Bibliometric Analysis of Inquiry-Based Science Research during 2000-2021

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Abstract
The aim of this research is to explore the research trends of inquiry-based science (IBS) articles in the Web of Science database during 2000-2021. The bibliometric method was used in the research. A total of 662 IBS education articles were included in the study, out of 1389 IBS publications covering all fields published in Web of Science during 2000-2021. Citation and co-citation analysis were applied using VOSviewer software. The data obtained from this analysis are presented with tables, graphs, and bibliometric maps. According to the results, there is an increase in the number of IBS publications or citations in the recent years. The most cited keywords are teacher development, professional development, primary school, science achievement, and PISA. The most cited countries are the USA, Germany, and France. It has recently been determined that there is a trend towards sustainability education, local perspectives, technology, and interdisciplinary integration in IBS studies. The results were discussed with previous studies in the literature and some suggestions were made for future research. This research, which photographs inquired-based science studies published over the last two decades, may be useful to science education experts and curriculum evaluators.

Keywords: Inquiry-based Science, Bibliometric Analysis, Articles

Introduction

The following questions have become critical and urgent in today's world of uncertainty and change. How will the pandemic's negative effects in areas such as education, psychology, medicine, engineering, economics, and social fields be mitigated? How will global issues like health crises, war, food scarcity, and economic crises be addressed? In a world where the disparities between people are widening, how will humanity find salvation and prosperity? Against these issues, effective problem solvers, functional system builders, communication professionals, and collaborators, as well as interdisciplinary high-level knowledge producers, are urgently and imperatively required. The main goal in the digital age is to train strong future predictors, technology producers, and qualified citizens in the creation of appropriate technology, resources, and innovations. To achieve the desired results, sustainability-oriented policies have been proposed (Annan-Diab & Molinari, 2017; Sjöström et al., 2016), and the principle of Science for All and the Science, Technology, and Society Movement (American Association for the Advancement of Science, 1990) have been maintained, to expand societies with scientifically literate citizens for life (Queiruga-Dios et al., 2020). Equipping modern societies that are adapting to a new world order with scientifically literate citizens has been recognized as an essential value (Bell, 2016; Windschitl et al., 2008; Jeong et al., 2021). In this regard, the concept of scientific literacy, which aims to promote critical thinking and social participation, has been recognized as an important and necessary issue (Anderson, 2002; Bybee et al., 2009; Osborne, 2012).

Scientific literacy is the root of many literacy terms, including digital, communication, and media literacy (Park et al., 2021), information literacy

(Flierl & Maybee, 2020), and critical literacy (Johansson & Stenlund, 2021). Scientific literacy research in education, on the other hand, continues to be developed with various visions (Jeong et al., 2021; Sjöström et al., 2017). Such visions involve Pipeline Science, Preparing Future Scientists, and Critical Global Citizenship, as well as a vision of Science for All. Whether visions are transformed, restructured, or integrated, inquiry-based teaching is proposed as a means of developing scientific literacy based on student experience (Minner et al., 2010). Individuals can develop an understanding of the nature of science as well as their science process skills through inquiry-based teaching (Constantinou et al., 2018). Inquiry-based teaching with these elements is one of the most described goals for quality science education and scientific literacy instruction (Bybee & McCrae, 2011; Abd-El-Khalick & Lederman, 2000). Inquiry-based science (IBS) education is still useful for 21st-century education reform and professional science education (Song & Wen, 2018; Chu et al., 2021; Dahn et al., 2021).

What is IBS?

Different concepts are used in the literature, such as "inquiry-based teaching, inquiry-based learning, inquiry-based instruction, inquiry-based science instruction, inquiry-based science teaching" and no common concept has been reached. When the IBS definitions are examined, it becomes clear that this concept is closely related to concepts such as "connecting with process-oriented science, learning by discovery, an important part of meaningful learning, the application of constructivist elements, active learning, student research, scientific practices" (Gajic et al., 2021; García-Carmona, 2020; Minner et al., 2010). According to these concepts, IBS teaching is a multidimensional term that includes understanding, internalizing, exploring information, developing scientific process skills, and communicating with society, and it is linked to various methods, techniques, and strategies, including student-centered pedagogies.

As stated in important documents such as the National Research Council (2000) developing inquiry skills and understanding the nature of science are critical components of high-quality science education (Osborn, 2012). Cairns & Areepattamamil (2019) defined IBS as learning strategies that include various methods related to scientific processes and practices, as well as various types of pedagogy related to modern teaching practices. Five fundamental characteristics of inquiry-based teaching are i) scientifically oriented questions that will engage students, ii) evidence gathered about these questions, iii) explanations based on the evidence, iv) evaluation of alternative explanations, v) communication of proposed explanations and justification (Olson & Loucks-Hoursley, 2000). According to Minner et al. (2010), an important aspect of IBS teaching is that it allows students to engage in scientific research and design while also developing their science process skills. Constantinou et al. (2018) assessed IBS teaching and IBS learning within the context of IBS education. Figure 1 depicts the multidimensional structure of IBS learning and teaching concepts.

