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Science Education in Different Contexts: Regional and Local Differences in The Main Research Trends

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Abstract

This review aimed to understand how trends in science education have changed from 2000 to 2021 and how these patterns are studied in different regions. We investigated science education articles published in Web of Science (WoS) database and grouped them into five regions: North America, Europe, Australia, Asia, and South America & Africa. From 2000 to 2010, there were 2159 published articles, with North America accounting for 51% of these. From 2011 to 2021, the number of publications increased to 7186 articles, with North America accounting for 43% of the articles. From 2000 to 2010, Asia published fewer studies than Australia, but from 2011 to 2021, Asian countries published more. The top journal analysis revealed that local journals and technology related journals were instrumental in non-English speaking countries. The number of common keywords appearing in different regions increased concurrently with the number of studies. Conceptual change and scientific literacy appeared as frequently used keywords in four different regions from 2000 to 2010. On the other hand, teacher education, professional development, scientific literacy, argumentation and nature of science appeared as frequently used keywords in four different regions from 2011 to 2021. Scientific literacy was a common theme across different periods, and the emphasis on inquiry shifted to argumentation. While presenting the changing dynamics across different spans and our review also included evidence that scholars in different countries started to investigate similar ideas in different contexts from 2011 to 2021.

Keywords

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Introduction

Science education review studies continue to highlight the increasing number of publications and how the emphasis areas change over time by examining specific journals. Lin, Lin, and Tsai (2014), Lin, Lin, Potvin, and Tsai (2019) conducted two review studies by building on the work of Tsai and Wen (2005) and Lee, Wu, and Tsai (2009). This review series looked at articles published in three journals between 1998 and 2002, including the International Journal of Science Education, the Journal of Research in Science Teaching, and Science Education. Lin et al. (2019) compared their review findings to earlier time intervals, spanning the years 1998 to 2017. When the studies in these selected journals were examined, six countries were always placed in the top ten in these five-year intervals: the United States, the United Kingdom, Australia, Taiwan, Israel, and Canada. However, Sweden, South Africa, the Netherlands, Germany, Spain, and Türkiye joined these countries at different times. Lin et al. (2019) discovered that the proportion of empirical studies in these journals is increasing. Furthermore, when investigating topics, it was discovered that learning-context had the highest frequency after 2003. While the percentage of studies examining learning-concepts has decreased, it remains one of the top three research topics.

Wang, Chen, Lv, and Xu (2022) conducted a bibliometric review of seven different journals in another review study. Wang et al. (2022) expanded on Lin et al.'s (2019) review by including Research in Science Education, Studies in Science Education, Science & Education, and Journal of Baltic Science Education. According to Wang et al. (2022), in terms of the number of publications, Türkiye has risen to fourth place, trailing only the United States, Australia, and England. Following Türkiye were Canada, Taiwan, Germany, Israel, Sweden, and the People's Republic of China. Wang et al. (2022), like Lin et al. (2019), examined changes in research topics by reviewing studies from 2001 to 2005, 2006 to 2015, and 2016 to 2020. Wang et al. (2022) discovered that from 2001 to 2005, the emphasis was on learning, and from 2006 to 2015, it was on scientific literacy and socio-scientific issues. The emphasis has been on argumentation and science, technology, engineering, and mathematics (STEM) education over the last five years (2016 to 2020). Recently, Tosun (2022) followed a similar approach by including more science journal in the search. Tosun included 14 journals having the following keywords: "physics" or "chemistry" or "biology" and "teaching," or "education" or "learning" or "instruction" and "science". Tosun named these journals science education research journals and reported that STEM, nature of science, assessment and professional development were top keywords in science education journals.

Previous review studies on science education (Lee et al., 2009; Lin et al., 2014; Lin et al., 2019; Tsai & Wen, 2005; Wang et al., 2022) provided an overview by examining studies published in specific journals. These overview studies had a significant potential to inform science education researchers about the field's current status as well as future directions. When rapid globalization is taken into account, however, there is a need for review studies that focus on comparisons across regions and countries. Previous studies investigated country-based differences based on specific journals (e.g. Tosun, 2022). Thus, the first goal of this study is to provide a broader perspective by examining science education studies without having journal constraints.

The second goal is to offer a different perspective to bibliometric studies by examining how trends differ across regions by comparing North America (the United States and Canada), Europe (Türkiye, England, Spain, Germany, Sweden, Israel, the Netherlands, Finland, Greece, Portugal, and Norway), Australia (Australia and New Zealand), Asia (Taiwan, People's Republic of China, South Korea, and Singapore), and South America and Africa (Brazil and South Africa).

Our regional review examines the importance of context in science education. For instance, Gonzalez-Weil et al. (2014) reported that teachers make adaptations in the curriculum for their local settings, and Sanchez Tapia, Krajcik, and Reiser (2018) discussed the importance of cultural adaptations for indigenous students. Departing from these studies, our review study will investigate how regional science education trends are translated into a local context. We reviewed articles published by Turkish scholars during this process. The reason for choosing Türkiye is related to Türkiye's position in previous review studies. Lin et al.'s (2019) study revealed that Türkiye was in the top ten countries at different time intervals, and Wang et al.'s (2022) and Tosun's (2022) review revealed that Türkiye became the leading non-English speaking country in science education literature when looking at the number of publications.

Overall, reports based on analyses of science education journals (e.g. Tosun, 2022; Wang et al., 2022) provided science education researchers with an overview of the field's current state of the literature based on different countries. Previous review studies provided a preliminary framework for analyzing the science education literature, and our study primarily emphasized on the top keywords among the productive countries. When determining these criteria we reviewed previous studies. Song et al. (2021) reviewed diabetes studies from 1980 to 2019, and included keywords that appeared more than 100 times in their analysis. On the other hand, Tosun (2022) included authors that had more 100 citations to examine the top authors. Connected with these studies, we only included countries that published at least 100 articles in Web of Science (WoS) database. In addition, we only emphasized on investigating the connections between top keywords. Finally, we investigated the current state and research trends across regions.

Purpose and Significance of the Research: How do International Trends Translate into a Local Context?

Sözbilir and Kutu (2008) examined 413 studies in the Turkish science education literature. From 1987 to 2008, the researchers presented an early overview of Turkish science education literature. Of the papers in this review, 76% focused on four topics: how to teach different science concepts, analyzing concepts, attitudes, and misconceptions. The remaining topics (for example, teacher education and how to develop teaching materials) were examined in less than 5% of the studies. The first study in science education, according to Sözbilir and Kutu (2008), was conducted in 1987. Initially, 66% of researchers preferred quantitative research methods, and 33% of studies were conducted with undergraduate students.

The findings of Sözbilir and Kutu (2008) are related to the findings of Lee et al. (2009). The top topics in several international journals were examining student learning and conceptions, and these research areas became prominent in Türkiye. Following 2010, there were numerous review articles examining a specific topic in science education. Minner, Levy, and Century (2010) reviewed various inquiry approaches, Cavagnetto (2010) presented the structure and components of argumentation activities, Zohar and Barzilai (2013) discussed instructional strategies for promoting metacognition in students, Li and Tsai (2013) concentrated on game design and use, and Duschl, Maeng, and Sezen (2011) investigated how researchers develop, implement, and assess learning progressions.

