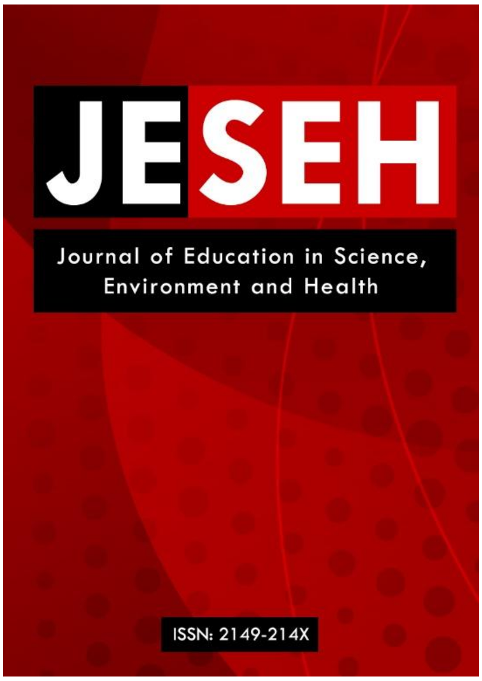

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Research at the Intersection of Science Education and Neuroscience: A Bibliometric and Content Analysis

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Research at the Intersection of Science Education and Neuroscience: A Bibliometric and Content Analysis

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Abstract

Along with the growing interest in neuroscience and advances in the field, research on the neuroscience of science learning has increased considerably. Despite the growing body of literature, comprehensive review studies integrating bibliometric and content analysis perspectives remain limited. To address this gap, this study aims to provide a comprehensive analysis of research integrating science education and neuroscience using bibliometric and content analysis methods. The data for this study comprise 288 articles published between 1992 and 2024, retrieved from the Web of Science database. The scientific mapping software VOSviewer and SciMAT were used for data analysis and visualization of the relevant literature. Research results indicate that neuroscience research in science education has seen significant growth in recent years. The United States is the country with the highest levels of productivity, impact, and collaboration. The leading journal in the field is the ‘‘Journal of Chemical Education’’, and Yu-Cin Jian has been identified as the most productive researcher. The most-cited article, authored by Makransky et al. (2019), has received 769 citations. Keyword co-occurrence analysis revealed shifts in research focus over the field's thematic evolution. The results of the content analysis showed that the most commonly used neurocognitive tools are eye tracking and electroencephalography, whereas tools such as brain stimulation, galvanic skin response, and functional near-infrared spectroscopy are used quite sparingly. From a methodological perspective, it has been determined that the studies largely rely on quantitative research designs, that participants consist predominantly of university students, and that sample sizes are generally small. This study provides a comprehensive framework regarding the themes shaping the field, its intellectual structure, its evolution, and trends over time, and serves as a fundamental reference point for future research.

Introduction

Learning is not merely a cognitive process; it is a complex and dynamic process shaped by the interplay of numerous factors, including emotional, social, and interest-related aspects, as well as physical and psychological states (Antonopoulou et al., 2023; Granado De La Cruz et al., 2025). Educational neuroscience is an interdisciplinary field that aims to understand the neural mechanisms underlying learning and to integrate this knowledge into educational practices. This field integrates findings from psychology, educational sciences, and neuroscience to conduct an in-depth examination of how learning works in the brain (Thomas et al., 2019). The primary goal of educational neuroscience is to develop more effective teaching strategies that enhance the learning process by elucidating the neurobiological foundations of cognitive processes such as learning, memory, attention, motivation, and emotion (Thomas & Arslan, 2025). Additionally, educational neuroscience aims to support learners’ active participation in knowledge production and ensure the retention of learned information (Altuntaş et al., 2024). This approach goes beyond traditional educational research and offers new perspectives on learners’ individual differences and neurocognitive learning difficulties (Pradeep et al., 2024).

Educational neuroscience not only provides a theoretical understanding but also offers the opportunity to objectively observe learning processes through the methods neuroscience provides, thereby contributing to grounding educational practices in scientific evidence (Thomas, 2018). Among these tools, electroencephalography (EEG) is a neurophysiological technique used to study and enhance learning processes by monitoring electrical signals in the brain (Leikin et al., 2025). Among other imaging tools, functional near-infrared spectroscopy (fNIRS) provides information about brain regions involved in cognitive processes by measuring changes in blood oxygenation. This technique is an imaging method that uses near-infrared light to assess oxygenation and blood flow in brain areas (Pinheiro et al., 2024). Functional magnetic resonance imaging (fMRI) is a neuroimaging technique that measures brain activity by detecting signals related to blood oxygen levels (Oliver, 2011; Rashid et al., 2020). Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation technique that uses magnetic fields to stimulate specific regions of the brain (Gongalla et al., 2026). On the other hand, eye tracking is a non-invasive technique used to measure and track eye movements and fixation patterns during various learning tasks and interactions with instructional materials (Ulukök Yıldırım & Sönmez, 2024).

The field of educational neuroscience contributes to the development of teaching methods in various areas, including language acquisition, reading, science education, and, with a particular focus on mathematics education, to support learners' educational experiences. Science education not only aims to provide students with scientific knowledge and skills but also to foster their abilities in scientific thinking, problem-solving, and critical analysis (Holbrook & Rannikmae, 2007). In this context, understanding science concepts, developing scientific process skills, and improving the ability to generate solutions for complex scientific problems are highly important (Liu & Huang, 2015). The role of neuroscience in science education is to better understand the cognitive challenges students face and the strategies they use when learning science. For example, processes such as mentally manipulating chemical formulas or grasping abstract scientific concepts require specific cognitive loads and brain activations (Liu & Huang, 2015). Neuroscientific techniques provide objective data on the effectiveness of learning processes by tracking changes in students' brains during such tasks (Pradeep et al., 2024). This data can offer valuable insights for designing science courses, developing instructional materials, and personalizing students' learning experiences (Ballesta-Claver et al., 2024; Vaughn et al., 2020). In this way, neuroscience enriches both the theoretical and practical aspects of science education, paving the way for more effective and student-centered approaches. As a key field shaping the future of science education, the neuroscience of science education enables us to gain a deeper understanding of learning processes and to incorporate this knowledge into educational practices. Consequently, in recent years, researchers have focused on this interdisciplinary interaction between science education and neuroscience (Cho & Yeh, 2026), and neuroscience-based research in science education has been increasing at both the theoretical and practical levels.

A study compiling neuroscience-based research in science education reveals that researchers such as Dubinsky, Michlin, and Pate have emerged as leading figures in this field; there has been a marked increase in publications, particularly since 2020; and the majority of research on this topic is being conducted in the USA (Bakır et al., 2023). However, it is important to note that the study considered only research in the Web of Science (WoS) database and did not provide a detailed analysis of the studies examined. This includes lacking information on the specific scientific fields and skills they focused on, the participant profiles they targeted, and the neurocognitive tools that were used. In Turkey, neuroscience research in education has gained momentum since 2013, though it has largely remained at the theoretical level (Taşkıner-Şereflioğlu & Kılıç-Mocan, 2021).

Unlike previous studies, the present study examines research at the intersection of neuroscience and science education from a broad historical perspective. It adopts an integrated bibliometric approach by combining SciMAT and VOSviewer software and employs various bibliometric indicators, including the h-index, citation counts, centrality, density, and total link strength (TLS), to provide deeper insights into the field. In addition, the study analyzes the intellectual landscape, emerging trends, and thematic development of the literature through keyword and citation analyses. Content analysis was also employed to provide both a global perspective and structural depth regarding the integration of neuroscience and science education. In this context, the study addresses important gaps in the literature by conducting a large-scale bibliometric and content analysis of publications published between 1992 and 2024. Thus, by offering a detailed overview of the field, the study enhances understanding of the development, current status, and future directions of neuroscience-related research in science education.

Bibliometric analysis provides a comprehensive, data-driven understanding of publication trends, highly cited articles, key contributors, collaboration patterns, thematic structures, and the evolution of the field. The content analysis examined the neurocognitive tools employed in the studies, participant characteristics, research designs, and sample sizes.

Method

In this study, a combination of bibliometric and content analysis was employed to gain insights into studies integrating science education with neuroscience using WoS data, trace the evolution of these research areas over the years, and identify trends in the field. Relying solely on a single research method can introduce limitations and, to some extent, bias (Gao et al., 2020). Therefore, in this integrated approach, quantitative bibliometric tools were used to map critical elements such as authors, countries, and citations, as well as the relationships among these elements and their evolution. Content analysis was also used to examine topics and content in depth and to provide stronger insights through a qualitative systematic review (Sahar & Munawaroh, 2025; Wahyuningrum et al., 2023).