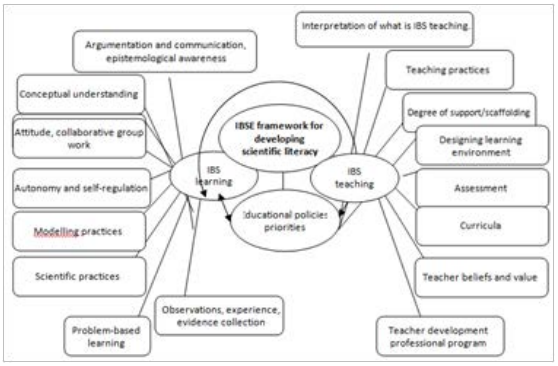

Figure 1 The Main Features of IBS Education (Constantinou et al., 2018, p. 8)

The purpose of IBS teaching is to use the student's knowledge acquisition process and problem-solving skills to search for information in life and develop skills and attitudes that will allow this information to be internalized (Wilder & Shuttleworth, 2005). IBS teaching should move away from passive observation of phenomena and traditional teaching of science-related laws, principles, and theory and toward a student-centered, active science approach in which students develop research and inquiry-based minds (Anderson, 2002). It entails students debating how to formulate questions, collect and

analyse data, and evaluate evidence (Hmelo-Silver et al., 2007). Furtak et al. (2012) determined the inquiry domains of experimental and quasi-experimental studies on IBS teaching with procedural, conceptual, epistemic, and social dimensions. Furtak et al. (2012, p.309) revealed scientific procedures such as asking scientifically oriented questions, designing experiments, and recording data in the procedural dimension. The epistemic dimension constitutes the processes of developing an understanding of the nature of science, drawing evidence-based conclusions, producing theory, and reviewing it. The conceptual dimension refers to students' making use of previous knowledge, making connections, revealing their ideas/mental models, and providing conceptually oriented feedback. In the social dimension, it is evident that students discuss, share, and collaborate on scientific ideas (Furtak et al., 2012). Furtak et al. (2012, p. 321) states that it is difficult to define and characterize reform-oriented science teaching practices.

IBS emphasizes noncognitive aspects of learning; it integrates the conceptual, epistemic, and social dimensions of scientific practice (Duschl, 2008). Good inquiry-based teaching is founded on authentic inquiry. The authentic inquiry has the potential to increase students' intrinsic motivation to meet basic psychological needs (Ryan & Deci, 2000). Its practices emerge from the development of models/ theories that explain some aspects of the natural world and the discussion of their dependability and validity (Osborne et al., 2013). There are four strategies for IBS teaching. Confirmatory inquiry, which includes traditional laboratory practices, entails students validating scientific principles through activities with predictable outcomes (Bell et al., 2005). Structured inquiry is the use of the teacher's question and the process by students. The guided inquiry includes applications that allow students to use the teacher's question and their processes (Bunterm et al., 2014). The highest level of inquiry, open inquiry, allows students to develop questions about research and design processes and practice self-directed learning (Sadeh & Zion, 2009). According to Schwartz et al. (2004), the best strategy for teaching through inquiry is open inquiry followed by guided inquiry.

Many studies have been conducted to investigate the relationship between IBS and different variables such as scientific achievement, attitude, scientific process skills, and critical thinking (Chi et al., 2021; Adimoto & Klieme, 2020; Cairns & Areepattamamil, 2019; Marshall & Horton, 2011; Ku et al., 2014). Cairns and Areepattamamil (2019, p.16) discovered a significant negative relationship between IBS teaching and science achievement and explained it as cognitive overload caused by the high level of skills and knowledge required to acquire the inquiry process. One of the limitations of this study, which analysis PISA data, is the inability to collect data on the types of inquiries students make. Adimoto & Klieme (2020) examined the relationship of IBS to learning outcomes for different countries by selecting nationally representative samples of 15-year-old students from the ten highest and ten lowest-performing regions in PISA 2015. They discovered, using some assumptions and data, that the positive relationship between guided inquiry and achievement was weaker in regions where the guided inquiry was more student-centered (measured using more items reflecting student-centered research activities) (Adimoto & Klieme, 2020, p.17). Experiments have shown that IBS teaching improves students' cognitive and affective characteristics, as well as their critical thinking abilities (Koksal & Berberoglu, 2014; Ku et al., 2014). Recently, IBS teaching with Prediction-Observation-Explanation (Zhao et al., 2021), improvisation (Dahn et al., 2021), virtual reality (Lai et al., 2022), and digital practice (de Jong et al., 2021; Song & Wen, 2018), some methods and techniques seem to be combined. In addition, the relationships between IBS and variables such as learning, attitude, achievement, and interest are still being investigated (Salchegger et al., 2021; Chi et al., 2021; Stender et al., 2018; Kang & Keinonen, 2018). Table 1 summarizes the findings of a few recent IBS studies.