Turkish science education studies also shifted to more thematic topics after 2010 and investigated socioscientific issue (SSI) studies (Topçu, Mugaloğlu, & Güven, 2014), pedagogical content knowledge (PCK) studies (Aydin & Boz, 2012), and STEM (science, technology, engineering, and mathematics) or STEAM (science, technology, engineering, arts, and mathematics) education studies (Ormanci, 2020; Yilmaz, Gülgün, Çetinkaya, & Doganay, 2018). These review studies continue to examine local studies and dissertation trends. Aydin and Boz (2012) reviewed 28 dissertations and journal articles on PCK. According to Topçu et al. (2014), the first dissertation on SSIs was published in 2008, and the first article on SSIs was published in 2009. SSIs published 13 dissertations and 11 journal articles between 2008 and 2014 (Topçu et al., 2014). Ormanci (2020) reviewed doctoral dissertations in

STEM education and found that from 2016 to 2019, 30 doctoral dissertations were completed with a focus on STEM or STEAM education. Yilmaz et al. (2018) reported in another review that there were 200 STEM or STEAM education studies in local index (ULAKBIM) published after 2010.

The purpose of this review was to understand the main research trends in science education and how these top trends in science education differ across regions without journal constraints. In addition, the links between main, regional and local trends have the potential to provide researchers with insights for both local and global contexts. This study's research questions were as follows:

- What were the main research trends in science education literature from 2000 to 2021?
- How did the main science education research trends differ across regions?
- How did the regional science education trends translate into a local context?
- What were the top preferred local and regional journals from 2000 to 2021?

Methods

The analysis for this study was divided into two stages: (1) science education research based on regions and (2) science education research in a local context (see Table 1). We began by conducting a search in WoS database. We used a selection criterion to include countries in the sample. We chose countries that had published at least 100 articles by January 2022 and divided them into five regions: North America, Europe, Australia, Asia, and South America & Africa. Countries with more than 100 articles accounted for 84% of the articles in our sample. We reviewed the main trends by examining this data set and used the country information provided in WoS database.

The regional search sought to demonstrate how trends in science education differ across regions by comparing top keywords from 2000 to 2010 and from 2011 to 2021. In the second phase, we investigated studies conducted in Türkiye with the same method. Türkiye was chosen because, as stated in the introduction, it was the leading country among non-English speaking countries.

Table 1. Phases of the Study

Phases of the Study	**Description**
WoS Abstract Search	- Abstract search - More than 11000 articles
Phase One: Science Education Trends in Different Regions	-Select countries published more than 100 articles until January, 2022 -Analyze main trends from 2000 to 2021 -Group countries in five regions -Analyze top keywords from 2000-2010 and 2011-2021 -Analyze top journals
Phase Two: Science Education Trends in a Local Context	-Select the country with the highest number of publications among non-English speaking countries: Türkiye -Analyze top keywords from 2000-2010 and 2011-2021 -Analyze top journals

Selecting Studies for Different Phases

To present the general comparisons in the first phase, we only searched abstracts for keywords. Our search terms were "science education", "science learning" and "science teaching". We searched these keywords in topic section and only included articles published in English. Using these keywords, over 11,000 articles were found under Educational Research. A big majority of these articles (92%) were published after 2000, and countries with more than 100 articles in this search published 84% of the articles based on the information provided by the WoS database. Previously Tosun (2022) applied 100 as a threshold for top authors and Song et al. (2021) used a similar threshold for analyzing top keywords. Connected with these studies, articles were downloaded from countries with more than 100 articles as of January 1, 2022. These countries included the United States (3836 articles), Türkiye (847 articles), Australia (656 articles), England (606 articles), Spain (512 articles), Canada (454 articles), Taiwan (425 articles), Germany (385 articles), Brazil (352 articles), Sweden (270 articles), People's Republic of China (256 articles), Israel (245 articles), the Netherlands (196 articles), South Africa (168 articles), Finland (166 articles), Greece (160 articles), South Korea (138 articles), New Zealand (135 articles), Portugal (121 articles), Singapore (114 articles) and Norway (103 articles). Figure 1 presents the Preferred Reporting Items for Systematic Reviews and Meta-analyses [PRISMA] flowchart created by using the guidelines presented in Moher, Liberati, Tetzlaff, Altman, and The PRISMA Group (2009).

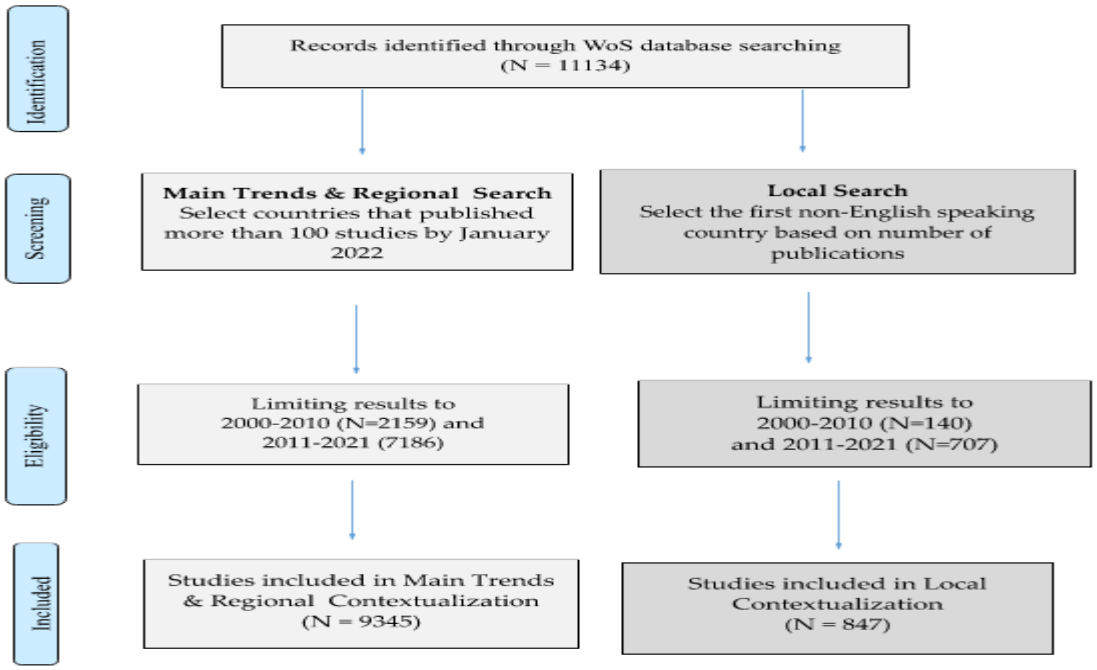

Figure 1. PRISMA flow chart

Countries in our analysis were grouped under five regions: North America (the United States and Canada), Europe (Türkiye, England, Spain, Germany, Sweden, Israel, the Netherlands, Finland, Greece, Portugal and Norway), Australia (Australia and New Zealand), Asia (Taiwan, People's Republic of China, South Korea and Singapore) and South America & Africa (Brazil and South Africa). We included Türkiye and Israel under Europe due their strong collaborations through European research programs (e.g. ERASMUS+, Horizon). Regional search presented the top keywords in these regions from 2000 to 2010 and from 2011 to 2021. All the data were filtered through the WoS database and downloaded based on years and regions (for example Asia 2000-2010, Asia 2011-2021, Europe 2000-2010, Europe 2011-2021). The data for local analysis is also downloaded from the WoS database in a similar way (Türkiye 2000-2010, Türkiye 2011-2021).

Data Analysis

We used VOSviewer software features that displayed keyword co-occurrence and keyword frequency to answer the first and second research questions. According to Zupic and Cater (2015), keyword co-occurrence reveals a field's conceptual structure and themes. The size of the label and the circle around it are determined by the frequency of an item, according to Van Eck and Waltman (2018). The links represent the connections between these circles. As the link strength increases, so does the connection (Van Eck & Waltman, 2018). We chose countries with at least 100 articles in WoS database for our article selection and reviewed only studies published from 2000 to 2021. To answer the first research question, we reported the connections between keywords that appeared in at least 100 articles in our first bibliometric analysis. The first research question examined trends after 2000 for all regions.