Data Collection Method

The WoS database, a major scientific resource, is used to access the dataset for this study. Known for its high quality, advanced data extraction capabilities, rigorous editorial processes, and reputable journals, the WoS is one of the most suitable databases for bibliometric analysis (Lu et al., 2024). Additionally, this internationally recognized database is selected because it is a reliable source frequently used in various research fields (Maral, 2026). To identify relevant studies, a comprehensive and efficient search strategy was developed by drawing on the academic literature cited in previous systematic and bibliometric reviews on the subject (Leikin et al., 2025). A systematic search was conducted in the WoS database in December 2025 using the final search query shown in Figure 1.

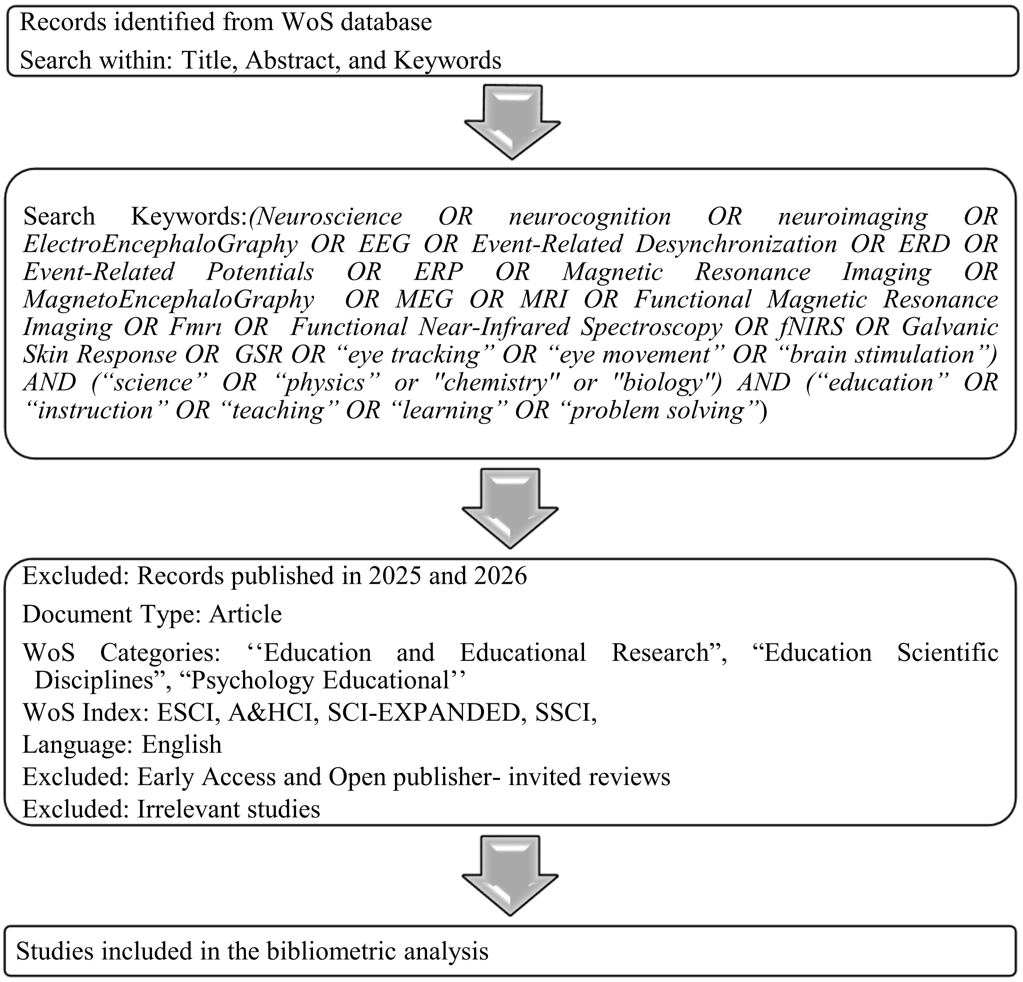

Figure 1. WoS database searching steps

The search is performed in the "topic" field to retrieve all relevant studies. The initial search yielded 8,081 published documents. The years 2025 and 2026 (n=1,341) were excluded from the analysis. Subsequently, 1,027 articles are identified after applying a filter to the publications in the "Education and Educational Research," "Education Scientific Disciplines," "Education Special," and "Psychology Educational" categories in the WOS database. The search results are narrowed down to 733 articles, and the articles are selected. By applying a language filter, only articles written in "English" are included in the analysis, reducing the dataset to 683. After selecting the ESCI, SSCI, SCI-EXPANDED, and A&HCI indexes, 36 studies are excluded, leaving 647 for analysis. After excluding Early Access articles and publisher-invited review papers, the dataset consisted of 642 publications. Full-text versions of studies whose relevance to the scope could not be clearly determined are accessed and reviewed. A total of 354 articles unrelated to the research topic are excluded from the dataset.

Following this comprehensive filtering process, the final sample of 288 articles is downloaded in "Plain Text" format and used for the bibliometric and content analyses. Details regarding the search process are presented in Figure 1.

To identify studies suitable for content analysis, the full texts of 288 articles obtained through bibliometric analysis are reviewed by two researchers. During this process, studies that directly used at least one neurocognitive assessment tool are included. The full texts of the studies meeting this criterion are included in the analysis. A total of 183 articles that do not focus on the specified criterion and instead addressed neuroscience through theoretical and indirect approaches are excluded. Consequently, 105 articles containing direct neurocognitive data and constituting original empirical research are included in the content analysis.

Data Analysis

This study employes content analysis and bibliometric analysis to provide an overview of research in science education and neuroscience. Content analysis is a qualitative method for identifying cognitive schemas and extracting meaningful insights from the literature (Prashar & Sunder, 2020). The content analysis focused on the neurocognitive tools used in the studies, the participant groups, the sample sizes, and the research designs.

Bibliometric analysis is a popular data-driven research method that enables the quantitative examination of a specific research field or topic using statistical methods (Zhang et al., 2025). This analysis combines two main procedures: performance analysis and scientific mapping. Performance analysis involves assessing the volume and publication impact of institutions, journals, publications, authors, and countries (Panday et al., 2025). On the other hand, scientific mapping focuses on the relationships among research components, revealing the dynamics and structural organization of the research field (Pizzi et al., 2020). As part of the bibliometric analysis, trends in publication, geographic distribution, leading authors, relevant journals in the field, collaboration patterns, citation analysis, keyword co-occurrence analysis, and co-citation networks were examined.

Two software programs, VOSviewer (Van Eck & Waltman, 2014) and SciMAT (Cobo et al., 2012), were used to conduct scientific mapping and performance analysis. Using VOSviewer, citation analysis, co-authorship analysis, and keyword co-occurrence analysis were conducted. The VOSviewer program, which enables the exploration and visualization of scientific maps, is an extremely comprehensive and user-friendly tool that analyzes the networks of relationships among authors, journals, countries, institutions, and keywords (Van Eck and Waltman, 2014). This software creates a network structure composed of nodes representing each element in the dataset, with the network connections illustrating the relationships that emerge (Dogru et al., 2025). The size of the circles indicates the importance of concepts or frequently referenced elements.

To conduct a longitudinal analysis of the structural and dynamic development of the relevant field, the SciMAT software (Cobo et al., 2012) was used. Using the SciMAT software, a key tool in bibliometrics, strategic diagrams were created to categorize themes within the research field, and a thematic evolution map was developed to examine their evolution over time. SciMAT categorizes themes into four groups in two-dimensional strategic diagrams. Motor themes are characterized by high centrality and density. These themes encompass research areas that have developed extensively and are highly influential. Highly developed and isolated themes: These themes have low centrality and high density values and have weak connections to other themes; they encompass marginal topics that, while well-developed in their own right, are becoming increasingly less significant within the field. Emerging or declining themes: These are themes characterized by low centrality and high density, representing areas that emerge or fade over time. Basic and transversal themes consist of fundamental topics with low density and high centrality and have the potential to significantly impact the field as a whole (Nurani, 2025). On the thematic evolution map, the size of the spheres reflects the number of related documents and scales proportionally with the increase in the number of documents. Continuous lines between clusters indicate that the related themes share a common main theme. This signifies a conceptual connection. Dashed lines, on the other hand, appear when the connection is based on keywords and indicate a non-conceptual relationship. The thickness of continuous or dashed lines is determined by the inclusion index and represents the number of overlapping themes or keywords (Özköse & Ayaz, 2026).