Table 1 The Aims and Results of Recent Studies on IBS

Authors (Year)	Aims	Results
Lai et al. (2022)	To examine the effect of an inquiry-based (IB) virtual reality science laboratory	Students using desktop virtual reality had the highest test scores among the three groups.
Dahn et al. (2021)	To examine classroom interactions of the IB improvisation model in a primary school science lesson.	Instructional improvisation enables students to engage in science and is a beneficial model.
Jong et al. (2021)	To examine teacher practices of digital IB teaching (an online lab called Go-Lab)	Teachers are eager to create personal learning material with Go-Lab inquiry apps and share products with their teacher communities.
Salchegger et al. (2021)	To reveal whether Waldorf students' attitude-achievement can be explained by high-level IBS teaching.	Attending a type of school with a high level of IBS has a positive effect on attitudinal outcomes (enjoyment and interest in science) but no significant effects on science achievement.
Chi et al. (2021)	To investigate the role of teacher feedback in moderating the relationships between IBS practices and students' science-related attitudes and beliefs.	IBS applications have significant positive associations with students' interest in and enjoyment of science and science self-efficacy.
Kotulakova (2021)	To identify teachers' beliefs before a private IBS education	Teachers make students curious, active, independent researchers and thinkers. Teachers believe they are providers of an encouraging environment for collaboration.
Zhao et al. (2021)	To examine the effects of a prediction-observation-explanation (POE) and IBS integration on concept achievement and scientific epistemological beliefs.	The combined use of the POE method and application of IBS increases epistemological beliefs and conceptual achievement.
Oliver et al. (2021)	To detect the effectiveness of IBS instruction through a comparative analysis of six countries using PISA 2015	Students in the six countries who reported a high frequency of inquiry strategies in the classroom had consistently lower levels of scientific literacy.
Cairns (2019)	To investigate the discrete effects of IB instructional practices that described the PISA 2015 construct IBI	Some inquiry practices demonstrated a significant, linear, positive relationship to science achievement.
Fitzgerald et al. (2019)	To explore the attitudes of positively inclined early-adopter teachers toward the implementation of IB pedagogies.	Excessive time constraints at all scales, scarcity of shared professional development experiences, and lack of good models and meaning for IB teaching are significant barriers identified.
Song and Wen (2018)	To examine the integration of the BYOD (Bring Your Own Device) technology model into IB pedagogical practices in primary schools.	BYOD apps could enhance their science knowledge without regard to time and place, as well as gain a greater sense of ownership in their learning.

Stender et al. (2018)	To reveal the effect of an IB activity on students' conceptual learning outcomes in physics.	Cognitive skills do not have a direct effect on students' content knowledge learning outcomes.
Kang and Keinonen (2018)	To investigate the effect of student-centered approaches in PISA data on students' interests and achievements.	Guided IB learning positively affects students' interest and success in science.

Gajic et al (2021) investigated methodological and theoretical approaches in inquiry-based learning studies in natural sciences education. The methodologies were found to have a heterogeneous distribution in the systematic review study, and the observation was neglected. Using the meta-analysis method, Furtak et al. (2012) examined 37 experimental and quasi-experimental studies on IBS teaching published between 1996 and 2006. In this study, studies involving teacher-led activities had an average effect size that was approximately.40 larger than student-led conditions. However, no study was found examining the research trends of the IBS studies, which is a well-established and well-known concept (Aditomo & Klieme, 2020; Luera & Otto, 2005; National Research Council, 2000), in the years 2000-2021. Photographing trends in IBS studies published in the last two decades and presenting current literature on this topic, this research will be a useful resource for science education researchers, science educators, and curriculum evaluators.

The research questions (RQ) for IBS studies in the Web of Science (WoS) database between 2000 and 2021 are as follows:

- RQ1: What are the most-cited publication years and keywords?
- RQ2: What are the most cited authors, countries, organizations, and journals?

Methods

In this study, the bibliometric method was used to identify consistent and standardized indicators of IBS studies. Although bibliometric methods are quantitative in nature, they are used to explain qualitative characteristics (Wallin, 2005). In terms of scientific quality management, bibliometric studies benefit experts and stakeholders.

