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Research Article

Forecasting Methods in Science Education: A Bibliometric Analysis Using the Scopus Database

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Abstract.
This study utilizes a detailed bibliometric analysis to thoroughly explore the literature surrounding forecasting methods and models in science education. It highlights significant trends, applications, and impacts of these methodologies. Leveraging data from the Scopus database pinpoints essential themes and notable gaps within the current body of work. The research underscores the importance of integrating forecasting techniques across various scientific disciplines and applying these techniques to address real-world challenges in education. This comprehensive analysis is intended to contribute richly to academic dialogue and guide the development of future educational strategies and policies. By identifying and discussing these key elements, the study aims to enhance understanding and implementing forecasting methods in academic settings, ultimately influencing both practice and theory in science education.

Keywords: forecasting methods, science education, bibliometric

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1. INTRODUCTION

Forecasting methods and models hold a significant place in science education, equipping educators and students with the capabilities to predict future trends and. adapt to changing educational demands. The role of forecasting extends beyond mere predictions; it encompasses the integration of various scientific disciplines and the application of these methods to real-world problems. Recent literature highlights the importance of forecasting in enhancing educational outcomes and decision-making processes. For example, the application of machine learning models to predict student performance has demonstrated significant advancements in educational planning and personalized learning strategies [1]. Moreover, the incorporation of forecasting in ecological

education, such as uncertainty communication, has been shown to improve students' understanding of ecological dynamics and their implications [2, 3]

Continued advancements in forecasting methods, including grey prediction and hybrid filtering-based models, have been crucial in addressing diverse educational needs and complexities [4, 5]. This integration signifies a robust trend towards more dynamic and responsive educational systems, underscoring the critical need for comprehensive studies that map out the evolution and impact of these forecasting methodologies within the realm of science education.

The primary challenge in the field is the lack of comprehensive analysis that encapsulates the breadth and depth of forecasting methods utilized in science education. While individual studies have explored specific aspects, a holistic overview that systematically evaluates these methods through bibliometric analysis is markedly absent. This study proposes to fill this gap by utilizing bibliometric techniques to map out the literature, providing a macroscopic insight into the trends, applications, and impacts of forecasting models in science education.

Upon receiving specific reference documents from your side, this section can be developed to include detailed methodologies and specific approaches cited in contemporary scientific literature. These references will guide the bibliometric analysis, highlighting specific methodologies used in the field, their scientific basis, and their relevance in educational forecasting.

Despite the rich tapestry of research in forecasting methods, significant gaps remain, particularly in the intersection of forecasting and interdisciplinary education. For instance, the integration of ethical considerations and scientific communication within forecasting courses is often overlooked[6–9]. Additionally, while some studies have addressed short-term educational planning, long-term forecasting that incorporates changing educational paradigms and technology advancements is underexplored. This bibliometric analysis aims to unearth these gaps, providing a comprehensive review that could set the stage for future research directions.

This study aims to conduct a thorough bibliometric analysis of forecasting methods and models in science education using the Scopus database [10–14]. The objective is to provide a comprehensive overview of the research trends, evaluate the impact of various forecasting models, and identify gaps in the literature. The novelty of this study lies in its comprehensive scope—ranging from data analysis to information science—and its use of advanced bibliometric techniques to offer a detailed and expansive understanding of the field. This analysis is not only expected to enrich the academic discourse but

also to aid in the strategic planning and implementation of future educational policies and practices.

By addressing these aspects, the manuscript will contribute significantly to the understanding of forecasting in science education, emphasizing its importance and the need for an integrated approach to educational planning and development.

2. METHOD

Bibliometric analysis is a widely used and precise method for examining and analyzing substantial amounts of scientific data. This technique aims to understand the interconnectedness among journal citations and to summarize the latest developments in current or emerging research topics [15–17]. In the study, the data utilized for the bibliometric analysis is sourced from Scopus. The Visualization of Similarities (VOS) viewer, which facilitates the easy creation and visualization of bibliometric maps, is becoming increasingly popular in bibliometric research. This method enables efficient collection of literature and the establishment of interrelationships among selected publications within the framework.

As of the end of December 2023, 861 publications have been retrieved by the database Scopus with the use of the following keywords search TITLE-ABS-KEY (forecasting AND methods) OR TITLE-ABS-KEY (forecasting AND models) AND TITLE-ABS-KEY (science AND education) OR TITLE-ABS-KEY (science AND teaching) AND PUBYEAR $>$ 2004 AND PUBYEAR $<$ 2024. The obtained results were downloaded in CSV format for processing with VOSviewer, which is used to visualize and analyze bibliometric trends. VOSviewer enables the creation of country maps through co-citation networks, constructs keyword maps from shared networks, and generates maps containing multiple items[18–21]. The software facilitates data mining, mapping, and grouping of articles retrieved from the database [22, 23].