Before the analyses, the dataset underwent cleaning and was prepared for bibliometric analysis. To this end, spelling errors, variations in keywords, singular-plural usage, abbreviations, and synonyms were identified and corrected. Before proceeding to the thematic analysis in this study, three distinct time periods were established in SciMAT to examine the evolution of the relevant literature. By evaluating both the conceptual and historical turning points in the literature and the number of publications, three periods were identified for the analysis: 1992–2012, 2013–2018, and 2019–2024.

Results

Annual Scientific Production

Figure 2 shows the scientific output over time of research integrating science education with neuroscience, while Figure 3 shows the distribution of citations.

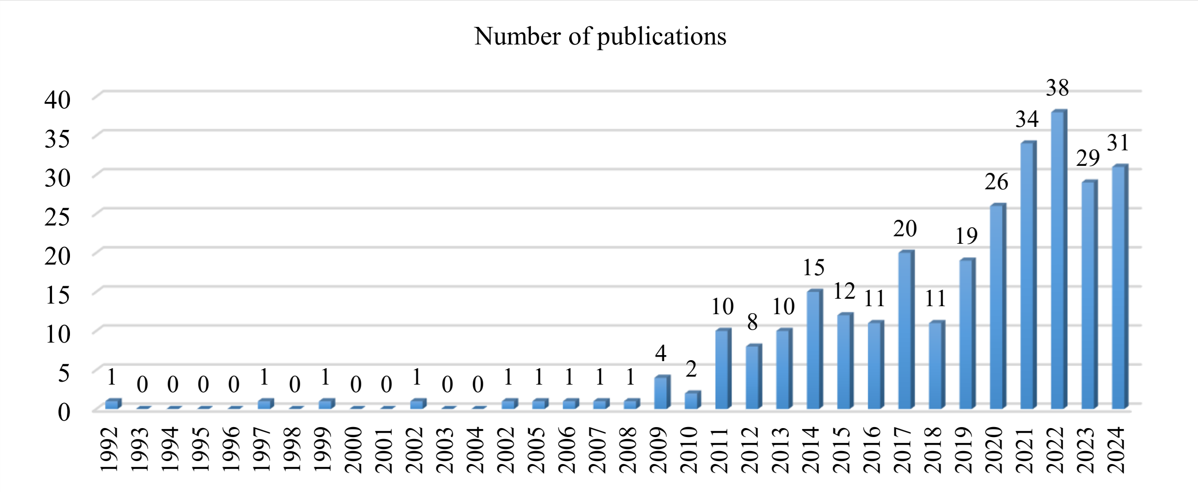

Figure 2. The number of publications according to years

A review of Figure 2 shows that the first publication in this research area dates back to 1992. From 1992 to 2009, publication activity remained low. Although initial developments were slow, the number of publications reached double digits for the first time in 2011. Although a slight decline was observed in 2012, the number of publications increased significantly between 2013 and 2017, reaching 10-15 documents. Since 2017, a fluctuating upward trend in the number of publications has continued. The highest number of publications was recorded in 2022, reaching 38. Additionally, a significant portion of the total academic output was produced between 2020 and 2024.

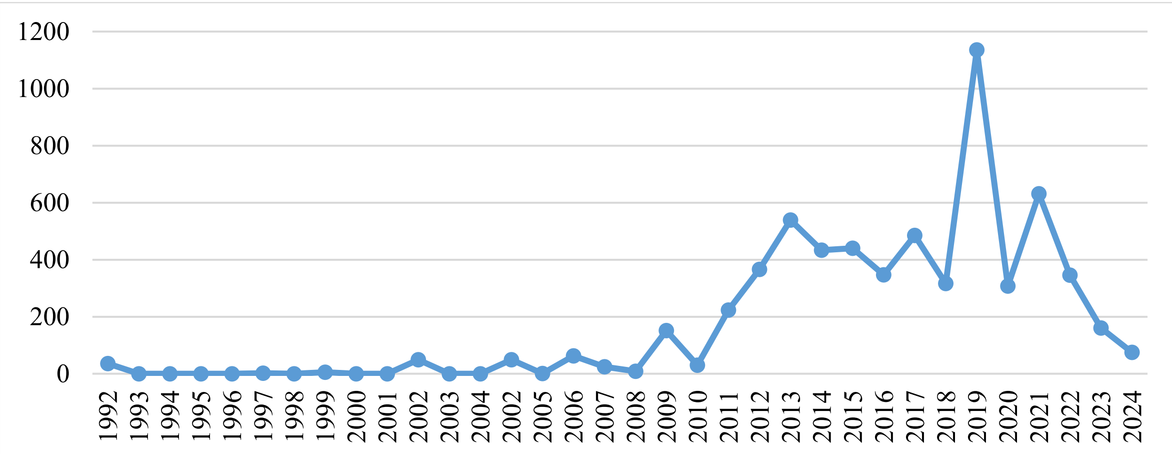

Figure 3. Number of citations by year

Graphical data on research integrating neuroscience with science education indicate that the field got off to a slow start and exhibited a very low citation rate between 1992 and 2005. Since 2006, however, a steady upward trend has been observed. In particular, 2013, 2015, and 2017 stand out for their higher citation counts. The field reached its highest citation level in 2019 with 1136 citations. A relative decline has been observed since 2022. This trend is likely attributable to the fact that articles published in recent years initially received fewer citations, rather than a loss of influence in the field.

Analysis of Country/Region Distribution

Figure 4 presents detailed information on the top 15 countries that have contributed the most publications to the field and received the most citations.

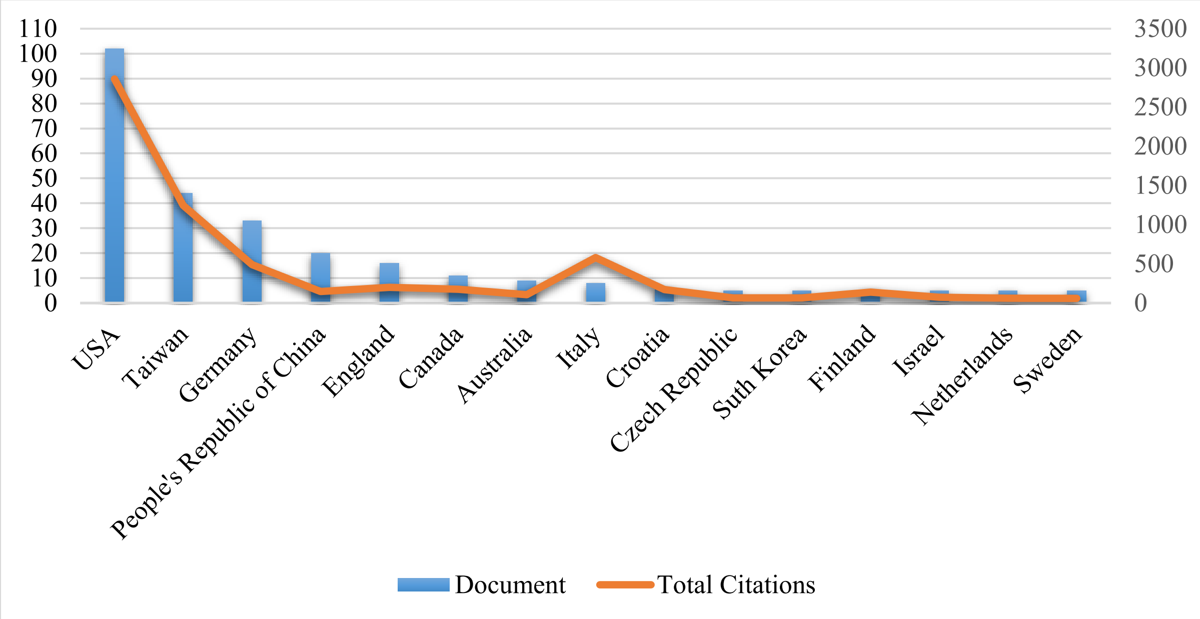

Figure 4. Distribution of publications and citations by country/territory (Top 15)

As shown in Figure 4, the USA ranks first in terms of both the number of publications and total citations, with 102 publications and 2,859 citations. Taiwan (44 publications, 1,247 citations) and Germany (33 publications, 489 citations) are among the countries following the USA in terms of publications. These countries have contributed to advancing neuroscience in science education. England (16 publications, 200 citations) and Canada (11 publications, 175 citations) have also made notable contributions through their publication output. Although Italy has a lower number of publications, it has garnered a significant number of citations. The network of co-authorship between countries was visualized using VOSviewer software and is presented in Figure 5. For this analysis, the minimum number of articles per country was set at five. Sixteen countries met this criterion, yielding a network comprising five clusters.