Selection and Analysis of Publications

Bibliometrics analysis techniques were used to map IBS-related scientific publications indexed in Clarivate Analytics' WoS. The publications were gathered using the following search strategy:

ts: "inquired based" (title) AND "learning" (topic) OR "education" (topic) OR "science" (topic) OR "science teaching" (topic) OR "science instruction" (topic) OR "inquired based science teaching" (topic) OR "inquired science instruction" (topic)

Refined by: WoS categories: Education and Educational Research. Not Publications years: 2022 or 1990, 1991, 1992...1999.

Document types: Articles. Indexes: Social Sciences Citation Index (SSCI), Emerging Sources Citation Index (ESCI) Book Citation Index – Social Sciences & Humanities (BKCI-SSH), Science Citation Index Expanded (SCI-EXPANDED), Book Citation Index – Science (BKCI-S), Arts & Humanities Citation Index (A&HCI), Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH).

1389 IBS publications were reached in all fields in the WoS database (February 2022). These publications were selected according to some criteria in terms of a research area, publication year, and document type. Article selection criteria and publication numbers are shown in Figure 1. The IBS publication criteria selected for the research are as follows; i) Education and Educational Research category, ii) Timespan: 2000-2021, iii) articles as document type. As can be seen in Figure 1, a total of 662 educational articles selected according to these criteria were included in the study.

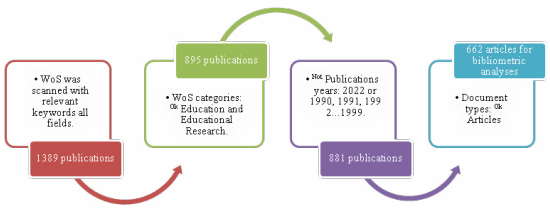

Figure 1 Article Selection Process

The full records of the selected 622 articles have been made ready for bibliometric analysis. The language of these articles is English (f=634), Spanish (f=14), Turkish (f=6), Czech (f=2), Bulgarian (f=1), Chinese (f=1), Dutch (f=1), Japanese (f=1), Russian (f=1), and Welsh (f=1). The data were analyzed with the citation and co-citation analyses in the VOSviewer Software Program (Van Eck & Waltman, 2010). The data from the program was presented with tables, graphs, and bibliometric maps.

Findings

Year-wise Distribution of Publications

The distribution of IBS publications by year is shown in Figure 2. Accordingly, most of the publications were published in 2020 (f=83, Citation=1370), Aside from 2020, the years with the most publications were 2019 (f=71, Citation=1326), 2015 (f=61, Citation=615), and 2014 (f=58, Citation=598). The highest number of citations was received in 2021 (f=54, Citation=1443).

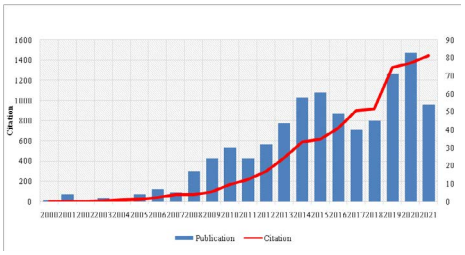

Figure 2 Year-wise Distribution of IBS Publications

The Most Cited Keywords

The most cited keywords in IBS publications were identified using co-occurrence analysis. The keyword option's minimum number of occurrences is set to 1. The results of the analysis yielded 150 keywords. The first six most cited keywords are "inquired-based science teaching (f=10)", "inquired-based teaching (f=6)", "inquiry (f=6)", "inquired-based science education (f=4)", "inquired-based learning (f=3)", "inquired based science instruction (f=3)". The other most cited keywords are "teacher development (f=3)", "professional development (f=4)", "primary school (f=3)", "science achievement (f=3)", and "PISA (f=3)". Figure 3 shows a map of the most cited keywords in IBS publications.

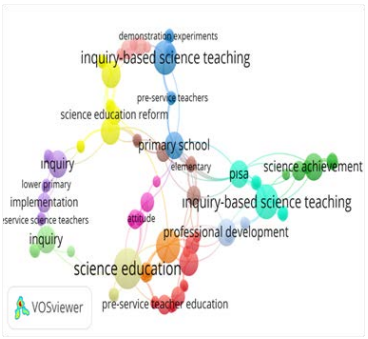

Figure 3 The Most Cited Keywords in IBS Publications

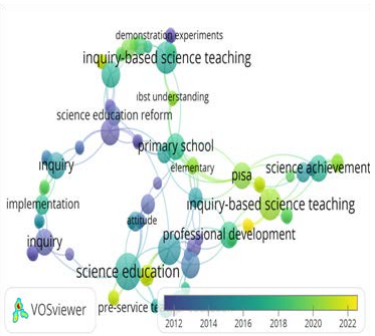

Figure 4 The Most Cited Keywords in IBS Publications by Year

Figure 4 shows the most cited keywords in IBS articles by year. In recent IBS publications, the terms of "learning environment", "preservice teachers", "teacher beliefs", "cooperative learning", "empowerment evaluation", "hierarchical linear modeling", "models and modeling", "interaction rituals", and "PISA" have become popular.