3. RESULTS AND DISCUSSIONS

This bibliometric study, utilizing data from the Scopus database, explores the utilization of forecasting methods and models in science education from 2004 to 2024. The search, which involved terms like 'forecasting methods', 'forecasting models', and 'science education', identified a total of 861 documents. This review reveals an upward trend in publications, highlighting the growing importance of forecasting in shaping educational policies and practices. Key findings include the increased use of ecological

forecasting to teach students about real-world uncertainties, as noted in Woelmer's 2023 study, and the employment of grey prediction models by Tang and Chou in 2016 to predict educational outcomes. The integration of forecasting with interdisciplinary subjects such as ethics and science communication, discussed by Willson et al. in 2023, points to the evolving role of educators in providing comprehensive scientific education. Historical references like Lederman & Lederman (2018) and Schultz (1984) underscore forecasting's crucial role in adapting educational practices for future challenges. The use of machine learning techniques in forecasting, as demonstrated by Dhar & Jodder in 2020, shows the integration of advanced technologies in educational strategy, essential for effective planning and resource allocation. This analysis provides insights into the trends and dynamics of research in forecasting within educational contexts, assessing how interest and research in this field have evolved, reflecting the academic community's response to technological advancements and educational policy shifts.

TABLE 1: Number of Publications by Years.

Years	Number of Publications	Annual Growth Rate (%)
2004	19	0
2005	23	21.05
2006	24	4.35
2007	23	-4.17
2008	23	0
2009	71	208.7
2010	35	-50.7
2011	34	-2.86
2012	37	8.82
2013	28	-24.32
2014	23	-17.86
2015	34	47.83
2016	34	0
2017	37	8.82
2018	41	10.81
2019	51	24.39
2020	67	31.37
2021	78	16.42
2022	72	-7.69
2023	83	15.28
2024	24	-71.08

The analysis of data retrieved from Scopus as of the end of December 2023 shows a total of 861 publications identified using keywords related to forecasting methods and models in the context of science education and teaching from 2004 to 2023. During the period 2004-2023, the annual number of publications ranged from 19 to 83. A surge in publications occurred in 2009 with an AGR of 208.70%, followed by a sharp decline of -50.70% in 2010. Subsequently, the number of publications stabilized and gradually grew from 2015-2021 with positive AGRs, indicating a sustained interest in forecasting in science education. However, 2022 and 2023 experienced moderate decreases and increases. This analysis illustrates the dynamics of research on the use of forecasting methods in science education, with significant year-to-year variations reflecting changes in educational needs, technological advancements, or other external factors influencing the academic research focus. The visualization in Figure 1 clarifies the complex growth patterns and fluctuations in publications from 2004-2024, highlighting events such as the 2009 surge and the varying publication rates in subsequent years, as well as the sharp decline in 2024 that requires further investigation.

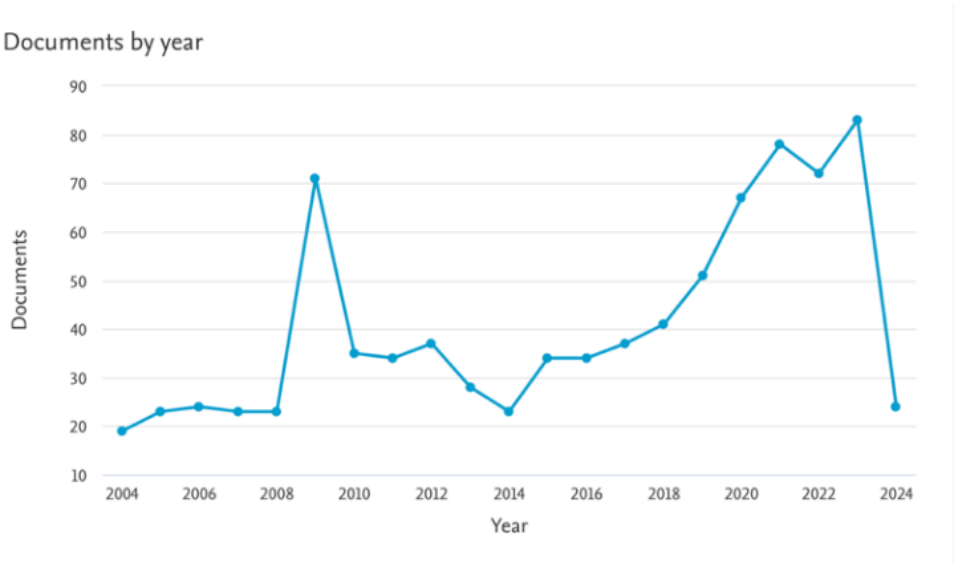

Figure 1: Documents by year.