Figure 5. Co-authorship networks of countries

A review of Figure 5 reveals that international collaboration in this field remains limited. The USA has the highest level of collaboration, with a total connectivity score of 13. Taiwan and Germany are other countries demonstrating strong collaborations with high total connectivity scores. The USA and Taiwan exhibit intense collaboration. On the other hand, Germany has weaker connections with other countries but is engaged in collaboration with other European nations.

Source Analysis

Table 1 presents a list of the top ten journals that have published research integrating neuroscience with science education over the years.

Table 1. Top 10 most influential journals

Rank	Source	Documents	Citations	TLS
1	Journal of Chemical Education	20	405	26
2	Computers & Education	19	1146	58
3	Physical Review Physics Education Research	18	325	26
4	Frontiers in Education	16	95	17
5	Mind, Brain and Education	13	141	7
6	Research in Science Education	12	92	11
7	Journal of Science Education and Technology	11	115	17
8	International Journal of Science and Mathematics Education	10	300	42
9	Education Sciences	9	83	5
10	CBE–Life Sciences Education	8	147	3

Table 1 reveals that the "Journal of Chemical Education," "Computers & Education, and "Physical Review Physics Education Research" are the leading journals in terms of both the number of publications and total citations. In particular, "Computers & Education" has the highest number of citations, with 1,146. In terms of the number of issues published, these journals follow journals such as "Frontiers in Education", "Mind, Brain and Education", and "Research in Science Education". This distribution indicates that research on the integration of science education and neuroscience is represented in journals focused on disciplinary studies, educational technology, neuropedagogy, and that this research area is addressed across a broad spectrum.

Leading Authors in Terms of Productivity and Citations

A total of 832 authors contributed to the research in the publications included in the analyzed dataset. Authors with at least 5 publications were included in the study; 10 authors met this threshold. The top ten authors who contributed most significantly to the current research topic, along with the number of publications they produced and the total citations these publications received, are listed in Table 2.

Table 2. Top 10 most influential authors

Rank	Author	Documents	Citations
1	Jian, Yu-Cin	9	180
2	Tsai, Meng-Jung	8	451
3	Yang, Fang-Ying	8	395
4	Mason, Lucia	7	539
5	Bubic, Andreja	6	171
6	Palmovic, Marijan	6	171
7	Planinic, Maja	6	171
8	Susac, Ana	6	171
9	Pluchino, Patrik	5	426
10	Mayer, Richard E.	5	1055

According to the Table 2, Yu-Cin Jian leads the other authors as the researcher with the highest number of publications, nine in total, related to the subject of this study. He is followed by Meng-Jung Tsai and Fang-Ying Yang, each with eight study. These three authors share a common approach in that they address cognitive processes, visual information processing, and attention distribution in the context of science learning through eye tracking based experimental research. Lucia Mason is another prominent author in this field, having contributed to seven publications on the subject. Authors such as Andreja Bubic, Marijan Palmovic, Maja Planinic, and Ana Susac are among the other contributors to this field of research. Although Richard E. Mayer has contributed 5 publications to the field, he is researcher with the highest total number of citations, at 1055.

Figure 6 illustrates the co-authorship network of authors collaborating on research in the field of integrating science education and neuroscience. In this visualization, every author in this field has at least five publications. As shown in Figure 6, this collaborative group comprising Andreja Bubic, Marijan Palmovic, Maja Planinic, and Ana Susac forms a shared academic network. The connections among the authors in this group indicate that they are affiliated with the same research group or share a similar field of study.

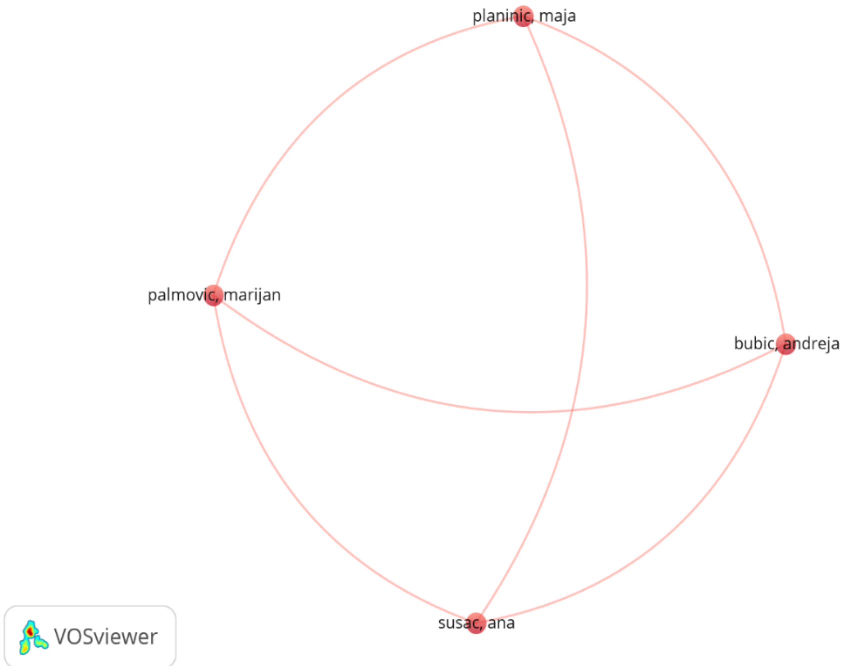

Figure 6. Co-authorship networks of authors

Influential Documents

Table 3 presents the most frequently cited articles in the field of research integrating science education and neuroscience. Table 3 reveals that these most cited documents in the current field are centered on cognitive processes, visual attention, immersive technologies, and multimedia learning. Methodologically, eye tracking has been used as the primary data collection tool in these studies.

Table 3. Most cited articles

Rank	Authors	Publication Year	Title	Total Citations
1	Makransky, G., Terkildsen, T. S., & Mayer, R. E.	2019	Adding immersive virtual reality to a science lab simulation causes more presence but less learning	769
2	Tsai, M. J., Hou, H. T., Lai, M. L., Liu, W. Y., & Yang, F. Y.	2012	Visual attention for solving multiple-choice science problem: An eye-tracking analysis	204
3	Parong, J., & Mayer, R. E.	2021a	Cognitive and affective processes for learning science in immersive virtual reality	195
4	Mason, L., Tornatora, M. C., & Pluchino, P.	2013a	Do fourth graders integrate text and picture in processing and learning from an illustrated science text? Evidence from eye-movement patterns	174
5	Mason, L., Pluchino, P., Tornatora, M. C., & Ariasi, N.	2013b	An eye-tracking study of learning from science text with concrete and abstract illustrations	126
6	Miller, B. W.	2015	Using reading times and eye-movements to measure cognitive engagement	97
7	Tsai, M. J., Huang, L. J., Hou, H. T., Hsu, C. Y., & Chiou, G. L.	2016	Visual behavior, flow and achievement in game-based learning	96
8	She	2009	The impact of multimedia effect on science learning: Evidence from eye movements	88
9	Susac, A. N., Bubic, A., Kaponja, J., Planinic, M., & Palmovic, M.	2014	Eye movements reveal students' strategies in simple equation solving	79

The most cited study, titled “Adding immersive virtual reality to a science lab simulation causes more presence but less learning”, was published in the Journal of Learning and Instruction and has received 769 citations. This study demonstrates that incorporating immersive virtual reality into virtual learning simulations reduces students’ learning levels, even though they experience a greater sense of presence in the immersive virtual reality environment.

The second most cited study, titled “Visual attention for solving multiple-choice science problems: An eye-tracking analysis”, was conducted by Tsai et al. (2012) has received 204 citations. In this study, analyzes students’ visual attention while solving a multiple-choice science problem using eye-tracking data, highlighting their cognitive strategies during multiple-choice questions.

The third most cited study, conducted by Parong and Mayer (2021a), has been referenced 195 times in the scientific community. The research explored differences in academic learning between a course delivered in an immersive virtual reality environment and a traditional course delivered via a desktop computer. Starting from the fourth position, the number of citations for the studies ranges from 79 to 174. Among these highly cited articles, eye tracking technology stands out as the most widely used tool.

Keyword Analysis

SciMAT was used to analyze the co-occurrence of keywords in research that integrates the fields of science education and neuroscience.

Structural and Thematic Development

The level of keyword overlap can be determined by examining the evolution of keywords over time. Upward and diagonal arrows indicate the number of keywords that were not used in the subsequent period, that is, those that were eliminated. Downward and diagonal arrows indicate the keywords newly added in the subsequent period. The horizontal arrows pointing to the right show the percentage of keywords that match or overlap across periods, while the circles represent the keywords used in each period. Figure 7 illustrates the evolution of keywords over different periods.