We looked at top regional and local keywords for the second and third research questions. To accomplish this goal, we divided the data set into two intervals: 2000 to 2010 and 2011 to 2021. The results were then divided into different regions. We used VOSviewer to determine the most popular keywords. Table 2 and 3 present keywords based on frequency. If two keywords had the same frequency in the final row, we chose the keyword with the stronger link strength. The fourth research question focused on popular regional and local journals. We used information from the WoS database to answer the last research question.

Findings

In this section, first we will present overall trends and then switch to regional and local trends.

What were the Main Research Trends in Science Education Literature from 2000 to 2021?

There were 14160 keywords in the regional data, demonstrating the breadth of the topics explored globally. We chose keywords that appeared more than 100 times, similar to the country selection criteria. There were 63 keywords were grouped into four different clusters (see Figure 2). Among these keywords, three of them appeared more than 1000 times: science education (occurrence=1880, link strength= 4450), science (occurrence=1256, link strength= 3481), knowledge (occurrence=1187, link strength= 4478).

In the red cluster, attitude (occurrence=411, link strength= 1547), achievement (occurrence=443, link strength= 1809) and technology (occurrence=316, link strength= 1168) emerged as central themes. This cluster also included culture, elementary, engagement, equity, experiences, gender, identity, language, mathematics, motivation, participation, pedagogy, perceptions, performance, self-efficacy, and STEM.

Green cluster had science (occurrence=1256, link strength= 3481), science education (occurrence=1880, link strength= 4450), and knowledge (occurrence=1187, link strength= 4478) at the center. Other keywords in this cluster were biology, chemistry, children, conceptual change, construction, design, evolution, explanations, framework, mental models, misconceptions, models, physics, representations, science learning, and thinking.

Blue cluster had inquiry (occurrence=850, link strength= 3182), beliefs (occurrence=493, link strength= 2075) and curriculum (occurrence=396, link strength= 1359) at the center. This cluster also included assessment, conceptions, impact, instruction, nature of science, pedagogical content knowledge, professional development, reform, science teaching, scientific inquiry, teacher education, and views.

Yellow cluster had argumentation (occurrence=395, link strength= 1712) and scientific literacy (occurrence=368, link strength= 1111) at the center. This cluster included context, decision-making, discourse, literacy, perspectives, school science, scientific argumentation, and socioscientific issues.

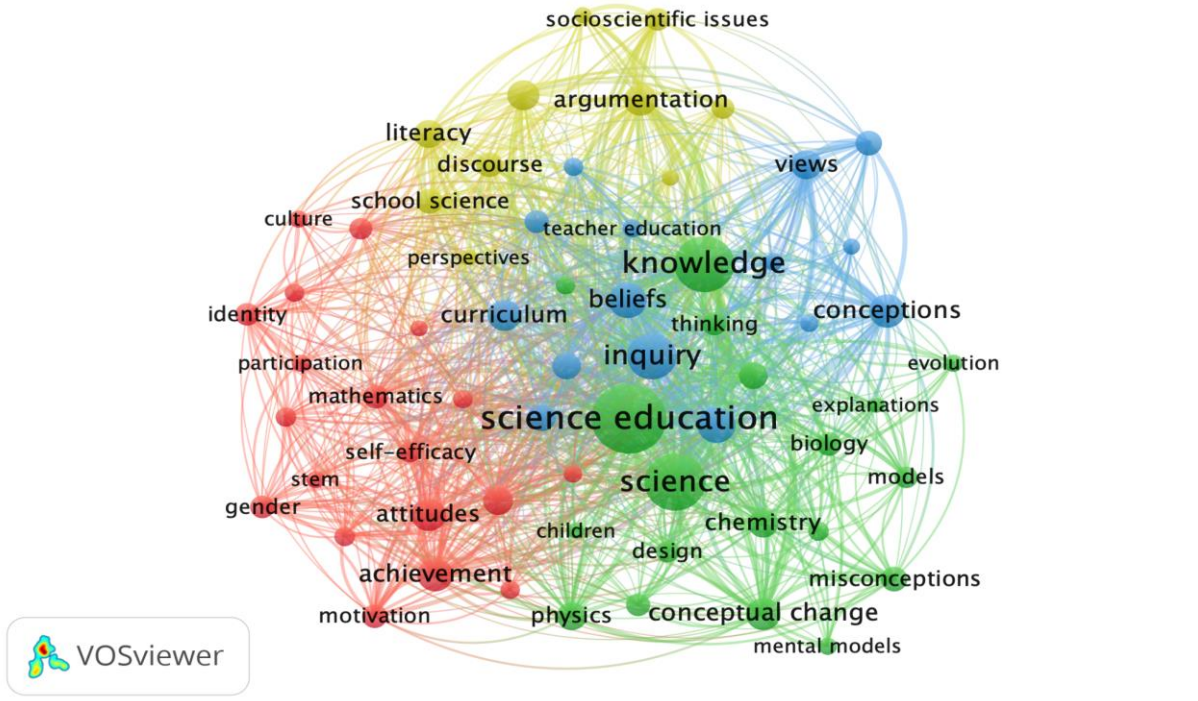

Figure 2. Bibliometric analysis for keywords appearing at least 100 times after 2000

How did the main science education research trends differ across regions?

A review of science education studies in five different regions revealed the top keywords, with science education being the top keyword in all regions in two different time intervals (see Table 2). Since science education was the top keyword in our analysis, we reported 10 more keywords after science education for each region at different time spans. Table 2 displays keywords in the order in which they were placed using the VOSviewer software (Van Eck & Waltman, 2018). Table 2 presents each keyword based on frequency in each region.

Over two time intervals, our results revealed that science learning was the top keyword in Australia and Asia, while science teaching was the top keyword in South Africa and Asia. While conceptual change was the top keyword in Europe from 2000 to 2010, science teaching was the top keyword from 2011 to 2021 in Europe. In both time intervals, professional development was the most frequently used keyword in North America.

During both time intervals, only science education and science teaching emerged in all regions. Science, scientific literacy, and conceptual change were frequently studied in four regions from 2000 to 2010. Even though scientific literacy was still commonly studied in four regions from 2011 to 2021, the emphasis on student learning was increased by focusing on science learning, argumentation, and NOS in four regions. Furthermore, more regions have begun to prioritize teacher development by emphasizing professional development, teacher education, and teacher training keywords from 2011 to 2021.

From 2000 to 2010, only three keywords appeared in four different regions. From 2011 to 2021, the number of keywords appearing in four regions increased to seven keywords. The greatest shift was seen in Europe and Asia. There were five keywords emerging only from Europe from 2000 to 2010 (secondary education, environmental education, gender, computer science education, and argumentation). Six keywords (self-efficacy, game-based learning, collaborative learning, pedagogical issues, teaching & learning strategies, mobile learning) only appeared in Asia from 2011 to 2021. Multiculturalism, indigenous knowledge, history and philosophy of science, and rural education emerged as a top keyword only in South America & Africa. This finding indicates that cultural issues drew the biggest attention from researchers in this region.

