the interconnectedness among keywords in clusters

reflects a strong interdisciplinary nature, in which various disciplines contribute to one another to build a comprehensive understanding of climate change issues.

Thus, integrating the results of the *VOSviewer* visualization with findings from relevant journals reinforces the interpretation that research in this field does not stand in isolation but rather forms an interconnected network of knowledge. This also shows that there are opportunities for further research, especially in areas with low connectivity that have the potential to be studied in greater depth. To understand the structure of these connections in more detail, the next analysis focuses on each cluster in the network visualization. Each cluster represents a group of research themes that have a conceptual proximity and a high frequency of emergence in the study of interdisciplinary approaches to climate change-based education. Cluster 1 is shown with a red circle visualization consisting of 25 keywords, namely "academic research", "bibliometric analysis", "climate change", "climate change education", "climate communication", "creativity", "education", "education for sustainability", "germany", "higher education", "interdisciplinary", "interdisciplinary approach", "knowledge", "environment", "learning", "strategic approach", "students", "sustainability", "sustainable development", "thinking systemic", "teacher training", "teaching", and "America" In cluster 1, the most frequently mentioned keyword was "climate change", with a total of 46 incidents, 64 connections, and having a link strength of 277. Based on the composition of these keywords, Cluster 1 can be interpreted as a research theme in climate change education, grounded in an interdisciplinary approach to support sustainability. This theme emphasizes the integration of education, learning, and systemic thinking in higher education and teacher training, to improve comprehensive understanding and responses to climate change.

Cluster 2 is shown with a green circle visualization consisting of 19 keywords, including "Africa", "agriculture", "animals", "animals", "case studies", "coronavirus disease 2019", "COVID-19", "disease transmission", "environmental change", "environmental health", "global health", "human", "non-human", "health", "prevention and control", "psychology", "public health", "zoonoses", and "zoonoses". In cluster 2, the most frequently mentioned keyword is "humans", with 12 occurrences, 46 connections, and a link strength of 127. Based on the characteristics of these keywords, Cluster 2 can be interpreted as a theme of global health research and human-environmental interaction in the context of zoonoses and infectious diseases. This theme highlights the interconnectedness among humans, animals, and the environment, especially in the spread of diseases such as COVID-19, and the importance of public health approaches and environment-based prevention.

Cluster 3 is shown with a blue circle visualization consisting of 10 keywords, including "article", "conceptual framework", "curriculum", "curriculum development", "health education", "human", "interdisciplinary education", "medical education", "pedagogy" and "planetary health" In cluster 3 the most frequently mentioned keywords are "humans", with a total of 19 incidents, 55 connections, and have a link strength of 195. Based on the composition of these keywords, Cluster 3 can be interpreted as a research theme for curriculum development and interdisciplinary pedagogy in health and wellness education. This theme emphasizes the importance of integrating conceptual frameworks, pedagogical approaches, and curriculum innovations, especially in health and medical education, to build a holistic understanding of the linkages between human health and environmental sustainability. Cluster 4 is shown in a yellow circle visualization with 7 keywords: "adult", "citizen scientist", "female", "male", "perception", "questionnaire", and "thematic analysis". In cluster 4, the most frequently mentioned keyword is "female," with 8 occurrences, 35 connections, and 80 link strengths. Based on the characteristics of these keywords, Cluster 4 can be interpreted as a research theme on public perception and participation in environmental and health issues, grounded in social approaches. This theme focuses on the study of individual or group perceptions (based on gender and other demographic characteristics) through methods such as questionnaires and thematic analysis. It involves the role of *citizen science* in understanding environmental and health issues.

Cluster 5 is shown with a purple circle visualization consisting of 6 keywords, including "biodiversity", "ecosystem", "Europe", "mental health", "students", and "sustainable development" In cluster 5 the most frequently mentioned keywords are "biodiversity" with a total of 8 events, 42 connections, and has a link strength of 70. Finally, cluster 6 is shown as a light-blue circle visualization with 2 keywords: "artificial intelligence" and "interdisciplinary". Based on the composition of these keywords, Cluster 5 can be interpreted as a research theme on the relationship between biodiversity, ecosystems, and human welfare in the context of sustainable development. This theme highlights the relationship between environmental conditions, especially biodiversity and ecosystems, and aspects of human well-being, such as mental health, especially in student groups, in the framework of sustainable development. In cluster 6, the most frequently mentioned keyword is "artificial intelligence," with 3 occurrences, 17 connections, and a link strength of 23. Based on these results, it is proven that each cluster has similar characteristics, supports, and is interrelated with the others. Based on these characteristics, Cluster 6 can be interpreted as a research theme on the use of artificial intelligence in an interdisciplinary approach. This theme reflects emerging topics that emphasize the integration of artificial intelligence technology in various fields of science to support analysis, decision-making, and complex problem-solving, including in the context of the environment and health.