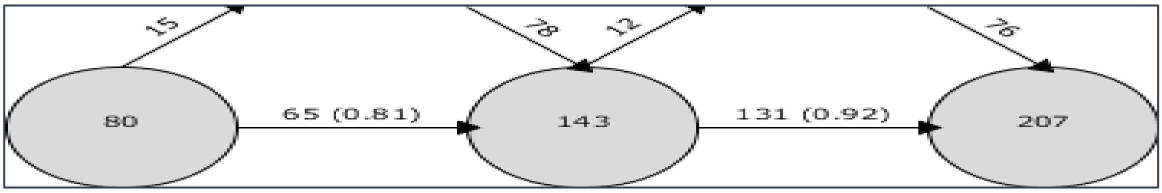

Figure 7. Continuity of keywords between intervals (Period 1: 1992–2012; Period 2: 2013–2018; Period 3: 2019–2024)

As shown in the overlay map in Figure 7, 80 different keywords were identified during the 1992–2012 period. Of these, 65 were retained, while 15 were lost in the subsequent phase. Approximately 81% of the keywords identified in the first period were carried over to the second period. Between 2013 and 2018, 78 new keywords were added, bringing the total to 143. Of these keywords, 12 were removed in the subsequent period, while 131 remained in the next time frame. During the most recent analysis period, 76 additional keywords were added to the research on the subject, bringing the total to 207. The increase in the number of keywords peaked during this period. The gradual emergence of new keywords confirms a significant evolution in the field, indicating that it has advanced considerably and that keyword diversity has increased. The themes associated with each period have been visualized using strategic diagrams.

Period 1 (1992–2012)

Figure 8 presents a strategic diagram showing the quadrants representing the themes of research integrating science education and neuroscience during the 1992–2012 period.

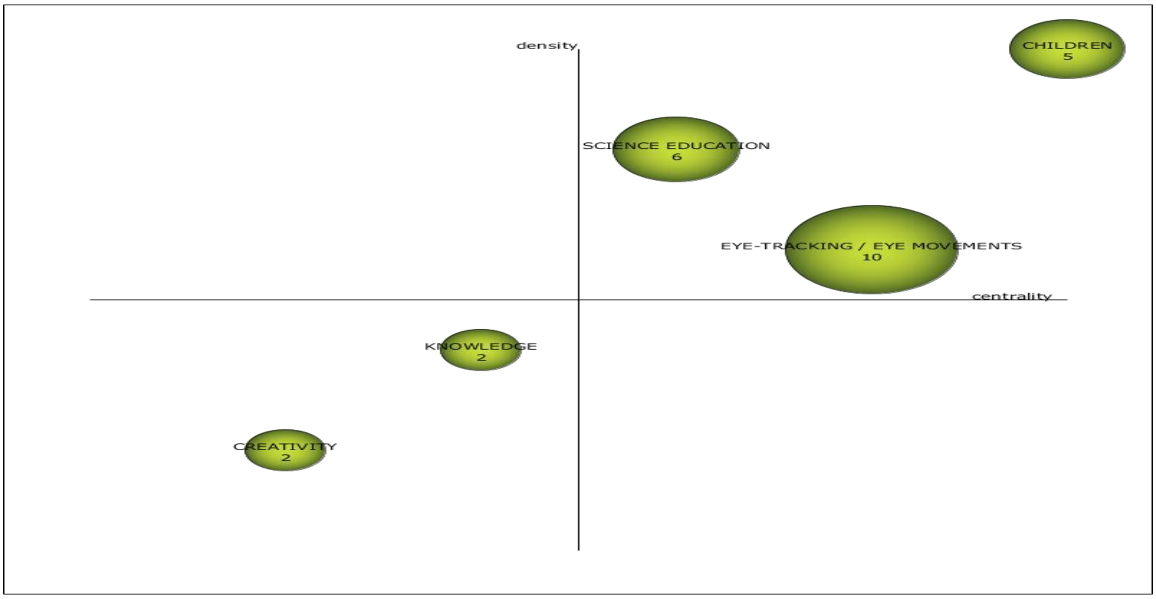

Figure 8. Period 1 (1992–2012) strategic diagram (h-index)

As shown in Figure 8, there are a total of five thematic clusters in the first period. Between 1992 and 2012, the themes of science education, children, and eye tracking/eye movements appear in the first quartile, indicating that these themes were the prominent research focuses of that period. Among these topics, eye tracking and eye movements have emerged as the most popular research topics of the current period. Neuroscience-based approaches have focused particularly on child learning during this period, and analyses of science learning processes have primarily used eye tracking methods. The themes of "knowledge" and "creativity" are located in the lower-left quadrant of the strategic diagram and represent emerging or declining themes. This suggests that academic interest in these themes has waned during the relevant period or that their conceptual frameworks may not yet be sufficiently developed.

Period 2 (2013–2018)

Figure 9 presents a strategic diagram showing the positioning of themes within the quadrant for the 2013–2018 period.

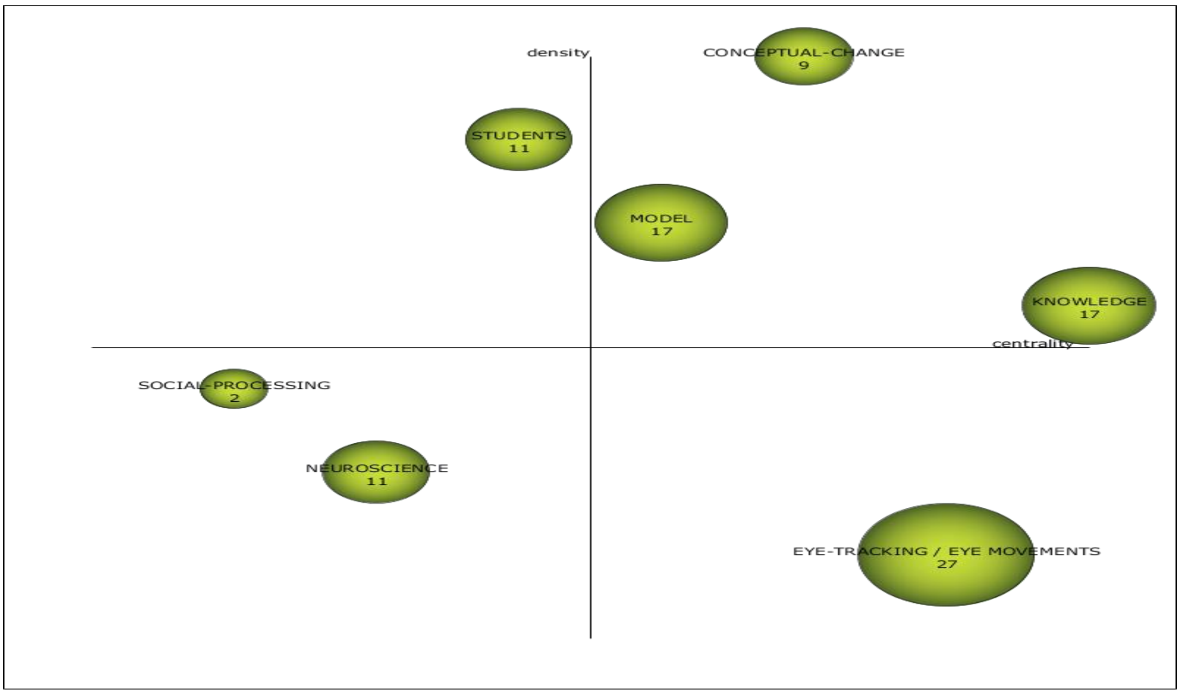

Figure 9. Period 2 (2013–2018) strategic diagram (h-index)

The distribution of themes during the 2013–2018 period shows significant differences compared to the previous period. It is evident that the themes of “knowledge” and “eye tracking/eye movements” continued to be studied during this period. Among these themes, “eye tracking/eye movements” had the highest h-index. In the second phase, the themes of "knowledge" and "conceptual change" were identified as driving themes. In contrast, the "students" theme appears to be a highly developed and isolated theme. The themes of "social processing" and "neuroscience" are associated with emerging or declining themes, those that are losing their significance. Although the theme of eye tracking/eye movements first emerged as a basic and transversal theme, it is now regarded as the sole foundational theme underpinning the field's conceptual basis during this period. It is evident that, during the 2013–2018 period, research integrating science education and neuroscience continued to be structured around eye tracking-based process analyses; that learning increasingly came to be explained through individual cognitive profiles; and that neuroscientific methods were linked to learning constructs such as knowledge construction, theoretical model generation, and conceptual change.