Table 2. Top Keywords in Different Regions at Different Intervals

#	**Top 11 Keywords from 2000 to 2010**				
	North America (1115 articles)	**Europe (683 articles)**	**Australia (205 articles)**	**Asia (161 articles)**	**South America & Africa (75 articles)**
1	Science education[5]	Science education[5]	Science education[5]	Science education[5]	Science education[5]
2	Professional development[2]	Conceptual change[4]	Science learning[3]	Science learning[3]	Science teaching[5]
3	Science teaching[5]	Science teaching[5]	Science teaching[5]	Constructivism[3]	Teacher education[1]
4	Inquiry[1]	Scientific literacy[4]	Constructivism[3]	Assessment[3]	Multiculturalism[1]
5	Science[4]	Science[4]	Conceptual change[4]	Science[4]	Discourse analysis[2]
6	Conceptual change[4]	Secondary education[1]	Science[4]	Curriculum[2]	Scientific literacy[4]
7	Scientific literacy[4]	Environmental education[2]	Scientific literacy[4]	Mobile learning[1]	Environmental education[2]
8	Discourse analysis[2]	Gender[1]	Curriculum[2]	Nature of science[1]	Indigenous knowledge[1]
9	Science learning[3]	Constructivism[3]	Pedagogy[1]	Conceptual change[4]	History and philosophy of science[1]
10	Assessment[3]	Computer science education[1]	Assessment[3]	Science teaching[5]	Professional development[2]
11*	Urban education[1]	Argumentation[1]	Teacher development[1]	Internet[1]	Teacher learning[1]
#	**Top 11 Keywords from 2011 to 2021**				
	North America (3093 articles)	**Europe (2710 articles)**	**Australia (564 articles)**	**Asia (721 articles)**	**South America & Africa (439 articles)**
1	Science education[5]	Science education[5]	Science education[5]	Science education[5]	Science education[5]
2	Professional development[4]	Science teaching[5]	Science learning[4]	Science learning[4]	Science teaching[5]
3	Equity[1]	Teacher education[4]	Science[4]	Scientific literacy[4]	Teacher training[1]
4	Science[4]	Science[4]	Science teaching[5]	Self-efficacy[1]	Rural education[1]
5	Teacher education[4]	Nature of science[4]	Scientific literacy[4]	Game-based learning[1]	Environmental education[1]
6	Science learning[4]	Argumentation[4]	Higher education[1]	Collaborative learning[1]	Teacher education[4]
7	Nature of science[4]	Science learning[4]	Nature of Science[4]	Pedagogical issues[1]	Argumentation[4]
8	Computer science education[2]	Professional development[4]	Teacher education[4]	Science teaching[5]	Science[4]
9	STEM[1]	Scientific literacy[4]	Curriculum[1]	Teaching & learning strategies[1]	Nature of science[4]
10	Argumentation[4]	Primary education[1]	Professional development[4]	Mobile learning[1]	Scientific literacy[4]
11*	Science teaching[5]	Computer science education[2]	Socioscientific issues[1]	Argumentation[4]	Professional development[4]

* If there are two keywords with the same frequency, the keyword with more link strength is selected. (1: Keyword appearing in one region, 2: Keywords appearing in two regions, 3: Keywords appearing in three regions, 4: Keywords appearing in four regions, 5: Keywords appearing in five regions)

How did the regional science education trends translate into a local context?

To discuss local trends, we chose the first country after the United States. The number of publications in Türkiye showed an intriguing trend. The first study published by Turkish scholars in our sample was in 2001 (Irzik, 2001) and the number of studies reached to 30 after 2008 in Türkiye. Science, science education, and science teaching appeared as keywords in both intervals, similar to regional data (see Table 3). Furthermore, attitude and NOS were present in both intervals. The shift from conceptual change, misconceptions, constructivism, and achievement to argumentation, self-efficacy, science process skills, and motivation is evident in local analysis. Achievement, attitude, scientific process skills, and motivation emerged as frequently used keywords only in the local analysis.

Table 3. Top Keywords in Turkish Science Education Studies at Different Intervals

#	**Top 11 Keywords from 2000 to 2010**	**Top 11 Keywords from 2011 to 2021**
1	Science education[2]	Science education[2]
2	Science[2]	Science teaching[2]
3	Learning environment[1]	Nature of science[2]
4	Science teaching[2]	Teacher education[1]
5	Conceptual change[1]	Argumentation[1]
6	Misconceptions[1]	Self-efficacy[1]
7	Constructivism[1]	Attitude[2]
8	Achievement[1]	Science process skills[1]
9	Attitude[2]	Science[2]
10	Gender[1]	Motivation[1]
11*	Nature of science[2]	Pre-service teachers[1]

* If there are two keywords with the same frequency, the keyword with more link strength is selected (1: Keywords appearing in one interval; 2: Keywords appearing in two intervals)

What were the top preferred local and regional journals from 2000 to 2021?

When we look at the top ten journals across regions (see Table 4), International Journal of Science Education and Cultural Studies of Science Education appeared in all regions. There were two more journals appearing in four different regions (Research in Science Education, Journal of Research in Science Teaching).

School Science and Mathematics appeared only in North America; Revista Eureka Sobre Ensenanza Y Divulgacion De Las Ciencias, Ensenanza De Las Ciencias and Practice appeared only in Europe; Australian Journal of Teacher Education and Research in Science Technological Education appeared only in Australia; Computers and Education, Eurasia Journal of Mathematics Science and Technology Education and Educational Technology and Society appeared only in Asia; Brazilian Journal of Rural Education, Remea Revista Eletronica Do Mestrado Em Educacao Ambiental, Educar Em Revista, Dialogia, and South African Journal of Education appeared only in South America & Africa. There were multiple journals that only appeared in one region, with the exception of North America. Due to journals published in Spanish or Portuguese, Europe, South America, and had more journals appearing only in these regions.

Table 4. Top Journal for Preferred by Science Education Researchers in Different Regions

	North America		Europe		Australia		Asia		South America & Africa	
#	Journal	NoA*	Journal	NoA*	Journal	NoA*	Journal	NoA*	Journal	NoA*
1	Journal of Research in Science Teaching[4]	393	International Journal of Science Education[5]	350	Research in Science Education[4]	106	International Journal of Science Education[5]	136	Cultural Studies of Science Education[5]	38
2	Cultural Studies of Science Education[5]	374	Research in Science Education[4]	180	International Journal of Science Education[5]	78	International Journal of Science and Mathematics Education[4]	63	International Journal of Science Education[5]	34
3	Science Education[3]	318	Science & Education[3]	130	Cultural Studies of Science Education[5]	60	Journal of Baltic Science Education[2]	43	Science & Education[3]	33
4	International Journal of Science Education[5]	312	Journal of Baltic Science Education[2]	107	Journal of Research in Science Teaching[4]	27	Research in Science Education[4]	41	Brazilian Journal of Rural Education[1]	19
5	Journal of Science Teacher Education[2]	279	Revista Eureka Sobre Ensenanza Y Divulgacion De Las Ciencias[1]	104	Science Education[3]	23	Journal of Science Education and Technology[3]	39	Remea Revista Eletronica Do Mestrado Em Educacao Ambiental[1]	18
6	Journal of Science Education and Technology[3]	192	Cultural Studies of Science Education[5]	101	Australian Journal of Teacher Education[5]	21	Eurasia Journal of Mathematics Science and Technology Education[1]	38	Research in Science Education[4]	18
7	Research in Science Education[4]	169	Journal of Research in Science Teaching[4]	92	International Journal of Science and Mathematics Education[4]	19	Computers & Education[1]	36	Educar Em Revista[1]	16
8	School Science and Mathematics[1]	119	Science Education[3]	88	Journal of Science Teacher Education[2]	13	Educational Technology and Society[5]	26	Dialogia[1]	15
9	International Journal of Science and Mathematics Education[4]	96	Ensenanza De Las Ciencias[1]	85	Journal of Science Education and Technology[3]	12	Journal of Research in Science Teaching[4]	24	South African Journal of Education[1]	14
10	Science & Education[3]	92	International Journal of Science and Mathematics Education[4]	80	Research in Science Technological Education[2]	12	Cultural Studies of Science Education[5]/ Research in Science & Technological Education[2]	23	Americana De Estudos Em Educacao[1]	12