Overall, the analysis of the six clusters shows that research on interdisciplinary approaches to climate change-based education is developing widely and is interconnected across fields. Cluster 1 confirms the dominance of the theme of climate change education for sustainability, which aligns with recent research indicating that education plays an important role in building knowledge, skills, and capacity to adapt to climate change (Luthfia, 2025). An interdisciplinary approach in education has also been shown to integrate various perspectives on science to holistically understand the complexity of climate change (Morales-Aguilar et al., 2025).

Clusters 2 and 3 extend the study into the realm of global health and the development of interdisciplinary curricula, demonstrating that climate change impacts not only the environment but also human health and social systems. Recent research confirms that a transdisciplinary approach in higher education and health is needed to respond to the complex and interconnected climate crisis (Aeschbach, 2026). Furthermore, Cluster 4 highlights the importance of public perception and participation, which shows that understanding of climate change is shaped through social interaction and public engagement. This is supported by studies showing that climate change education should be contextual and experiential to increase public awareness and engagement (Kundariati et al., 2025).

Cluster 5 links biodiversity, ecosystems, and human well-being, reinforcing the finding that climate change education integrates ecological dimensions and human well-being. Meanwhile, Cluster 6, as *an Emerging Topic, demonstrates* the role of technology, such as artificial intelligence, in supporting the learning and analysis of increasingly complex climate change issues, including in the development of technology- and data-based learning (Suryati et al., 2025). Thus, the entire cluster reflects strong linkages among education, health, the environment, social factors, and technology. This confirms that an interdisciplinary approach is the main key to comprehensively understanding and responding to climate change, while opening up opportunities for the development of more integrative and innovation-based research in the future.

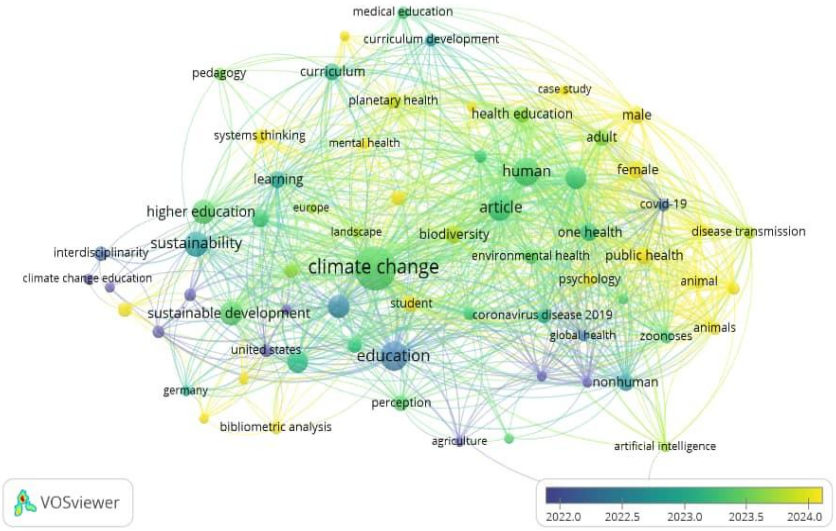

Figure 5. Keyword mapping based on publication year

Potential for new research innovation in related fields

In the *VOSviewer* software, there are 3 visualization views for bibliometric analysis: network, Overlay, and density visualization. Network functions to show the network between terms that are visualized, if the trajectory or network in bibliometric analysis is in bold print, then it shows that there is a relationship between one term (term) and another term (term) that is quite numerous and strong, on the other hand if the relationship between terms (terms) is thin printed with small circles. It shows a weak relationship between the observed terms. The overlay displays the historical traces of the research. The darker the visualization of the bibliometric analysis, the longer the research has been carried out; if the visualization shows light colors, then the research will be carried out in the near future. The last visualization is density, with density functions to display density or to emphasize the research group. This bibliometric analysis visualization can be used to identify research areas that are still rarely pursued or that have been pursued extensively (Nurul & Winoto, 2022). For example, in the period 2020 to 2025, the Overlay Visualization section of 2018 will be displayed as a dark network and will become brighter in the following years. This indicates that 2025 will be the network's brightest year.