Period 3 (2019–2024)

Figure 10 presents a strategic diagram showing the positioning of the themes for the current phase (2019–2024) within the quadrant.

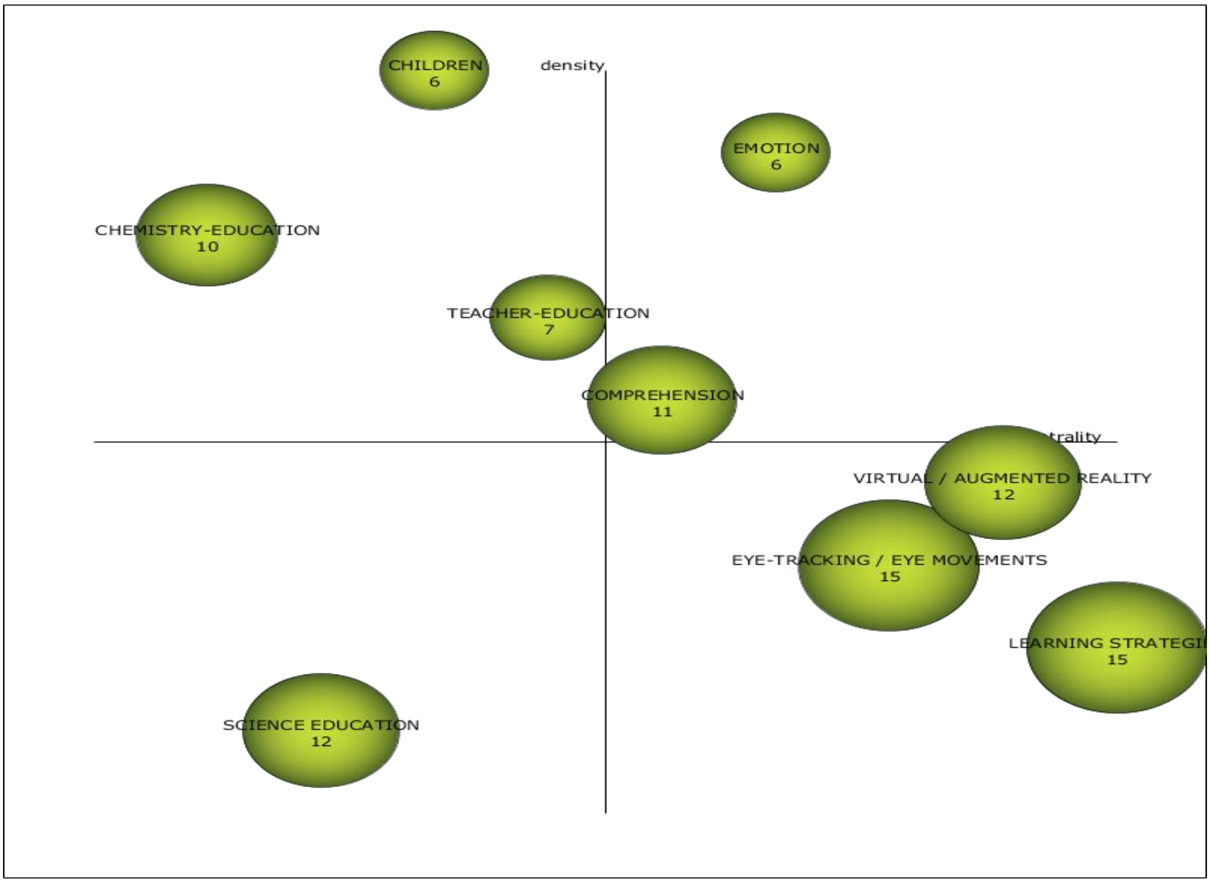

Figure 10. Period 3 (2019–2024) strategic diagram (h-index)

As shown in Figure 10, nine thematic clusters were identified during this period. Among these, the themes of “children,” “science education,” and “eye tracking/eye movements” were revisited. Additionally, there was a marked shift in thematic trends during this period compared to the previous one. While the themes of "emotion" and "comprehension" stand out as central to this period, those of "children," "chemistry education," and "teacher education" fall into the category of highly developed and isolated themes. The theme of "science education" is listed as an emerging or declining theme. Virtual and augmented reality, learning strategies, and eye tracking/eye movements are among the basic and transversal themes in this field, suggesting that further research is needed to advance our understanding of this period. These themes also have the highest h-index values, indicating that recent research in science education has integrated the understanding of learning processes, cognitive and emotional processes, learning strategies, and innovative learning environments and interventions.

Thematic Evolution Analysis

The thematic evolution map presented in Figure 11 illustrates the development of themes addressed in research integrating science education and neuroscience over the periods 1992–2012, 2013–2018, and 2019–2024. When the thematic evolution of terms is examined from a vertical perspective, it can be seen that the themes emerging in each period correspond to the results presented in the thematic diagram. When examined from a horizontal perspective, it is observed that new branches emerge and the number of groups increases over time.

Figure 11. Thematic evolution based on the h-index

Upon examining the map in Figure 11, it can be observed that there are more non-conceptual relationships than conceptual ones, and that new keywords emerge gradually. The "eye tracking/eye movements" theme is present in all three time periods, and there is a conceptual connection among them. This situation demonstrates that eye tracking-based process analyses constitute a significant research focus and a consistent area of inquiry in neuroscience-based research within the field of science education. Another research area is "science education-neuroscience-science education," which strongly represents the research track that integrates science education with neuroscience.

It can be seen that there were a few themes in the first period. While the themes of "eye tracking/eye movements" and "knowledge" continued into the second period, the other three themes evolved into different themes. The "eye tracking/eye movements" theme had a significant relationship with the "conceptual change" theme. A total of seven themes were identified in the second period. Of the seven themes identified for this period, "eye tracking/eye movements" persisted into the third period. In comparison, the remaining six themes were found to have evolved into new themes in the following period. By the final period, it was observed that the capacity for themes to evolve had increased, the total number of themes improved, and nine distinct themes emerged. The themes of "children" and "science education," which emerged in the first period and disappeared in the second, reappeared in the third period. In addition, the themes of "learning strategies," "virtual/augmented reality," "comprehension," "emotion," "chemistry education," and "teacher education" appeared for the first time during this period.

Results of the Content Analysis

Neurocognitive Tools Used in the Studies

The neurocognitive tools used in studies in the field of science education are presented in Figure 12.

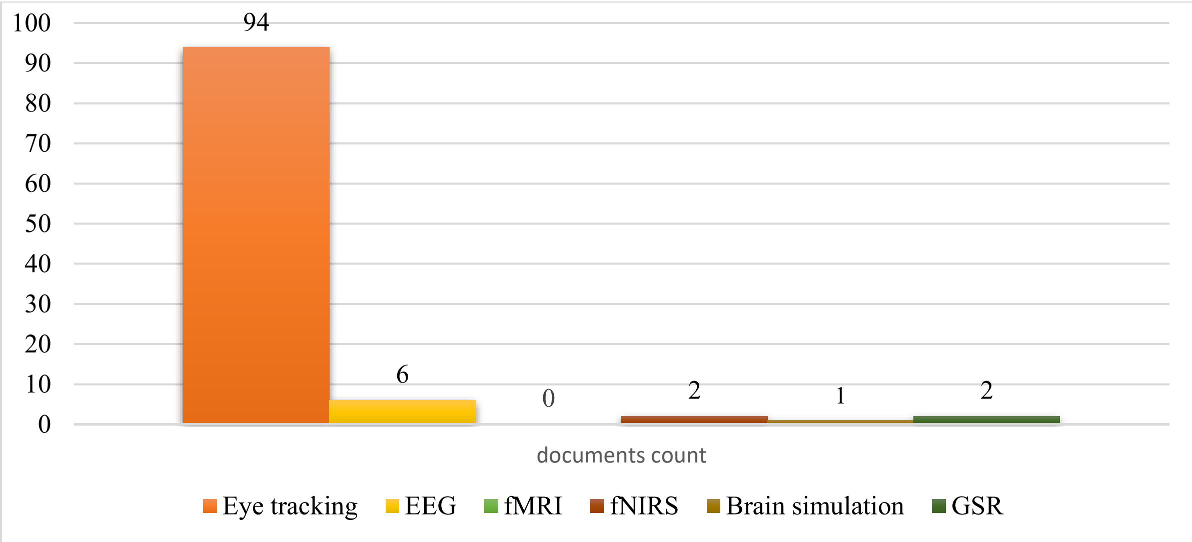

Figure 12. Neurocognitive tools used in research

The distribution of the studies included in our research indicates that the most commonly used tools in neurocognitive research are eye tracking and EEG. It is believed that this preference stems from the fact that these methods are becoming increasingly affordable and are based on reliable methodological foundations. Galvanic Skin Response (GSR) and fNIRS techniques have been used rarely. The brain-simulation technique has been included in only a few studies. Figure 13 shows the number of studies using neurocognitive techniques, including eye tracking, EEG, fNIRS, and GSR.

