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Authentic Inquiry in Science Education Between 2003 and 2023: A Bibliometric Analysis Use RStudio

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Abstract.
The primary aim of this study is to investigate scholarly literature about the utilization of authentic inquiry in the context of science education throughout the past two decades (2003–2023). Additionally, this analysis aimed to examine the collaborative efforts of authors, institutions, and nations in domains closely associated with this research. Thematic and keyword analyses were performed to discover the most current and up-to-date study topics. The present study reveals 271 scholarly articles about authentic inquiry in science education identified from the SCOPUS database. These articles were sourced from 128 distinct publications, which involved the collaborative efforts of 812 authors. The time frame for this analysis spanned from 2003 to 2023. The annual growth rate observed in this study was 2.98%. Furthermore, the average number of citations per document was 23.62, while the study included 12.479 references cited. In the current context, Yarden from the Weizmann Institute of Science is foremost among the authors, having authored four publications and amassed ninety citations. Furthermore, the aggregate quantity of papers written by individuals from the United States amounts to 116. In addition, Australia is identified as the second most significant contributor, having nine published publications. The theme analysis method is utilized to present a network of thematic keywords consisting of 50 keywords that have been identified as appearing at least four times throughout the text being examined. Based on the bibliometric analysis, the authors propose a need for further enhancement of authentic inquiry research in science education.

Keywords: authentic inquiry, science education, bibliometric, RStudio

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1. INTRODUCTION

Inquiry-based learning (IBL) is a method of teaching that focuses on students as the primary agents of their education and incorporates student-centered learning activities such as problem-solving, exploration, and collaboration[1–4]. There has been a growing interest in undergraduate science education over the past few decades[5–7], and inquiry-based learning has a long history in K-12 science education[8–10]. Students

participate in many of the same activities and ways of thinking that scientists do. Making observations, formulating questions and hypotheses, designing and carrying out scientific investigations, developing scientific explanations and models based on evidence and logic, communicating results, and revising descriptions or revisiting experiments based on feedback and criticism from peers are all examples of activities that fall under this category[11–14].

Inquiry learning concluded to be a learning model that requires students to carry out the process of discovering their knowledge independently through a series of investigations, searches, and explorations [15], so this can be concluded based on the experts' opinions discussed above—research to solve a problem or learn more about the subject matter being examined. Constructivism[10, 16], which holds that learning is a process of knowledge construction, is the philosophical underpinning for using inquiry methods in the educational setting—a technique for developing new knowledge.

In learning practice, the application of inquiry is only partially meaningful because it is still accompanied by activities unrelated to students' lives. This makes learning less meaningful and unable to be a solution to the problems faced by students in the real world. Authentic inquiry learning is needed when students face an exact situation to overcome this. Authentic learning is based on a constructivist view, in which learners create their understanding of what they are learning about new concepts and practices. A significant paradigm shift from behaviorist to constructivist models of learning has been in stimulating the movement towards the design of learning experiences that are learning experiences that are situated in the real world, complex, and generated by learners. This trend is expected to grow in its application in higher education[17, 18]. Learners create their understanding of what they are learning about new concepts and practices by integrating their prior experiences, resources they have access to, their research, and their current experiences[18, 19].

Authentic learning experiences are designed to correlate more closely with how learning is accomplished in real-world settings. Authentic learning experiences should be designed around characteristics that concentrate on real-world relevance over a long period, the exposure to and collaboration with multiple roles and perspectives; reflection; articulation of knowledge and learning, primarily through public presentation; scaffolding; and authentic assessment [20–26]. These activities include role-playing, involvement in virtual or in-person communities of practice, and case studies [27–29],. The overarching goal is to find solutions to problems that occur in the real world. According to[25, 30], authentic learning consciously introduces various views and interdisciplinarity.

To synthesize Authentic Inquiry publications in science learning from around the world, a bibliometric analysis needs to be conducted to analyze this research. Bibliometric analysis is a new technique to study the scientific literature in a particular field of study. It helps researchers understand the field's development and aims to provide an overview of the constantly updated literature. Based on the above description, the study will determine the growth of citations and publications on Authentic Inquiry in science learning. The objectives of this study are: (1) identifying the development trend of scientific publications related to Authentic Inquiry in science learning, (2) identifying the relationship between authors, organizations, and institutions in this field, and (3) understanding the structure and thematic focus of Authentic Inquiry in science learning.

2. METHODOLOGY/ MATERIALS

A bibliometric analysis was utilized in this work to review the previous research on authentic inquiry in science education[31, 32]. According to [33, 34], bibliometric analysis can be undertaken through keywords by describing the unique structure of the topic and how it links to each article, as well as revealing information about trends by year. The procedure for bibliometric analysis consists of the following five stages: study design, data collecting, data analysis, data visualization, and interpretation Figure 1.