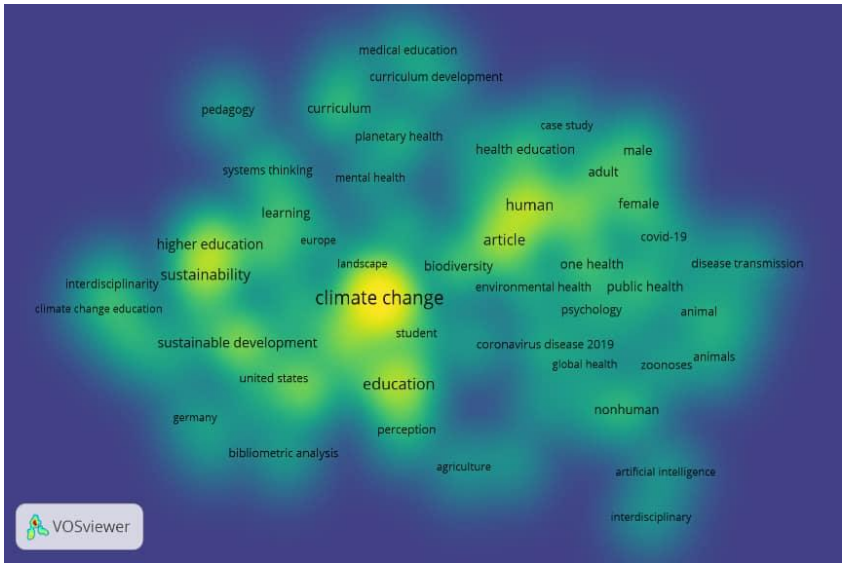

Figure 6. Keyword density

Figure 5 provides an overview of the novelty of research keywords based on the year of publication of the article (2020-2025). The color represents the average number of publications each year (Septiyanto et al., 2022). The brighter the color of the circle and the surrounding tissue, the more recent the research. In contrast, darker colors indicate older research. From Figure 5, it can be concluded that research topics on education for sustainable development, climate change, ecosystems, bibliometric analysis, strategic approaches, mental health, case studies, and prevention and control are relatively new and have the potential to continue to develop.

Notably, the topics highlighted in the brightest colors include education for sustainable development, climate change, and strategic approaches. Interdisciplinary values in climate change-based education can therefore be integrated through case studies, mental health, and efforts to prevent and control it. Meanwhile, the density of mapped keywords is shown in Figure 6. The brighter the color, the higher the density of research on the theme (Astuti et al., 2023). The analysis shows that keywords such as education, human, higher education, and sustainability have been extensively studied. In contrast, keywords with fainter or darker colors represent topics with potential for future research. They have not been studied extensively, especially regarding their relationship to interdisciplinary approaches and climate change. Examples: continuing education, interdisciplinary approach, strategic approach, environmental education, climate change education, artificial intelligence, and conceptual framework.

From Figures 7 and 8, innovative new research topics can be formulated. A line that connects one keyword to another indicates the research relationship of the published article. Longer distances may indicate a less explored relationship between these contexts. Figure 6 illustrates a research network on the keyword "interdisciplinary approach in climate change", showing the potential for novelty when it comes to curriculum development, case studies, curriculum, conceptual frameworks, On the other hand, Figure 7 illustrates a research network on the keyword "climate change in research" with potential novelties in several topics such as artificial intelligence, health education, disease transmission, and agriculture. If these keywords intersect with "interdisciplinary approaches" and "climate change-based educational research", the potential to link them becomes greater.