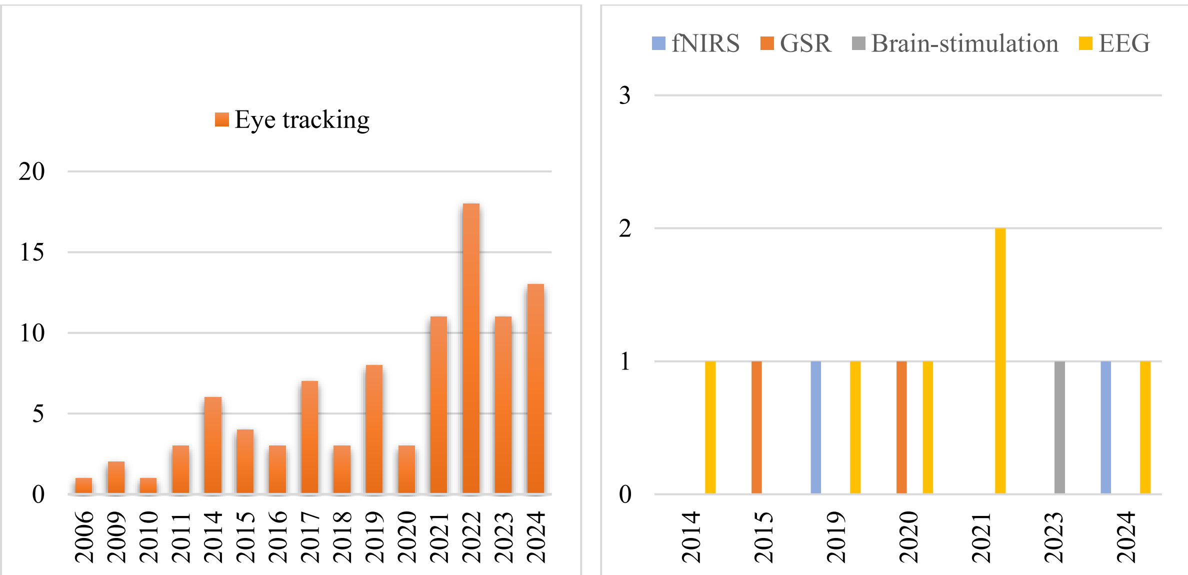

Figure 13. Neurocognitive tools used in the studies and their temporal distribution

The first use of eye tracking technology in research occurred in 2006, and the number of annual publications remained below 10 until 2020. The highest number of publications was recorded in 2022, with 18 publications. This increase reflects the growing importance of eye tracking in science education, its increased accessibility, and greater recognition by researchers. Furthermore, none of the studies reviewed utilized MRI or fMRI. The use of EEG, fNIRS, GSR, and brain stimulation techniques was minimal, and it appears that these tools have been employed primarily in recent years.

Groups of Participants in the Studies

Groups of participants examined in the studies are presented in Figure 14.

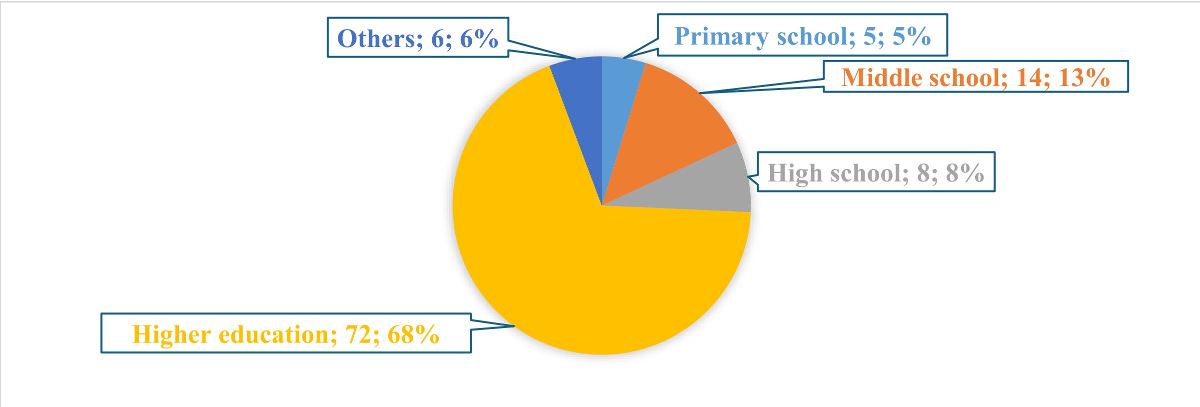

Figure 14. Distribution of studies by groups of participants

Upon examining Figure 14, it is evident that although all participant groups except the preschool period are addressed in the studies, these levels are not treated equally. The university level accounts for the highest percentage at 68% (72), followed by the middle school level at 13% (14). Only 5 studies (5%) focused on elementary school children. In addition, 6 of the studies (6%) focused on more than one group of participants, including teachers, faculty members, and visitors. Figure 15 shows the distribution of studies using various neurocognitive tools by educational level.

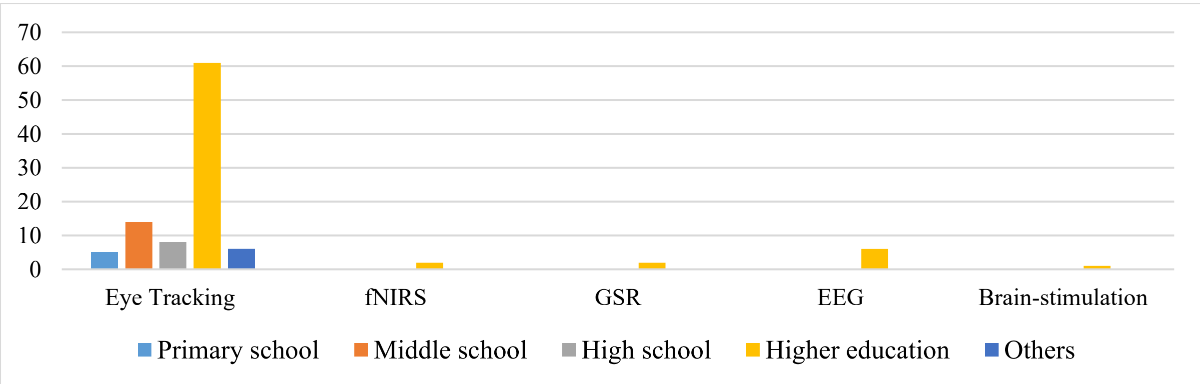

Figure 15. Use of neurocognitive tools at different educational levels

The vast majority of eye tracking studies have been conducted on university students. There are fewer studies using eye tracking with smaller groups, such as middle school students (14 studies), high school students (8 studies), and elementary school students (5 studies). In contrast, it appears that other neurocognitive tools, such as EEG, GSR, brain stimulation, and fNIRS, are not used at all at the elementary, middle, and high school levels, but are limited to the higher education population.

Research Methodology and Sample Size

Statistical information regarding the research methods used in studies integrating science education with neuroscience is presented in Figure 16.

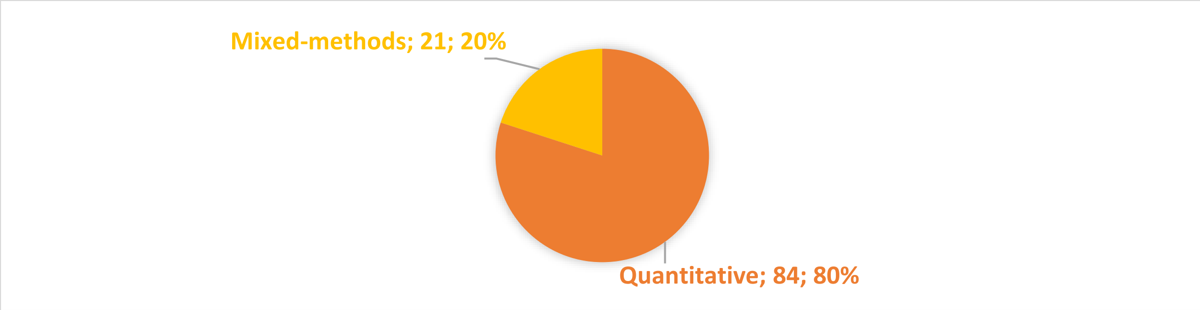

Figure 16. Research methodology

An examination of neuroscience research in science education reveals that these studies are predominantly designed using quantitative research methods. The distribution of sample sizes in articles published within the scope of studies integrating science education and neuroscience is listed in Table 4.