*NoA: Number of Articles; 1: Journals appearing in one region, 2: Journals appearing in two regions, 3: Journals appearing in three regions, 4: Journals appearing in four regions: 5: Journals appearing in five regions

Top journal for Turkish authors was Journal of Baltic Science Education (see Table 5). Similar to the regional trends, there were three journals (Hacettepe University Journal of Education, Education and Science, and Pamukkale University Journal of Education) publishing articles in Turkish and English. Five journals (International Journal of Science Education, Research in Science Education, Eurasia Journal of Mathematics Science and Technology Education, Journal of Baltic Science Education, and Journal of Science Education and Technology) emerged in different regions were also commonly preferred by Turkish researchers.

Table 5. Top 10 Journals for Studies Published by Turkish Scholars

#	Journal	Number of Articles
1	Journal of Baltic Science Education	78
2	Hacettepe University Journal of Education	67
3	Education and Science	46
4	Eurasia Journal of Mathematics Science and Technology Education	35
5	International Journal of Science Education	33
6	Pamukkale University Journal of Education	33
7	Eurasian Journal of Educational Research	32
8	Journal of Science Education and Technology	32
9	Energy Education Science and Technology Part B-Social and Educational Studies	30
10	Research in Science Education	29

Discussion

Investigating how ideas and concepts presented to students has been an important topic for for science education researchers (Rivet & Kracik, 2008). Several studies have focused primarily on understanding how science concepts can be applied in local contexts (Gonzalez-Weil et al., 2014; Sanchez-Tapia et al., 2018), but studies also reported differences among applications (Barab et al., 2009; Bell, Mulvey, & Maeng, 2016). How science concepts are applied can vary based on the context. Thus, the goal of this review was to look at the contexts from a different angle. We divided science education research into five regions (North America, Europe, Australia, Asia, and South America & Africa) by selecting countries with more than 100 articles published in the WoS database by the end of 2021. Our sample contained 2159 articles published between 2000 and 2010, with 51% of the articles published in North America. From 2011 to 2021, the number of publications increased to 7186 articles, with North America accounting for 43 percent of the total. This demonstrates a shifting dynamic in science education research after 2010. From 2000 to 2010, Asia published fewer studies than Australia, but from 2011 to 2021, Asian countries published more.

Our bibliometric analysis of keywords appearing in more than 100 articles from 2000 to 2021 revealed four main themes: (1) attitude, achievement and technology, (2) science, science education, and knowledge (3) argumentation and scientific literacy, (4) inquiry, beliefs and curriculum. We examined the top keywords in two intervals to better understand the trends in science education studies.

From 2000 to 2010, and from 2011 to 2021, we compared 55 keywords across five different regions. The common keywords appearing in four different regions increased as the number of studies increased (from 2159 articles to 7186 articles) during these intervals. This could be evidence that scholars in different countries investigated similar ideas in different contexts from 2011 to 2021. In this section, we discussed how this trajectory differed across regions and how it influenced curriculum updates and research conducted in a local context.

The Emphasis on Attitude, Achievement and Technology

According to Lin et al. (2019), studies examining learning context are on the rise. Lin et al. argued that interest, motivation, or attitudes could all be classified as "Learning-Context." Motivation and attitudes were among the top ten keywords in our local analysis (e.g., Gencer & Çakıroğlu, 2007; Taş, Apaydın, & Çetinkaya, 2011), but not in the regional analysis. In Asia, only self-efficacy came out on top (e.g., Chen, Wang, & Lin, 2015; Looi et al., 2014). According to Lin et al. (2019), learning context is a broad category that includes learner characteristics, learning environment, and higher-order thinking.

Lin et al. (2019) also added that studies investigating educational technology in science education are on the decline. Connected with this result, there were no technology-related keywords in Australia, South America, or Africa. The emphasis on educational technology, on the other hand, is growing in Asia, and the top cited articles (Hwang, Tsai, & Yang, 2008; Wu, Lee, Chang, & Liang, 2013) in our search from Asia focused on educational technology. There were also four Asian journals that focused specifically on technology education (Journal of Science Education and Technology, Eurasia Journal of Mathematics Science and Technology Education, Computers & Education, Educational Technology and Society). This could be used to demonstrate how top themes influence authors' journal selection.

In addition, computer science education emerged as a top keyword only in North America and Europe. Computer science education opens up new opportunities for science educators. Jayathirtha and Kafai (2020) examined electronic textile studies that sought to integrate microcontrollers, sensors, and actuators. In an editorial, Hubwieser, Armoni, and Giannakos (2015) presented several case studies and emphasized that many questions about computer science education remain unanswered. The prominence of computer science education could be related to specific teachers working on the subject in secondary education in the United States (Yadav, Gretter, Hambrusch, & Sands, 2016). However, it is important to underline that scholars continue to discuss computer science education as an emerging field of research in the United States (Yadav et al., 2016) and Europe (Nijenhuis-Voogt, Meijer, & Barendsen, 2018).

It is important to note that achievement remains a central theme for science education studies. Santos and Prudente (2021) explored the effect on academic achievement in virtual laboratories, in serious games (Riopel et al., 2019) and in augmented reality applications (Kalemkuş & Kalemkuş, 2022). All of these studies confirm the connection between science education, technology and achievement. Our cluster analysis also included math and STEM education. STEM education emerged as a top keyword only in North America. Our results confirm recent meta analysis stating science education becoming the leading discipline in STEM education and there is a scarcity of research in mathematics education (Delen & Şen, 2023).

Finally, equity and gender emerged as top keywords in bibliometric analysis, but equity emerged as a top keyword only in North America, and the top cited articles in this area are conducted in the United States (e.g., Calabrese Barton & Tan, 2010; Calabrese Barton et al., 2013). Recent reports in the United States is also debating how to promote equity in science education (National Academies of Sciences, Engineering, and Medicine, 2022a, 2022b).

The Emphasis on Knowledge, Conception, and Misconceptions

In our regional analysis conceptual change was a top keyword from 2000 to 2010. Connected with this result, Lin et al. (2019) reported a decrease in studies examining learning and conceptions. There could be a decline in recent years, but our results provide evidence that knowledge related keywords were frequently studied in science education. But the knowledge investigated in different studies may vary based on the context. For instance, Hannigan, Wickman, Ferguson, Prain, and Tytler (2022) explored students knowledge on Australian endangered animals, and Gnesdilow and Puntambekar (2021) investigated students' understanding of physcis concepts. In another study, Larkin, Carletta, and Evans (2022) created a longitudinal study to understand how one physics teachers'

conceptions and knowledge evolve in a ten-year span. In addition, misconception studies also focused on knowledge from a different perspective. Potvin, Masson, Lafortune, and Cyr (2015) focused on buoyancy for secondary school students, Andersson and Gullberg (2014) emphasized on how one teacher's conception about density may have an impact in early childhood education.