The Most Cited Authors

Citation analyses were used to identify the authors with the most citations. Figures 4 and 5 show the most cited authors/by years. As a result, the following authors are the most cited, Minner (Documents=1, Citations=605), Levy (Documents=1, Citations=605), Century (Documents=1, Citations=605), Furtak (Documents=1, Citations=349), Seidel (Documents=1, Citations=349). Table 2 depicts the most-cited authors, citations, and papers.

Table 2 The Most-Cited Authors, Citations, and Papers

Papers	TC*	ACY**
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 year 1984 to 2002. *Journal of Research in Science Teaching*, 47(4), 474–496.	605	46.92
Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research*, 82(3), 300–329.	349	32.82
Artigue, M., & Blomhøj, M. (2013). Conceptualizing inquiry-based education in mathematics. *ZDM Mathematics Education*, 45, 797–810.	98	9.8
Areepattamannil, S. (2012). Effects of inquiry-based science instruction on science achievement and interest in science: Evidence from Qatar. *Journal of Educational Research*, 105(2), 134-146.	90	3.82
Cairns, D., & Areepattamannil, S. (2019). Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries. *Research in Science Education*, 49, 1-23.	49	12.5

*TC: Total Citation, **ACY: Average Citation per Year

Figures 6 and 8 show the bibliographic coupling authors/by years.

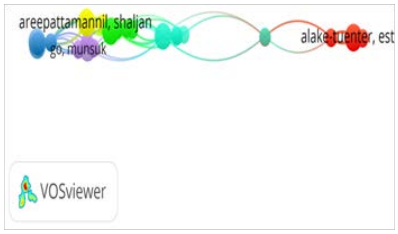

Figure 5 The Most Cited Authors

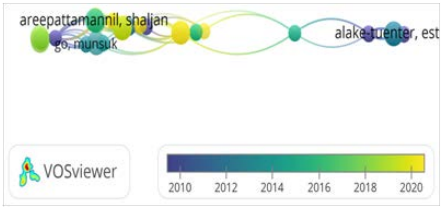

Figure 6 The Most Cited Authors by Year

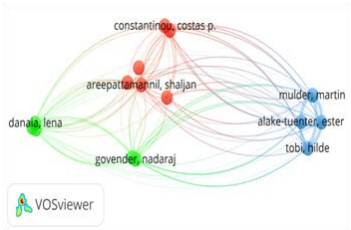

Figure 7 The Bibliographic Coupling Authors

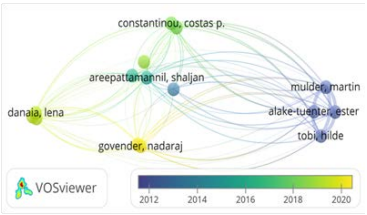

Figure 8 The Bibliographic Coupling Authors by Year

The most cited authors were subjected to a co-citation analysis. According to the findings of the analysis, the most cited authors are National Research Council (Citation=48), Crawford (Citation=20), Windschitl (Citation=16), Anderson (Citation=15), and Furtak (Citation=14). Figure 9 shows the map that was created.

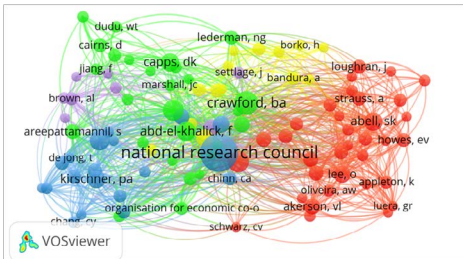

Figure 9 The Most Cited Authors (Co-citation Analysis)

The Most Cited Countries

The most cited countries were determined through citation and bibliographic coupling analysis. The number of source documents in the analysis was

set to 1, and the minimum number of citations for each country was set to 1. Table 3 shows the top eight countries ranked by document and citation of publications

Table 3 Top Eight Countries Ranked by Document and Citation of Publications

Country	Documents	Citations	Country	Documents	Citations
USA	16	1170	U. Arab Emirates	2	52
Germany	3	375	Netherlands	2	42
France	1	98	Singapore	1	41
Denmark	1	98	Australia	5	32

Figures 10 and 12 depict the bibliometric maps of the most cited countries.