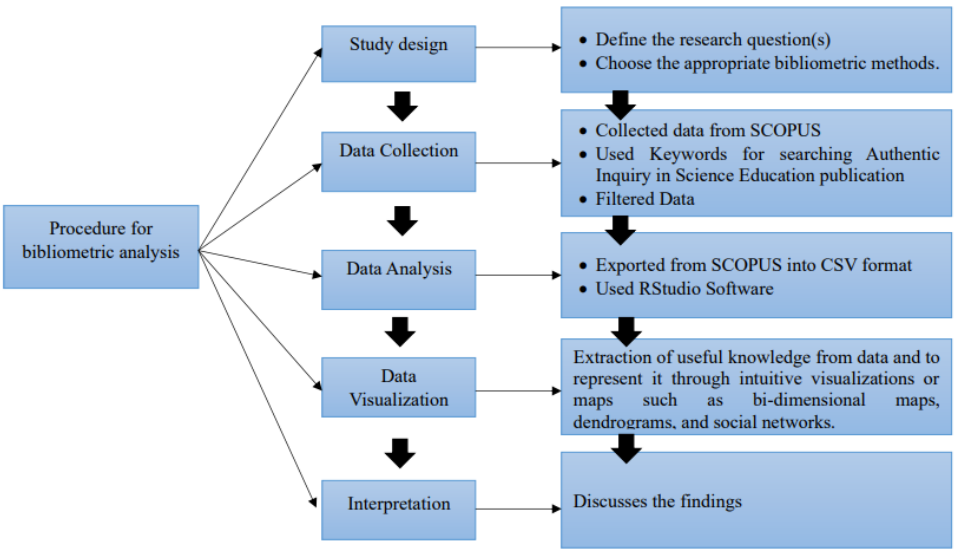

Figure 1: Research framework in bibliometric analysis.

This research utilized the SCOPUS database to retrieve publications related to authentic inquiry in scientific learning based on keywords. Because SCOPUS comprises journals with the highest impact on various academic topics, this database was chosen to retrieve the relevant publications[35, 36]. Keywords and operator methods

corresponding to the syntax were used to discover relevant data-gathering articles. SCOPUS (http://www. scopus.com/) was used to search the scientific literature and locate pertinent publication data for analysis. This search was performed on July 20th, 2023. The hunt lasted from 2003 until 2023. Previous research was located through the use of keyword searches.Therefore, the search queries that were utilized to get the database from SCOPUS are listed below in Table 1.

Query String	Total Documents
TITLE-ABS-KEY (authentic AND inquiry) AND TITLE-ABS-KEY (science AND education)	451 documents found
TITLE-ABS-KEY (authentic AND inquiry) AND TITLE-ABS-KEY (science AND education) AND PUBYEAR > 2002AND PUBYEAR < 2024	428 documents found
TITLE-ABS-KEY (authentic AND inquiry) AND TITLE-ABS-KEY (science AND education) AND PUBYEAR > 2002 AND PUBYEAR < 2024 AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "AGRI") OR LIMIT-TO (SUBJAREA , "BIOC") OR LIMIT-TO (SUBJAREA , "EART") OR LIMIT-TO (SUBJAREA , "PHYS") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "MEDI")) AND (LIMIT-TO (DOCTYPE , "ar"))	271 documents found

Figure 2: Keywords and search results in search stages.

For the data analysis, the obtained data were exported from SCOPUS into CSV format before being analyzed in RStudio software. The Bibliometric R software package (http://www.bibliometrix.org (accessed on 31 Juli 2022) provides a set of tools for quantitative research. Bibliometric is an open-source tool for quantitative research in scientometrics and bibliometrics that includes all primary bibliometric analysis methods [37, 38]. In the visualization, the nodes represent the objects of interest, such as authors, institutions, nations, publications, and important terms. The linkages between the nodes show the degree to which the nodes are connected. In addition, the distance between the nodes indicates the connections between the components of the research topic[39].

3. RESULTS AND DISCUSSIONS

3.1. The Development Trend in Scientific Publication of Authentic Inquiry in Science Education

Between the years 2003 and 2023, a total of 271 articles have been cataloged and included in the SCOPUS database. Since 2003, there has been a notable upward trajectory in the publication of scholarly articles on authentic inquiry in science education. From 2003 to 2005, there was no discernible growth in articles about authentic inquiry in science education. However, starting from 2006 and continuing until 2023, there was a notable increase in the production of such reports. The peak year of article output was 2018, with 30 articles accounting for 11.07% of the overall publications during this

period. Based on an analysis of data from the past five years, 120 articles (44.28%) have been published on the topic of authentic inquiry in science learning. Specifically 2018, there were 30 articles, followed by 17 articles in 2019, 26 in 2020, 25 in 2021, 13 in 2022, and 9 in 2023 (data available until August 1, 2023). Figure 2 displays the data about the progression of publications concerning authentic inquiry in cont education.