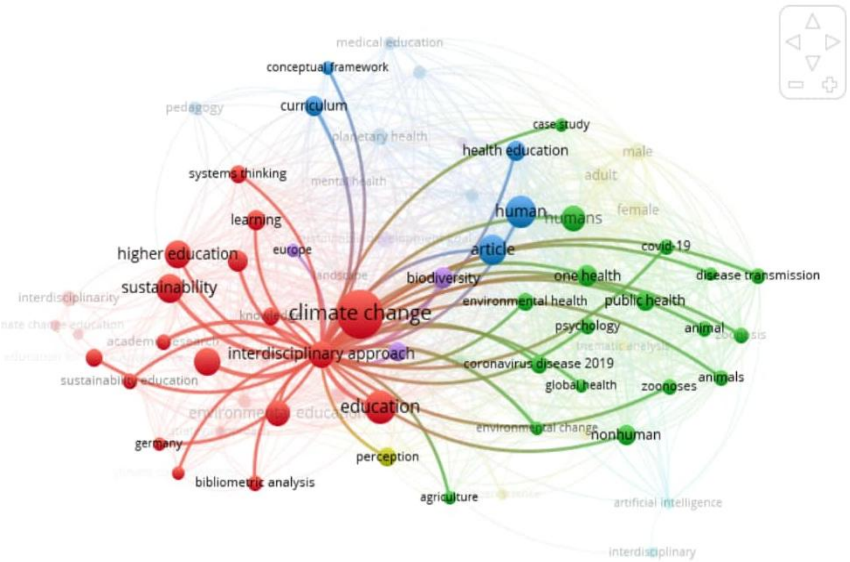

Figure 7. Research network on the keyword "Interdisciplinary Approach to Climate Change"

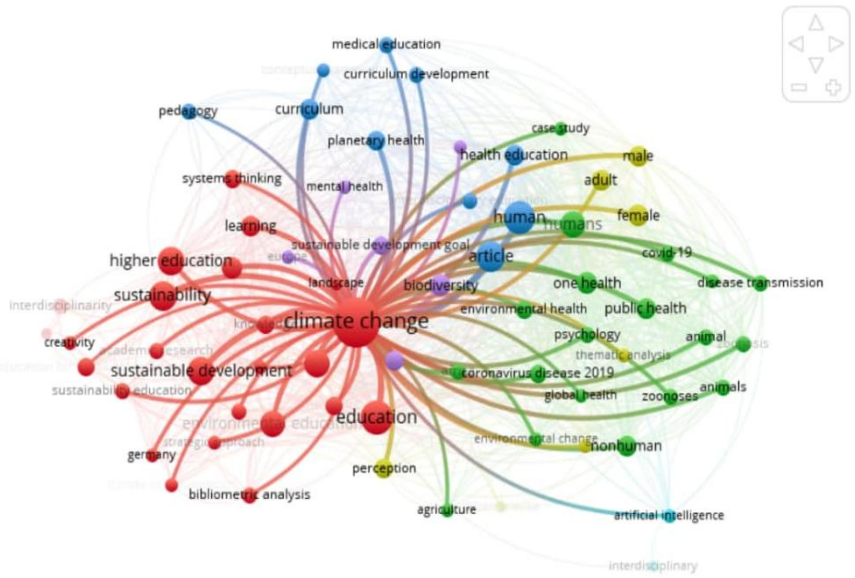

Figure 8. Research network on the keyword "Climate Change in Education"

Strategies that can be applied to integrate an interdisciplinary approach in climate change-based education

In climate change-based research with an interdisciplinary approach to the study of biology education, several research findings support the same implementation in implicit or explicit linkages, as shown in Table 2. A total of 8 articles were found, sourced from various Scopus-indexed journals, with research conducted in various countries, especially the United States, Germany, Spain, the United Kingdom, and China. This is consistent with research by Haunschild et al. (2016), which found that the United States often ranks first in both the number of publications and citations in bibliometric studies of climate change research. The accurate reason for this difference is that some irrelevant sources on the topic discussed are omitted in the analysis and synthesis stages. Moreover, the analyzed articles were only published from 2020 to 2025.

Table 2. Synthesis of 8 articles on climate change-based education research with an interdisciplinary approach

Author	Title	Country	Journal	Quotes
(Bakery et al., 2020)	The Global Museum: natural history collections and the future of evolutionary science and public education	Germany	*Peerj*	128
(Hallsworth et al., 2023)	Scientific novelty beyond the experiment	Spain	*Microbial Biotechnology*	45
(Russell et al., 2020)	ICDP workshop on the Lake Tanganyika Scientific Drilling Project: A late Miocene-present record of climate, rifting, and ecosystem evolution from the world's oldest tropical lake	Spain	*Scientific Drilling*	14
(Scarpa & Casu, 2024)	Genomics and Bioinformatics in One Health: Transdisciplinary Approaches for Health Promotion and Disease Prevention	United Kingdom	*International Journal of Environmental*	8

			Research and Public Health,	
(Horne et al., 2024)	Alignment among environmental programs in higher education: What Food-Energy-Water Nexus concepts are covered in introductory courses?	United States	*Journal of Geoscience Education*	6
(Kreher & McManus, 2023)	An interdisciplinary course on evolution and sustainability increases acceptance of evolutionary theory and increases understanding of interdisciplinary application of evolutionary theory	United States	*Evolution Education and Outreach*	2
(Tian et al., 2025)	Assessing coupling coordination between human-animal-environmental health for advancing uniform progress in One Health	China	*One Health*	1
(Schaefer, 2022)	The Territories Of Thinking And Feeling: Rethinking Religion, Science, And Reason With Alister Mcgrath	United States	*Zygon*	0