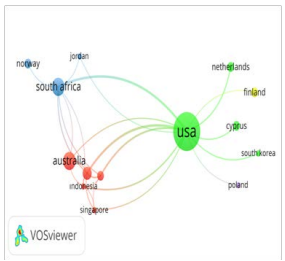

Figure 10 The Countries with the Most Citations

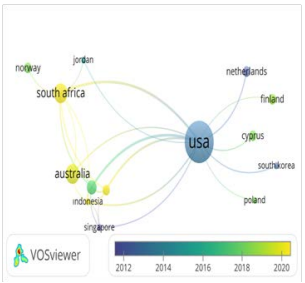

Figure 11 The Countries with the Most Citations by Year

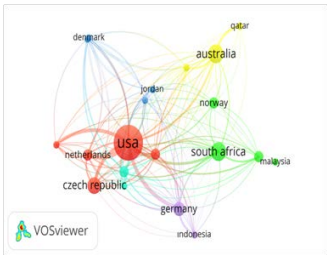

Figure 12 The Bibliographic Coupling Authors

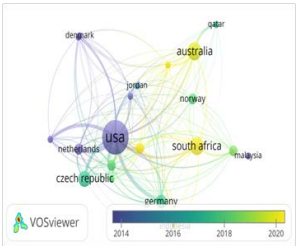

Figure 13 The Bibliographic Coupling Authors by Year

According to Tables 10 and 12, America is the most cited country. In recently, the most cited countries are South Africa, Australia and Indonesia in IBS publications.

The Most Cited Organizations

The minimum number of documents for an organization was set to 1 and the minimum number of citations was set to 1 as well. Figures 14 and 15 depict the bibliometric maps of the most cited organizations (citation and bibliographic coupling). University of Chicago (Citations=1, Documents=605), the Education Development Center (Citations=1, Document=605), the Technical University of Munich (Citations=2, Document=354) and University of Colorado (Citations=1, Document=349) are the most cited organizations. Figures 16 and 17 show the bibliographic coupling organizations/by years.

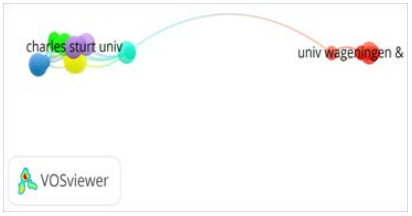

Figure 14 Organizations with the Most Citations

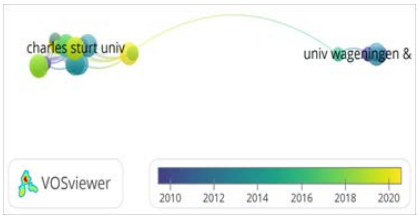

Figure 15 Organizations with the Most Citations by Year

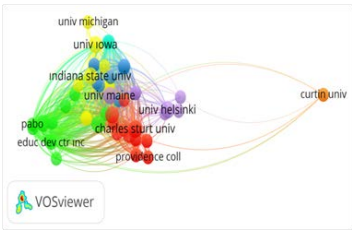

Figure 16 The Bibliographic Coupling Organizations

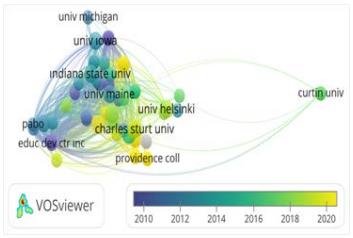

Figure 17 The Bibliographic Coupling Organizations by Year

According to Figure 17, the bibliographic coupling organizations were the University of Michigan, University of Iowa, Education Development Center Inc., Indiana State University, and the University of Maine before 2018. In recent years, the bibliographic coupling organizations were Charles Sturt University, Providence College, and the University of Helsinki.

The Most Cited Journals

The minimum number of the source options was set at 5 to perform co-citation analysis, and bibliometric maps were created for 938 sources. Figure 17 depicts the most cited journals in IBS publications. Accordingly, the most cited journals are Journal of Research Science Teaching (Citations=212), Science Education (Citations=127), Journal Science Teacher Education (Citation=86), and International Journal of Science Education (Citations=86).