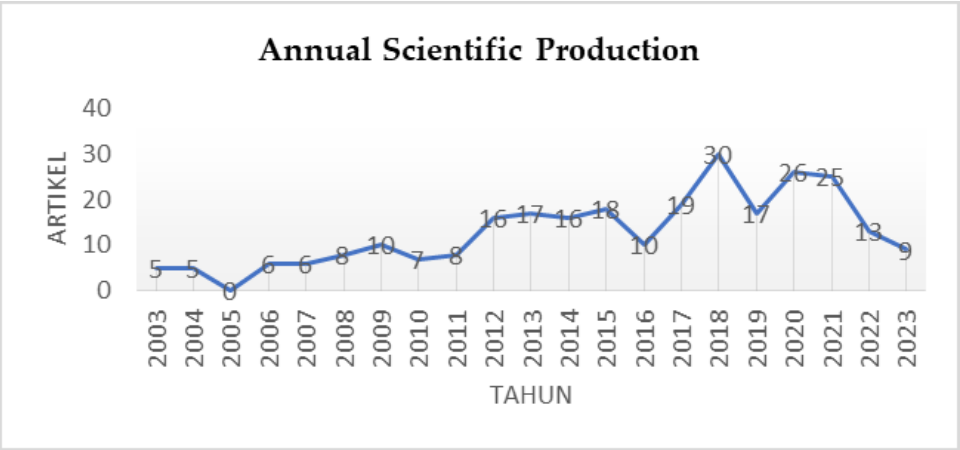

Figure 3: The bar chart illustrates the growth trends of published documents by year.

According to the data presented in Figure 3, there has been a noticeable rise in disseminating authentic inquiry in science education since 2006. This trend can be attributed to the recognition by numerous researchers of the significance of incorporating inquiry-based learning approaches. Such approaches foster students' motivation to acquire knowledge and enhance their scientific literacy. Using inquiry-based methods in education facilitates collaborative and authentic learning experiences, enabling students to engage in group work and actively participate in investigative processes[40].

3.2. Relationship between authors, organizations, and institutions

The data in Table 2 details the top 10 authors who have been actively publishing, including their affiliated institutions, countries, number of printed documents, citations received, and H-index. The authors hail from diverse geographical locations, including Israel, the United States, Chicago, New Zealand, Hong Kong, and Germany.

According to the findings presented in Table 2, Yarden A. from the Weizmann Institute of Science holds the top position among authors, having authored four articles and accumulated 90 citations. Following closely is Crawford, B.A. from the University of Georgia, who has written three articles and garnered 114 medals. Harnik P.G., Hodson D., Ross R. M., and Wong S. L. have each authored three articles. The final section includes

No.	Authors	Institution	Country	No. of Articles	No. of Citation	H-index
1	YARDEN A	Weizmann Institute of Science	Israel	4	90	4
2	CRAWFORD BA	University of Georgia	USA	3	114	3
3	HARNIK PG	University of Chicago	Chicago	3	31	3
4	HODSON D	University of Auckland	New Zealand	3	188	3
5	ROSS RM	University of Chicago	Chicago	3	31	3
6	WONG SL	The University of Hong Kong	Hong Kong	3	188	3
7	ABD-EL-KHALICK F	University of Illinois at Urbana-Champaign	USA	2	219	2
8	ANGELONI LM	Colorado State University	USA	2	12	2
9	BELL KC	University of California	USA	2	92	2
10	BOGNER FX	University of Bayreuth	Germany	2	27	2

Figure 4: Top 10 active authors based on nomor of articles.

the works of ABD-EL-Khalick, Angeloni L.M., Bell K.C., and Borner F.X., encompassing two scholarly articles.

In their initial publication in 2013, Machluf and Yarden elucidate the methodology of incorporating bioinformatics into the secondary education curriculum by actively involving students in genuine inquiry-based activities. Authentic inquiry allows students to cultivate a comprehensive and situated comprehension of scientific knowledge.