In addition to conceptual change and constructivism was another top keywords from 2000 to 2010. This could be connected to the local analysis results. In 2005, the science and technology curriculum was revised and the constructivist learning approach was introduced to the science education practices in Türkiye (Ministry of National Education [MoNE], 2005a). Constructivist approach gives emphasis on students' construction of knowledge in a meaningful manner by connecting newly learned knowledge and concepts with earlier learning experiences. It also prioritizes the importance of using a conceptual change approach if students have misconceptions. Connected with these ideas, misconceptions was a top keyword in our local analysis from 2000 to 2010.

The Emphasis on Argumentation and Scientific Literacy

Research on argumentation remained as an important theme in the last two decades (e.g., Driver, Newton, & Osborne, 2000; Zohar & Nemet, 2002) along with its emphasis in science curriculum across the world as well as in Türkiye (e.g., Australian Curriculum, Assessment and Reporting Authority [ACARA, 2009]; MoNE, 2005b). Argumentation encourages students to be involved in classroom discussion by using scientific evidence and data along with their critical thinking skills (Osborne, Erduran, & Simon, 2004). A number of science researchers have been investigated development of students' argumentation skills and how they used these skills to learn science concepts, discuss socioscientific issues (Evagorou & Osborne, 2013; Sampson & Clark, 2008; Topçu, Sadler, & Yılmaz-Tüzün, 2010). Effective implementation of argumentation in science classrooms have been achieved through use of discussion as a teaching method. During implementation of discussion interactions between students and teachers in classroom discourse have been investigated heavily by researchers (Mortimer & Scott, 2003; Soysal & Yilmaz-Tüzün, 2021). All these practices could be linked with the theme.

According to our bibliometric and regional analysis, scientific literacy was another important theme for science education researchers. The American Association for the Advancement of Science (AAAS) has launched Project 2061 to assist all Americans in becoming scientifically literate (AAAS, 1993). According to the Science Education in Europe report, scientific literacy is a goal of "good science education" (Forsthuber, Motiejunaite, & de Almeida Coutinho, 2011, p. 68). The emphasis on scientific literacy was a central theme in bibliometric and regional keyword analysis from 2000 to 2021.

Scientific literacy and argumentation cluster also had links with decision-making, discourse, literacy, perspectives, school science, scientific argumentation, and socioscientific issues. This cluster highlighted the influence of curriculum changes realized during the last ten years on science education research in the local context. When the top keywords found in this study are considered between 2011 to 2021, we might see the similar trends between keywords and this cluster. Scientific literacy has been accepted as the main goal of science curriculum since 2005. NOS, socioscientific issues, and sustainable development have been included in science curriculum with the revisions made in 2013 (MoNE, 2013). The revisions in 2018 emphasized inquiry-based learning as the primary teaching method. Along with this teaching method argumentation, project-based learning, problem-based learning, and cooperative learning strategies were included as teaching learning strategies and methods into the science curriculum (MoNE, 2018). Scientific literacy is considered as gaining knowledge, skills and values to better understand scientific concepts (Sadler & Zeidler, 2009). Thus, by focusing on this main goal stated in Turkish curricula, science education researchers in Türkiye studied development of scientific literacy along with other important ideas. Scientific literacy is crucial for raising scientifically literate students, who have the ability to make informed decisions regarding science-related societal issues such as genetically modified foods, nuclear energy etc. With this aim teaching and learning socioscientific issues became an important aspect of the science curricula. Turkish curriculum updates in 2013 showed similarities with the practices handled in the United States (21st Century Science Project Team, 2003), Europe (Sweden, Lpf 94, 1994) and Asia (Indonesia: Nida, Mustikasari, & Eilks, 2021).

The Emphasis on Inquiry, Beliefs and Curriculum

Shymansky, Hedges, and Woodworth (1990) labeled scientific curricula developed after 1955 as "inquiry-oriented" (p. 131) and curriculum updates were influenced by changing themes in science education trends over the last two decades. For example, Osborne and Dillon (2008) stated that European countries need to update the science education curriculum. Later, according to the European Science Education report (Forsthuber et al., 2011), many European countries updated their curricula between 2005 and 2011. The National Science Education Standards (NSES) in the United States of America were replaced by the Next Generation Science Standards in 2013 (NGSS). The National Science Education Standards (NSES) placed a premium on inquiry learning, scientific literacy, and conceptual understanding. These were the most commonly used keywords in our review of studies published between 2000 and 2010. Unlike the NSES, the NGSS prioritized cross-cutting concepts, STEM disciplines, the nature of science, and argumentation. These topics were observed as research topics between 2011 and 2021, connected to this curriculum change. Another country, South Africa, is updating its curriculum with a focus on indigenous knowledge, NOS, and argumentation (Erduran & Msimanga, 2014). As a result, this could be a reason to observe indigenous knowledge only in this region. Scholars continue to learn how to design effective professional development sessions in science education in this changing landscape (Hubers, Endedijk, & Van Veen, 2020). Connected with this continuously changing environment, examining teacher beliefs became an important topic for science education studies (Christian, Kelly, & Bugallo, 2021; Nouri, Saberi, McComas, & Mohammadi, 2021).

According to our bibliometric and regional keyword analysis, teacher education and professional development became an important theme in all regions from 2011 to 2021. This result is connected to other review studies. Xu, Williams, Gu, and Zhang (2020), for example, examined studies published in the International Journal of Technology and Design Education from 2000 to 2018. According to Xu et al. (2020), elementary teacher education is emerging as a central idea. Tosun (2022) reported teacher education as an important theme in science education journals.

Our local analysis also found a strong emphasis on teacher education, but it also highlights another interesting result. Pre-service teachers emerged as a central keyword in local keyword analysis, alongside teacher education. When we look at previous review studies, pre-service teachers were reported as an important participant group. Kanadli (2019), for example, reviewed qualitative STEM education studies conducted in Türkiye. Kanadli stated that the studies included in the review had 699 participants. Teachers and teacher candidates (464 pre-service teachers and 31 in-service teachers) made up 71% of the participants in qualitative STEM education studies (Kanadli, 2019). Teacher education emerged as a central keyword in our study's bibliometric and frequency analysis. Yildirim, Calik, and Ozmen (2016) conducted another study in which they reviewed dissertations and articles in local and international indexes. According to Yildirim et al. (2016), there were 200 studies discussing science process skills, with more than half (n=108) of these studies focusing on developing students' science process skills. Middle school students (n=67) were the most frequently chosen participant group in science process skills studies. There were 63 studies involving pre-service teachers and 15 studies involving in-service teachers (Yildirim et al., 2016). Aydın and Boz (2012) reported that 23 of the 28 PCK studies were conducted with pre-service teachers. These various review studies demonstrate how pre-service teachers became an important participant group for Turkish science education research.

Conclusions and Limitations

After reviewing the science education literature from 1990 to 2007, Chang, Chang, and Tseng (2010) concluded that Turkish scholars' productivity was among the top ten when compared to 83 countries. This is an intriguing result because 2004, in our analysis, was the first year that Turkish scholars published multiple studies in the WoS database. When we search for publications in the WoS database after 2000, Turkish scholars took the lead in non-English speaking countries for the number of publications in science education.

The number of studies in science education has gradually increased over the last decade. While the United States continues to lead in terms of publications, the proportion of studies from North America is decreasing. According to the journal analysis, local journals play an important role in this shift. When we look at local studies, there were at least two local journals in the top ten in each region, and there were three Turkish science education journals. Future studies can investigate how different countries contribute to top science education studies as the number of science education studies grows. Tosun (2022) reported that the International Journal of Science Education, Journal of Research in Science Teaching, and Science Education are the journals that publish more than other science education journals. In addition, Lin et al. (2019) stated that three English-speaking countries (the United States, the United Kingdom, and Australia) were in the top five from 2013 to 2017 in these journals. In our review, 393 publications by North American authors were published in the Journal of Research in Science Teaching. However, there were only 143 publications by researchers from Europe, Asia, and Australia in the same journal. Furthermore, environmental education emerged as a top keyword in South America & Africa. This could be linked to regional environmental education journals (e.g. Remea Revista Eletronica Do Mestrado Em Educacao Ambiental). The number of regional journals increased in Türkiye, South Africa and America. Journals publishing in two languages (e.g. Spanish and English, Turkish and English) became top journals. These results could be employed as proof that there are inconsistencies in the authorship at journals with high impact factor.