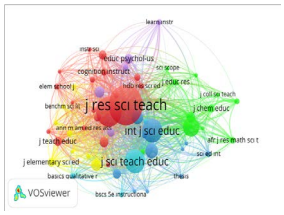

Figure 17 The Most Cited Journals with Co-citation Analysis

Discussion

This study used bibliometric analysis to identify IBS research trends in WoS from 2000 to 2021. According to the results, the highest number of publications on IBS was reached in 2019 (f=71, Citation=1326), and 2020(f=83, Citation=1370). The most cited year was found to be 2021(f=54, Citation=1443). Although there is a small decrease in the number of publications in 2021, it is seen that the citations have reached the highest levels in the last three years. The high number of publications or citations in the last three years shows that researchers' interest in the subject continues to increase. IBS is an important component of acquiring scientific literacy, a deeply rooted concept that is frequently emphasized in international perspectives (Forbes et al., 2020; Cairns & Areepattamannil, 2019; Bybee & McCrae, 2011; Bybee et al., 2009).When the most cited IBS publications in the last years were examined, they focused on IBS and technology integration (Pedaste et al., 2021; Jong et al., 2021; Huang et al., 2021; Liu et al., 2021), science achievement (Cairns & Areepattamannil, 2019; Aditomo & Klieme, 2020), and PISA-IBS patterns (Forbes et al., 2020). Furthermore, IBS integrations are used in mathematics education in some studies (Huang et al. 2021). The most cited studies in the last three years show that the subject of IBS demonstrates a re-evaluation of IBS with a trend towards technology and interdisciplinary integration. In addition, it remains important to investigate the relationship between IBS teaching and science achievement. Effective IBS teaching cannot be considered apart from technology and interdisciplinary approach (Song & Wen, 2018; Artigue & Blomhøj, 2013). Annan-Diab & Molinari (2017, p.73) reveals it is highly important to adopt an interdisciplinary approach to education for sustainable development.

Cairns & Areepattamannil (2019) point out that the keywords used in IBS publications are expressed using a variety of concepts and there is no common terminology. When the most cited keywords identified in the bibliometric analysis were examined, similar results were obtained. According to the findings, the most cited keywords in IBS research differ from each other in terms of fundamental terminologies (such as inquired-based science teaching, inquired-

based teaching, inquired-based science education, inquired-based learning, and inquired-based science instruction). These findings demonstrate that there is no agreement on this concept in IBS research. Even though the concepts of "inquired based science teaching" and "inquired based teaching" do not have a clear distinction from other terminologies, it has been determined that they have the highest frequencies. Anderson (2002), Furtak et al. (2012), and Cairns & Areepattamannil (2019) are some of the most cited authors on IBS. They prefer the concept of "inquired-based teaching". Minner et al. (2010), on the other hand, prefer to use the term "inquired-based science instruction". Norris & Kvernbekk (1997), in contrast to positivist approaches in science education, emphasize semantic approaches, that is, semantic structures rather than linguistic and logical structures. One of the reasons different terminologies are used in IBS studies could reflect the shift to semantic approaches in science education. The fact that the findings span from 2000 to the present, that science education is dynamic, and that the concept's nature includes changes and applications may have revealed the concept's different terminologies. The concept of IBS, which is described as a science education reform (National Research Council, 1996, 2000), has a rich naming with new paradigms (Windschitl, et al., 2008; Hester et al., 2018). The literature focuses on teaching practice and views of inquiry and the nature of science (Abd-El-Khalick & Lederman, 2000; Capps & Crawford, 2013), rather than an attempt to create IBS common terminology. In addition, the effect or relationship of the concept of IBS on various variables such as attitude and achievement (Areepattamannil, 2012; Cairns, 2019; Cairns, D. & Areepattamannil, 2019; Salchegger et al., 2021; Chi et al., 2021) is examined. The lack of clear operational terms for what creates and does not constitute a reform has hampered the advancement of research in science education (Klahr & Li, 2005). Therefore, there is a need for studies to ensure conceptual unity on IBS.

Leading trends in citing a particular article indicate the importance of the cited article in the literature (Wang et al., 2014). According to the results, the most cited authors in IBS publications are Minner et al. (2010), and Furtak et al. (2012). When these authors' research is examined, inquiry-based teaching is what it is, why it is used, and the meta-synthesis of experimental research on the subject. The authors are included in the scope of the most cited authors with one or two studies. These resources can be qualified as the fundamental resources used in IBS. According to the findings, the most cited country is America, followed by Germany and France. These countries have more research resources than developing or small countries (Mongeon & Paul-Hus, 2016). Similarly, in citation analysis, it was determined that the most cited organizations in IBS publications were from the USA (the University of Chicago, Education Development Center, and the University of Colorado), or Germany (the Technical University of Munich). Developed countries like these have a long history of academic publishing and large publishing companies. The United States leads the world in terms of the h-index (Hajar & Karakus, 2022). Ivanovic and Ho (2019) concluded from their bibliometric analysis that the United States, its institutions, and journals are the undisputed leaders in the category of Education and Educational Research. Effendi et al. (2021) found that most publications addressed the USA in scientific literacy and science education studies were followed by Canada and Australia. Jho stated the abundance of USA and Turkey articles on the nature of science, which is an important component of IBS.