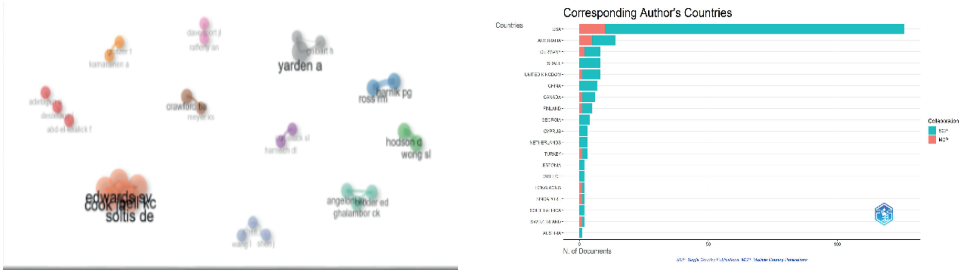

Figure 5: a. Collaboration between the authors and the visualization by RStudio b. corresponding authors countries.

Figure 3a illustrates the authors' collaborative efforts in researching the implementation of authentic inquiry in the context of science education. The figure shows the presence of collaboration among individual authors, indicating a need for more cooperation between authors from different groups. The absence of a connecting line between other groups is readily apparent. Figure 3b show a significant proportion of the writers engaged in collaborative research about this particular subject matter are affiliated with institutions in the United States. The cumulative number of articles authored by individuals from the USA amounts to 116. Subsequently, Australia emerged as the second most significant donor, having a cumulative count of 9 papers. The observation above indicates that the United States is essential in conducting genuine inquiry research in scientific education. In contrast, other countries have made a comparatively limited contribution by publishing less than ten documents from these nations.

3.3. Structure and thematic focus of Authentic Inquiry in science learning

A thematic keyword analysis is a valuable tool in bibliometric analysis as it facilitates identifying research themes associated with the keywords employed in published papers. Figure 5 displays the thematic keyword network with 50 keywords with a minimum occurrence of 4 times in the studied articles. In this context, individual keywords are represented as nodes, with the thickness of the connecting lines as an indicator of the intensity of the interaction between them. The color categories assigned to the nodes indicate the degree of proximity in the link between the keywords.

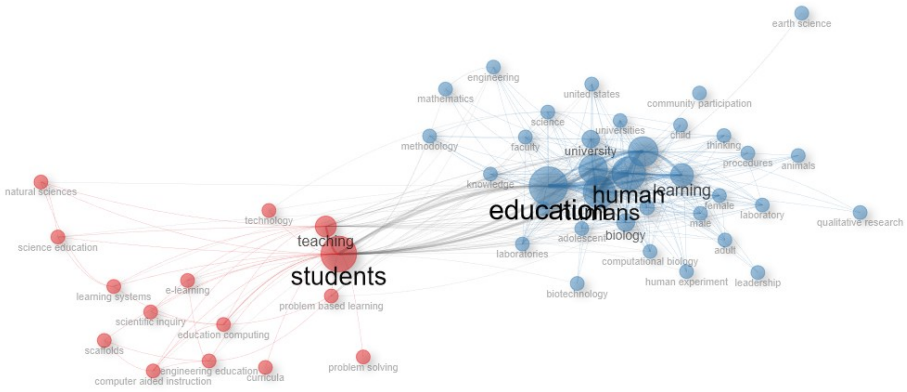

Figure 6: Co-occurrence network of 50 most influential keywords. The visualization network generated by RStudio.

The analysis reveals that specific keywords exhibit interrelatedness, suggesting that past researchers in the field of education have employed actual inquiry research in science learning. The utilization of this tool is intricately linked to the educational pursuits of students, encompassing both theoretical knowledge acquisition and practical application within laboratory settings. Authentic inquiry learning has been the subject of academic investigation, with findings indicating a positive correlation between enhanced information acquisition and the development of process skills[21]. Furthermore, this pedagogical approach has been successfully implemented in both postsecondary institutions and primary and secondary educational settings.

4. CONCLUSION

The present study determined that the number of scholarly publications about authentic inquiry in the context of scientific education amounted to 271 documents. Notably, this number exhibited a notable surge after the year 2016, following a complete absence of

publications in the preceding year of 2015. In 2018 they witnessed the highest number of publications, with 30 documents. However, subsequent years have seen a consistent fall in publication numbers. The articles are authored by individuals affiliated with diverse institutions and from different nations. Based on the results, it is evident that most of the writers involved in the collaboration were affiliated with institutions in the United States, contributing to a total of 116 papers. Following this, Australia emerged as the second most prominent contributor, with nine documents. This observation indicates that the United States remains the primary contributor to authentic inquiry research in science education. Lastly, the results of the keyword analysis indicate that a total of 50 keywords have been identified as repeated by the authors on at least four occasions.

The study also exhibits more limitations. First, the researcher's only utilization of the SCOPUS database so we recommended to incorporate other forms of publications, such as conference proceedings, books, or from other databases such as SINTA. Second, the keywords used can be further developed, such as projects, experiments, practicums, and actual problems.

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