Table 4. Distribution of publications by sample size

Sample size	f
1-10	8
11-30	30
31-50	26
51-70	17
71-90	7
91-110	6
111+	11

As for sample size, neuroscience research in science education is primarily conducted with small to medium samples. It has been found that the most commonly used sample size is 11–30 participants (f = 30). This is followed by the ranges of 31–50 participants (f = 26) and 51–70 participants (f = 17). Studies conducted with larger sample sizes, however, appear to be limited in number.

Conclusion, Discussion, and Recommendations

Bibliometric (288 articles) and content analysis (105 articles) of studies integrating science education and neuroscience reveal that interest in the subject emerged in the early 1990s. The growth of this field was initially slow and steady, but it has experienced rapid growth, particularly in the last decade, and has been shaped by emerging methodological approaches. While research integrating science education and neuroscience appears to have emerged later when compared to research integrating mathematics education and neuroscience (Leikin et al., 2025), there is an observed increasing trend in the number of neuroscience studies in science education. The significant increase in research output can be attributed to advances in neuroimaging techniques and eye tracking technologies, policy support, the growing availability of relevant devices, and the field's increasing interdisciplinary importance.

The geographic distribution of research outputs indicates that the USA and Taiwan are the leading countries with the highest output and citation impact. In a study by Xu et al. (2022) on neuroscience in education, the USA was also identified as the most productive and influential country. Similar results were observed in a recent systematic review of eye tracking in science education; the USA was identified as the leading country in terms of academic productivity (Tóthová & Rusek, 2025). Italy, meanwhile, stands out for its high citation impact in science education and neuroscience research, despite fewer publications. An analysis of international collaboration shows that the USA and Taiwan are closely collaborating, while collaboration networks involving other countries are limited. Therefore, it can be said that fostering scientific communication and more inclusive collaborations among different countries, facilitating the sharing of expertise and infrastructure as well as interaction, and overcoming the theoretical, methodological, and technical challenges that may arise during the application of neuroscience techniques will be of great importance.

Bibliometric findings regarding publication patterns indicate that the "Journal of Chemical Education" and "Computers & Education" are the most productive journals in the field and also have the highest citation counts. However, it has been determined that research integrating neuroscience to examine science learning is not limited to disciplinary journals but is also published in journals focused on educational technology and neuropedagogy.

This indicates that the field exhibits an interdisciplinary structure. In this context, strengthening interdisciplinary approaches to support the development of future research in neuroscience in science education and actively encouraging science education journals to promote such work through special issues and thematic series dedicated to this topic will make significant contributions to enriching the field.

As for the authors, Yu-Cin Jian, Meng-Jung Tsai, and Fang-Ying Yang stand out as the most prolific authors. The author with the most citations is Richard E. Mayer, who has made significant contributions to the field's development. These findings enable researchers in the field to identify potential collaboration partners, establish research communities, make more informed journal selection decisions, and streamline their publication strategies. The co-authorship network of researchers collaborating on studies at the intersection of science education and neuroscience is represented by a limited set of individuals. This indicates that interdisciplinary interaction in this field remains limited to a relatively small group of researchers. To gain a more comprehensive, both theoretical and practical, understanding of neurocognitive research in science education, greater collaboration among researchers in neurocognition and science education is needed. The most frequently cited document is the study by Makransky et al. (2019). Among the most frequently cited studies, there is a notable presence of those that use eye tracking.

With regard to the evolution of keywords, it has been observed that there is a high degree of keyword overlap between adjacent periods. Research fields are not entirely independent of one another during the evolutionary process; rather, they interact. In these developmental processes, eye tracking technology has emerged as a key research tool for analyzing cognitive processes. In addition, an analysis of the author’s keyword network has revealed various trends related to the identified time periods. During the initial period, studies focused largely on the theoretical foundations of neuroscience and its pedagogical integration into science education. Furthermore, eye tracking methods were incorporated into the field of research during this period to study science learning processes. In the second period, thematic diversity increased, and research shifted toward topics such as models, knowledge, and conceptual change. Research during this period indicated that the theme of eye tracking/eye movements remained prominent and emerged as a central theme. Studies conducted during this period integrated neurocognitive data with fundamental issues in science education, including support for conceptual change, correction of misconceptions, knowledge construction, and instructional design models. In the latest phase, the thematic focus has shifted toward teacher education and pedagogical transformation, subject-specific science learning processes, technology-enhanced learning environments such as virtual and augmented reality, the development of more effective learning strategies, the facilitation of students’ understanding of scientific concepts, and the development of new insights into learning processes. In recent years, the themes of emotion and comprehension have emerged as a significant research focus in neuroscience for science education, actively shaping current research agendas.

A content analysis of research integrating science education with neuroscience has also revealed various methodological approaches and the use of different tools. The results indicate that the field is primarily shaped by eye tracking and EEG, with these two technologies occupying a central position, while the adoption of other tools remains limited. Eye tracking research, in particular, reached its peak in 2022. Future research focused on developing methodological approaches that integrate fNIRS, EEG, fMRI, and eye tracking devices may provide valuable insights for more precise analysis and a deeper understanding of students’ cognitive processes, as well as for developing more effective educational strategies grounded in neuroscientific evidence.

This study reveals a striking pattern regarding participant profiles: University students appear to be the most frequently selected group in these studies because they are more easily accessible to researchers. Another possible explanation is that obtaining ethical approval is generally easier for this group. The preference for university students in research is consistent with trends observed in neurocognitive research on mathematics education (Leikin et al., 2025). However, young children and individuals in preschool and elementary school are underrepresented. This limited representation is thought to stem from the technical and organizational challenges associated with conducting research with these age groups. For this reason, there is a need for further research that addresses learning objectives and includes students from different educational levels to gain a more comprehensive understanding of the neurocognitive foundations underlying science learning and to enhance the generalizability of the findings.

In terms of research methodologies, quantitative designs predominated in these studies, and in most identified studies, sample sizes ranged from 1 to 50. This may be attributed to the research context, difficulties in accessing equipment and recruiting volunteer participants, the complexity of using this equipment, and the fact that it can be used with only one participant at a time. This is consistent with the findings of Ulusoy et al. (2025), who noted that the vast majority of studies in the field of neuroeducation were conducted with sample sizes ranging from 0 to 50.

In conclusion, neuroscience research in science education remains an emerging field. As advancements in eye tracking and neuroimaging technologies continue, their potential to reveal cognitive and neural mechanisms is expected to grow. In this regard, if researchers and educators closely monitor these developments and systematically integrate these technologies into science education research extending beyond the laboratory setting to the classroom, this will make significant contributions to the development of science teaching and learning practices and to enhancing ecological validity. Especially in this era of rapid digital transformation, closely monitoring the integration of technologies such as artificial intelligence and digital tools with neurocognitive approaches will play a significant role in shaping the future research agenda for the design and implementation of personalized, adaptive digital learning environments.

While the results of this study offer a comprehensive overview of the intellectual structure, evolution over time, and global research trends in studies that combine science education with neuroscience, certain limitations must be acknowledged. First, the bibliometric dataset was restricted to publications indexed in the WoS database, specifically within the SCI, SSCI, A&HCI, and ESCI categories. Future research could expand the analysis to include additional established databases to provide a comprehensive picture of the field and ensure its representativeness. Second, this study is limited to English-language articles, which may introduce linguistic and geographical biases. Future research could analyze studies published in other languages and across different document types (e.g., conference papers, book chapters, scientific reports). Finally, although the search strategy is based on a comprehensive set of keywords, the scope of the terms used to identify articles may be limited. To address this limitation, future studies could examine a broader range of literature by using different keyword strings and filters.

Scientific Ethics Declaration

* The author declares that the scientific, ethical, and legal responsibility of this article, published in the JESEH journal, belongs to the authors.

* The data used in this study were obtained from secondary bibliographic sources provided by WoS and did not involve any human participants or personal data. Therefore, this study does not require ethical committee approval. The principles of scientific research and publication ethics were strictly adhered to at every stage of the analysis process.

Conflict of Interest

* The author declares that there is no conflict of interest

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