In the bibliometric results, South Africa, Australia and Indonesia were found to be the most cited countries in IBS publications. Zidny et al. (2021, p.165) report that the integration of an indigenous perspective in science education has been widely practiced by scholars in some regions, including Africa, Australia, Asia, and the Americas. This integration argues that indigenous culture and modern science culture will complement each other so that students' daily world experiences can be improved (Pugh et al., 2017; Bell, 2016; Sjöström et al., 2016; Kim & Dionne, 2014). The exploration of various cultural experiences and local perspectives in IBS education or the integration efforts of these structures can explain the most cited countries for IBS such as South Africa, Australia, and Indonesia. Because the subject of IBS is a deep field of study that focuses on experience, cultural context, and

the acquisition of affective structures (such as attitude, perception, belief, and understanding) to develop students' inquiry skills (Lederman et al., 2013; Kaufmann, 2019). Therefore, the emphasis on sustainability, indigenous perspectives, socio-cultural context, and local experiences in science education (Zidny et al., 2021) may have increased citations in IBS studies to some studies from South Africa, Southeast Asia, and Oceania.

As results, bibliographic coupling organizations before 2018 were the University of Michigan, University of Iowa, Center for Education Development Inc., Indiana State University, and University of Maine. In recent years, bibliographic associations have been Charles Sturt University (Australia), Providence College (USA), and the University of Helsinki (Finland). Most co-cited organizations before 2018 are US-based and prestigious. In recent years, it has been determined that important organizations of Australian and Finnish origin, as well as the United States (Providence Collage), refer to each other. When the publications that these organizations give the most reference to each other are examined, issues such as teachers' pedagogical practices towards IBS, social justice in IBS teaching and teachers' understanding of science teaching are discussed. It turns out that these important organizations are interested in pedagogical practices in IBS, teachers' understanding of science in different settlements, and empowerment assessment. Therefore, the current content in IBS studies continues to spread among different organizations.

The most cited journals on IBS are the Journal of Research Science Teaching, Science Education, Journal of Science Teacher Education, and International Journal of Science Education in WoS. These journals have very high impact factors. These journals have been demonstrated to be pioneers in the field of IBS research. Similarly, Yen examined the science teacher publications in WoS through bibliometric analysis and determined that the journals with the most cited and high impact values (such ash index, and g index) are the International Journal of Science Education, Research in Science Education, Journal of Research in Science Teaching, Science Education. Orbay et al. (2021) found that education articles published in the Q1 journal had higher average citations and lower citation rates than other quarters. These science journals are well-known in the educational community, with high international citation rates, scientific contributions, and dependability. Therefore, these journals may be more preferred for the publication of IBS studies.

Conclusion

IBS is a well-known, effective, and well-established method for developing scientific literacy that is indispensable and widely used in science education reforms. IBS allows for active experiences that help students develop their perceptions of the nature of science and their inquiry skills. IBS is also a critical issue for the development of 21st-century skills such as critical thinking and social participation. In this research, the research trends of 662 IBS education articles published in WoS during 2000-2021 were examined. Through bibliometric analysis, these articles were examined according to some factors (most cited keywords, authors, countries, organizations, and journals), and IBS research trends were revealed. Quantitative data obtained from scientific network maps and citation values were qualitatively interpreted by the nature of bibliometric studies (Wallin, 2005). In the research, it was determined that although there was no unity of concept related to IBS in the years 2000-2021 in the most cited keywords, there was the highest number of publications or citations related to this concept, especially in 2019, 2020 and 2021.There are new directions in IBS studies with sustainability education, local perspectives, technology, and interdisciplinary integration based on the identification of the most cited keywords in recent years. The most cited authors and journals in IBS research published in 2000-2021 are of American origin. The most cited country is the United States of America, followed by Germany and France. However, the most cited countries in recent years are South Africa, Australia, and Indonesia. Similarly, between the years 2000-2016, American-based organizations were working collaboratively, recently, besides the United States, Finland, and Australia-based important organizations are the most cited. As a result, the subject of IBS has piqued the interest of researchers since the 2000s,

particularly in the last three years, as evidenced by an increase in the number of publications or citations. This topic is spreading across various countries and organizations, with varying content integrations. Future research can benefit from reaching a consensus in IBS studies, emphasizing sustainability education and local studies, and providing technology and interdisciplinary integration.

Limitations

This study has some limitations. First, the data obtained from the WoS database may have missed some important studies. Second, the analyses relied solely on bibliometric analysis. Based on the limitations, future studies could broaden the scope of the study by incorporating databases such as Eric and Scopus, as well as different techniques such as content analysis.

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No potential conflict of interest was reported by the authors.

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Ethics Statement

Ethical approval is not required as Clarivate WoS' data is used in the study.

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