While the number of studies increased from 2011 to 2021, there were more common keywords across regions. Connected with the global push for curriculum updates, teacher education and professional development became central themes. Emphasis on inquiry shifted to argumentation. On the other hand, equity emerged as a top keyword in North America, environmental education emerged as a top keyword in South America & Africa. Science process skills was a top keyword only in the local analysis. We hope that our preliminary findings will serve as a baseline for future research into the effects of curriculum updates implemented in various countries. It is important to note that we did not conduct a systematic review and only looked at the top keywords as reported by the authors. We also acknowledge that local studies provide numerous examples, and our analysis of science education trends was based solely on a search in the WoS database.

Previous review studies examined specific journals to present trends. Our study focused particularly on the most popular keywords among the most productive nations to add a new dimension to previous review studies. Similar patterns were found with other review studies. However, there is a need to understand how science education differs across regions and countries. Despite the fact that the number of common keywords continues to grow, our regional analysis did not reveal any affective keywords in many regions.

It is also important to underline that similar to other studies our search was also limited to specific keywords and expanding the number of search terms would be critical for future studies. We would like to add that the results may vary across institutions and the numbers can change as articles in recent years are assigned to issues.

References

21st Century Science Project Team. (2003). 21st century science—A new flexible model for GCSE science. *School Science Review, 85*(310), 27-34**.**

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy: A Project 2061 report.* New York: Oxford University Press.

Andersson, K., & Gullberg, A. (2014). What is science in preschool and what do teachers have to know to empower children?. *Cultural Studies of Science Education, 9*, 275-296.

Australian Curriculum, Assessment and Reporting Authority. (2009). Australian Curriculum, Assessment and Reporting Authority: Annual Report 2008-2009. Retrieved from https://docs.acara.edu.au/resources/ACARA_AnnualReport_08-09.pdf

Aydin, S., & Boz, Y. (2012). Review of studies related to pedagogical contentknowledge in the context of science teacher education: Turkish case. *Educational Sciences: Theory and Practice*, *12*(1), 497-505.

Barab, S. A., Scott, B., Siyahhan, S., Goldstone, R., Ingram-Goble, A., Zuiker, S. J., & Warren, S. (2009). Transformational play as a curricular scaffold: Using videogames to support science education. *Journal of Science Education and Technology, 18*(4), 305-320.

Bell, R. L., Mulvey, B. K., & Maeng, J. L. (2016). Outcomes of nature of science instruction along a context continuum: Preservice secondary science teachers' conceptions and instructional intentions. *International Journal of Science Education, 38*(3), 493-520.

Calabrese Barton, A., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences, 19*(2), 187-229.

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Educational Research Journal, 50*(1), 37-75.

Cavagnetto, A. R. (2010). Argument to foster scientific literacy: A review of argument interventions in K-12 science contexts. *Review of Educational Research, 80*(3), 336-371.

Chang, Y. H., Chang, C. Y., & Tseng, Y. H. (2010). Trends of science education research: An automatic content analysis. *Journal of Science Education and Technology*, *19*, 315-331.

Chen, C. H., Wang, K. C., & Lin, Y. H. (2015). The comparison of solitary and collaborative modes of game-based learning on students' science learning and motivation. *Journal of Educational Technology & Society, 18*(2), 237-248.

Christian, K. B., Kelly, A. M., & Bugallo, M. F. (2021). NGSS-based teacher professional development to implement engineering practices in STEM instruction. *International Journal of STEM Education, 8,* 1-18.

Delen, I., & Şen, S. (2023). Effect of design-based learning on achievement in K-12 education: A meta-analysis. *Journal of Research in Science Teaching, 60*(2), 330-356.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287-312.

Duschl, R., Maeng, S., & Sezen, A. (2011). Learning progressions and teaching sequences: A review and analysis. *Studies in Science Education, 47*(2), 123-182.

Erduran, S., & Msimanga, A. (2014). Science curriculum reform in South Africa: Lessons for professional development from research on argumentation in science education. *Education as Change, 18*(sup1), S33-S46.

Evagorou, M., & Osborne, J. (2013). Exploring young students' collaborative argumentation within a socioscientific issue. *Journal of Research in Science Teaching, 50*, 209-237. doi:10.1002/tea.2107

Forsthuber, B., Motiejunaite, A., & de Almeida Coutinho, A. S. (2011). *Science education in Europe: National policies, practices and research.* Brussels: Education, Audiovisual and Culture Executive Agency, European Commission.

Gencer, A. S., & Çakıroğlu, J. (2007). Turkish preservice science teachers' efficacy beliefs regarding science teaching and their beliefs about classroom management. *Teaching and Teacher Education, 23*(5), 664-675.

Gnesdilow, D., & Puntambekar, S. (2021). Comparing middle school students' science explanations during physical and virtual laboratories. *Journal of Science Education and Technology*, 31, 191-202.

Gonzalez-Weil, C., Merino-Rubilar, C., Ahumada, G., Arenas, A., Salinas, V., & Bravo, P. (2014). The local territory as a resource for learning science: A proposal for the design of teaching-learning sequences in science education. *Procedia-Social and Behavioral Sciences, 116*, 4199-4204.

Hannigan, S., Wickman, P. O., Ferguson, J. P., Prain, V., & Tytler, R. (2022). The role of aesthetics in learning science in an art-science lesson. *International Journal of Science Education, 44*(5), 797-814.

Hubers, M. D., Endedijk, M. D., & Van Veen, K. (2020). Effective characteristics of professional development programs for science and technology education. *Professional Development in Education, 48*(5), 827-846.

Hubwieser, P., Armoni, M., & Giannakos, M. N. (2015). How to implement rigorous computer science education in K-12 schools? Some answers and many questions. *ACM Transactions on Computing Education (TOCE), 15*(2), 1-12.

Hwang, G. J., Tsai, C. C., & Yang, S. J. (2008). Criteria, strategies and research issues of context-aware ubiquitous learning. *Journal of Educational Technology & Society, 11*(2), 81-91.

Irzik, G. (2001). Universalism, multiculturalism, and science education. *Science Education, 85*(1), 71-73.

Jayathirtha, G., & Kafai, Y. B. (2020). Interactive stitch sampler: A synthesis of a decade of research on using electronic textiles to answer the who, where, how, and what for K12 computer science education. *ACM Transactions on Computing Education (TOCE), 20*(4), 1-29.

Kalemkuş, J., & Kalemkuş, F. (2022). Effect of the use of augmented reality applications on academic achievement of student in science education: Meta analysis review. *Interactive Learning Environments, 31*(9), 6017-6034.

Kanadli, S. (2019). A meta-summary of qualitative findings about STEM education. *International Journal of Instruction, 12*(1), 959-976.

Larkin, D. B., Carletta, L., & Evans, S. (2022). A longitudinal investigation of changing conceptions about teaching science and pedagogical implications of student diversity. *Science Education, 106*(2), 335-363.

Lee, M.-H., Wu, Y.-T., & Tsai, C.-C. (2009). Research trends in science education from 2003 to 2007: A content analysis of publications in selected journals. *International Journal of Science Education, 31*(15), 1999-2020.