The prominence of education and sustainability themes in the bibliometric results indicates that education is the primary means of building awareness of climate change. This indicates that research focuses not only on cognitive aspects, but also on the formation of environmental attitudes and behaviors. These findings are in line with environmental education theory, which emphasizes the role of education in shaping ecological literacy and social responsibility, and refers to the ability to understand, evaluate, and make decisions and take actions that are responsible for the environment (Nazili et al., 2025). In addition, these results are consistent with previous research showing that integrating environmental issues into the curriculum can increase students' awareness and participation in climate change mitigation efforts.

In a broader context, education is often considered to play an important role in increasing awareness and understanding of climate change across generations. Student awareness of environmental care is very important, especially if environmental issues are first identified in schools (Halek et al., 2021). Humans, in meeting their needs, need the environment as a source of life (Kayaalp et al., 2021). The education sector is one of the fields that can help in the process of adaptation and mitigation within the community (Hasanah et al., 2023). Students in schools are part of society and can be agents of change in reducing the impact of climate change. The education process is the basic foundation that shapes how humans behave, think, and act towards the environment.

Climate change education should be a priority for fulfilling children's rights, especially in the context of the right to life, protection rights, the right to education, and the right to participation. To be able to sustain life in the midst of the climate crisis, they need adequate provisions in the form of basic attitudes, knowledge, and capacity to be able to respond effectively and innovatively to the climate crisis (Coren & Wang, 2024; Imran et al. , 2025; Jimenez & Moorhead, 2021). Changes and developments in the existing curriculum have not succeeded in fostering students' and school residents' awareness of and capacity to overcome climate change (Prasad, 2022; Ratinen, 2021). To increase students' awareness of overcoming

climate change, it is necessary to initiate the transformation of the Indonesian education system by integrating environmental education with the Sustainable Development Goals (SDGs). So that students can have literacy about climate change adaptation and mitigation. To confirm this statement and determine the urgency of environmental education, especially regarding climate change, it is necessary to research the picture of climate change-based education in Indonesia (Baga et al., 2022; Guo et al., 2015).

In line with that, an educational approach grounded in sustainable principles is needed to equip the current generation to meet their needs without risking future generations' ability to do so. There are three basic pillars of the ESD concept: environmental sustainability, economic progress, and the socio-cultural aspects of the community (Syakur, 2017). Research Laurie *et al.* (2016) across 18 countries shows that ESD contributes to improving the quality of education in the primary (elementary), junior high, and high school (SMA) sectors. SMA Tumbuh is a school that applies the concept of ESD and participates in realizing the Sustainable Development Action Plan SDGs in implementing education. The principles of ESD align with the City of Yogyakarta's philosophical values, which the SMA Tumbuh has adopted. One of SMA Tumbuh's philosophies is *hamemayu hayuning bawana*, which serves as the basis for achieving the school's vision and mission. In short, *hamemayu hayuning bawana* can be interpreted as "saving and prospering the earth as a whole". SMA Tumbuh collaborates on three concepts, namely people, profit, and planet. These values vary and are not only focused on providing education on environmental aspects, but a combination of several aspects that are also pillars in Education for Sustainable Development (Primasti, 2021).

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Conclusion

This study shows that the study of interdisciplinary approaches in climate change-based education has increased significantly in the period 2020–2025 and forms six main clusters that are interconnected across fields. Theoretically, these findings reinforce that interdisciplinary approaches, systems thinking, and the Education for Sustainable Development framework are important cornerstones in understanding the complexity of climate change holistically, while expanding the perspective that learning is not only cognitive, but also includes social, health, and technological dimensions. Practically, these results imply that educators and curriculum developers need to integrate case-based learning, problem-based learning, and environmental literacy in a cross-disciplinary context. In addition, the use of technology such as artificial intelligence can be used to support more adaptive and contextual learning on climate change issues. For further research, empirical studies are needed that specifically test the effectiveness of interdisciplinary approaches in improving science literacy, environmental awareness, and adaptive behavior of students at various levels of education. Future research is also suggested to explore topics that are still limited, such as the integration of artificial intelligence, environment-based mental health, and the development of interdisciplinary curricula based on local contexts.

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