Li, M. C., & Tsai, C. C. (2013). Game-based learning in science education: A review of relevant research. *Journal of Science Education and Technology, 22*(6), 877-898.

Lin, T. C., Lin, T. J., & Tsai, C. C. (2014). Research trends in science education from 2008 to 2012: A systematic content analysis of publications in selected journals. *International Journal of Science Education, 36*(8), 1346-1372.

Lin, T. J., Lin, T. C., Potvin, P., & Tsai, C. C. (2019). Research trends in science education from 2013 to 2017: A systematic content analysis of publications in selected journals. *International Journal of Science Education, 41*(3), 367-387.

Looi, C. K., Sun, D., Wu, L., Seow, P., Chia, G., Wong, L. H., ... & Norris, C. (2014). Implementing mobile learning curricula in a grade level: Empirical study of learning effectiveness at scale. *Computers & Education, 77*, 101-115.

Lpf 94. (1994). Curriculum for the non-compulsory school system, Lpf 94. Sweden: Skolverket.

Ministry of National Education. (2005a). *Elementary science and technology curriculum for grades 4 and 5.* Ankara: MoNE Publishing.

Ministry of National Education. (2005b). *Elementary science and technology curriculum for grades 6 to 8.* Ankara: MoNE Publishing.

Ministry of National Education. (2013). *Science education curriculum for grades 3 to 8.* Ankara: MoNE Publishing.

Ministry of National Education. (2018). *Science education curriculum for grades 3 to 8.* Ankara: MoNE Publishing.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474-496.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G. ve The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA. *Physical Therapy, 89*(9), 873-880.

Mortimer, E., & Scott, P. (2003). *Meaning making in secondary science classrooms.* Maidenhead, England: Open University Press.

National Academies of Sciences, Engineering, and Medicine. (2022a). *A Vision and Roadmap for Education Statistics.* Washington, DC: The National Academies Press.

National Academies of Sciences, Engineering, and Medicine. (2022b). *The future of education research at IES: Advancing an equity-oriented science.* Washington, DC: The National Academies Press.

Nida, S., Mustikasari, V. R., & Eilks, I. (2021). Indonesian pre-service science teachers' views on socio-scientific issues-based science learning. *EURASIA Journal of Mathematics, Science and Technology Education, 17*(1), 19-32.

Nijenhuis-Voogt, J., Meijer, P. C., & Barendsen, E. (2018). *Context-based teaching and learning of fundamental computer science concepts: exploring teachers' ideas*. Paper presented of the 13th Workshop in Primary and Secondary Computing Education, ACM, Potsdam Germany. doi:10.1145/3265757.3265772

Nouri, N., Saberi, M., McComas, W. F., & Mohammadi, M. (2021). Proposed teacher competencies to support effective nature of science instruction: A meta-synthesis of the literature. *Journal of Science Teacher Education*, *32*(6), 601-624.

Ormanci, U. (2020). Thematic content analysis of doctoral theses in STEM education: Turkey context. *Journal of Turkish Science Education, 17*(1), 126-146.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13). London: The Nuffield Foundation.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020.

Potvin, P., Masson, S., Lafortune, S., & Cyr, G. (2015). Persistence of the intuitive conception that heavier objects sink more: A reaction time study with different levels of interference. *International Journal of Science and Mathematics Education*, *13*, 21-43.

Riopel, M., Nenciovici, L., Potvin, P., Chastenay, P., Charland, P., Sarrasin, J. B., & Masson, S. (2019). Impact of serious games on science learning achievement compared with more conventional instruction: An overview and a meta-analysis. *Studies in Science Education, 55*(2), 169-214.

Rivet, A. E., & Krajcik, J. S. (2008). Contextualizing instruction: Leveraging students' prior knowledge and experiences to foster understanding of middle school science. *Journal of Research in Science Teaching, 45*(1), 79-100.

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching, 46*(8), 909-921.

Sampson, V., & Clark, D. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education, 92*(3), 447-472.

Sanchez Tapia, I., Krajcik, J., & Reiser, B. (2018). "We do not know what is the real story anymore": Curricular contextualization principles that support indigenous students in understanding natural selection. *Journal of Research in Science Teaching, 55*(3), 348-376.

Santos, M. L., & Prudente, M. (2021). Effectiveness of virtual laboratories in science education: A meta-analysis. *International Journal of Information and Education Technology, 12*(2), 150-156.

Shymansky, J. A., Hedges, L. V., & Woodworth, G. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's on student performance. *Journal of Research in Science Teaching, 27*(2), 127-144.

Song, Y., Ma, P., Gao, Y., Xiao, P., Xu, L., & Liu, H. (2021). A bibliometrics analysis of metformin development from 1980 to 2019. *Frontiers in Pharmacology, 12,* 645810.

Soysal, Y., & Yilmaz Tüzün, Ö., (2021). Relationships between teacher discursive moves and middle school students' cognitive contributions to science concepts. *Research in Science Education, 51*, 325-367.

Sözbilir, M., & Kutu, H. (2008). Development and current status of science education research in Turkey. *Essays in Education, 24*(1), 3.

Taş, E., Apaydın, Z., & Çetinkaya, M. (2011). Research of efficacy of web supported science and technology material developed with respect to constructivist approach. *Energy Education Science and Technology Part B: Social and Educational Studies, 3*(4), 455-468.

Topçu, M. S., Mugaloğlu, E. Z., & Güven, D. (2014). Socioscientific ıssues in science education: The case of Turkey. *Educational Sciences: Theory and Practice, 14*(6), 2340-2348.

Topçu, M. S., Sadler, T. D., & Yılmaz-Tüzün, O. (2010). Preservice science teachers' informal reasoning about socioscientific issues: The influence of issue context. *International Journal of Science Education*, *32*(18), 2475-2495.

Tosun, C. (2022). Analysis of the last 40 years of science education research via bibliometric methods. *Science & Education,* 1-30.

Tsai, C. -C., & Wen, L. M. C. (2005). Research and trends in science education from 1998 to 2002: A content analysis of publication in selected journals. *International Journal of Science Education, 27,* 3-14.

Van Eck, N. J., & Waltman, L. (2018). *Manual for VOSviewer version 1.6. 8. CWTS Meaningful Metrics.* Hollanda: Universiteit Leiden.

Wang, S., Chen, Y., Lv, X., & Xu, J. (2022). Hot topics and frontier evolution of science education research: A bibliometric mapping from 2001 to 2020. *Science & Education, 32,* 845-869.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education, 62*, 41-49.

Xu, M., Williams, P. J., Gu, J., & Zhang, H. (2020). Hotspots and trends of technology education in the International Journal of Technology and Design Education: 2000-2018. *International Journal of Technology and Design Education, 30*(2), 207-224.

Yadav, A., Gretter, S., Hambrusch, S., & Sands, P. (2016). Expanding computer science education in schools: Understanding teacher experiences and challenges. *Computer Science Education*, *26*(4), 235-254.

Yildirim, M., Calik, M., & Ozmen, H. (2016). A meta-synthesis of Turkish studies in science process skills. *International Journal of Environmental and Science Education, 11*(14), 6518-6539.

Yilmaz, A., Gülgün, C., Çetinkaya, M., & Doganay, K. (2018). Initiatives and new trends towards STEM education in Turkey. *Journal of Education and Training Studies, 6,* 1-10.

Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. *Studies in Science Education, 49*(2), 121-169.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, *39*(1), 35-62.

Zupic, I., & Cater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, *18*(3), 429-472.