The graph shows the trend of document publications related to forecasting methods in science education from 2004 to 2024. Publications were relatively stable between 2004-2008, then dramatically surged in 2009 reaching 71 documents, before sharply declining in 2010 and fluctuating until 2014. Since 2015, there was a steady increasing trend reaching a peak of 83 publications in 2023, before drastically dropping to 24 publications in 2024, indicating a need for further investigation into the contributing factors. This study examines various types of documents, which include research related to forecasting. Articles make up the largest portion at 45.9%, followed by conference

papers at 35.2%, indicating these are the dominant publication formats in this field. Figure 3 shows a network visualization of word frequencies and connections between keywords from scientific papers. Circle size represents how often a term appears in publications. Colours denote clusters of related terms. Curved line length indicates general connectivity based on term repetition, while line thickness represents strength of connections between topic areas/keywords. The clusters outline relationships between different topics.

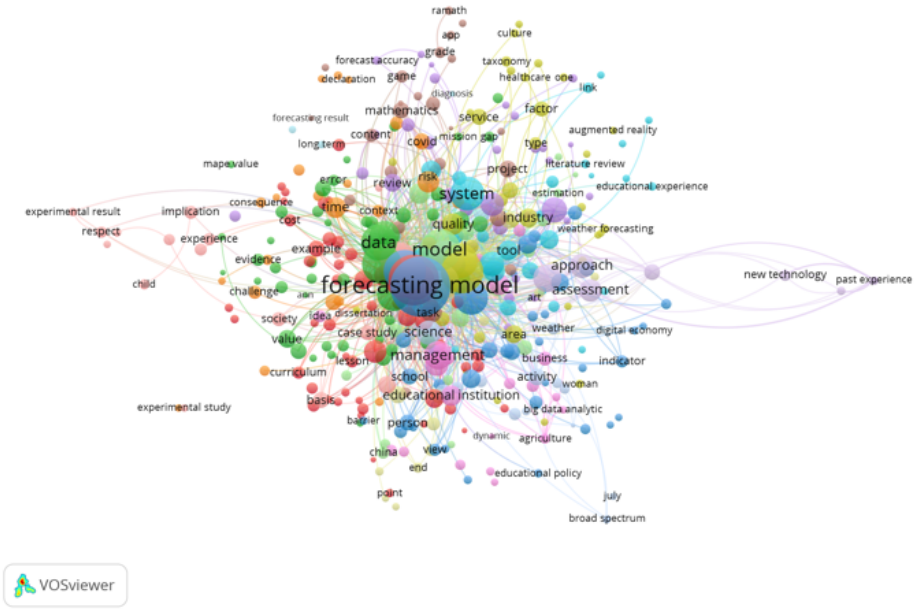

Figure 2: Network Visualization.

This visualization outlines the interconnections among key concepts, keywords, and topics in forecasting methods and models for science education, emphasizing main keywords like “forecasting model”, “data”, “system”, “science education”, and “forecasting methods” at the core of the network. Different colored clusters indicate varied research subthemes, ranging from theoretical aspects to practical applications, and incorporating a wide array of topics such as “mathematics”, “error”, and “big data”. Keywords such as “educational institution” and “school” highlight the practical implications of the research, demonstrating its applicability in educational settings. The visualization effectively demonstrates the research’s comprehensive approach, blending theoretical insights with practical applications in the field of science education.

Table 2 outlines the frequency and connectivity of key terms related to forecasting in science education, underscoring their prominence within the research. “Forecasting Model” and “Forecasting Methods” are the most frequently mentioned, appearing 173

Table 2: Most Occurred Keywords.

Keywords	Cluster Number	Links	Total Link Strength	Occurrences
Forecasting Model	3	297	1047	173
Forecasting Methods	1	263	746	121
Forecasting	3	229	557	86
Forecast	2	173	346	52
Science Education	2	193	504	76
Prediction	4	216	508	86
Analysis	4	187	392	58
Model	11	221	528	83
Develop	3	195	420	54
System	6	163	336	56

and 121 times respectively, highlighting their central importance. With link strengths of 1047 and 746, these terms show deep integration within the field. Other terms like “Science Education”, “Prediction”, and “Analysis” illustrate how forecasting is embedded in the wider context of science education, with “Model” and “System” emphasizing the development and analysis of systematic models. The strong connectivity of these keywords suggests active discussions and significant linkages in the academic community. VOSviewer is capable of producing three distinct mapping visualizations as shown in Figure 3 (network visualization), Figure 4 (overlay visualization), and Figure 5 (density visualization).

Figure 4 depicts the evolution and interconnectedness of forecasting methods and models in science education from 2004 to 2024. It uses colored data points to represent shifts in research focus, with warm colors such as yellow highlighting current trends like “digital economy” and “big data.” Central keywords including “forecasting model,” “data,” and “system” are connected by lines, indicating interdisciplinary relationships, such as between “data” and “educational policy.”

Figure 5 presents a density visualization from the bibliometric analysis of the article “Forecasting Methods and Models in Science Education: A Bibliometric Analysis Using the Scopus Database.” This visualization highlights the frequency and interconnections of certain topics or keywords within the field. Prominent keywords like “forecasting model,” “data,” and “system” signify their importance in research. Other terms such as “management,” “science,” “educational institution,” and “curriculum” illustrate a wider spread of sub-topics. Lines connecting keywords demonstrate thematic relationships,

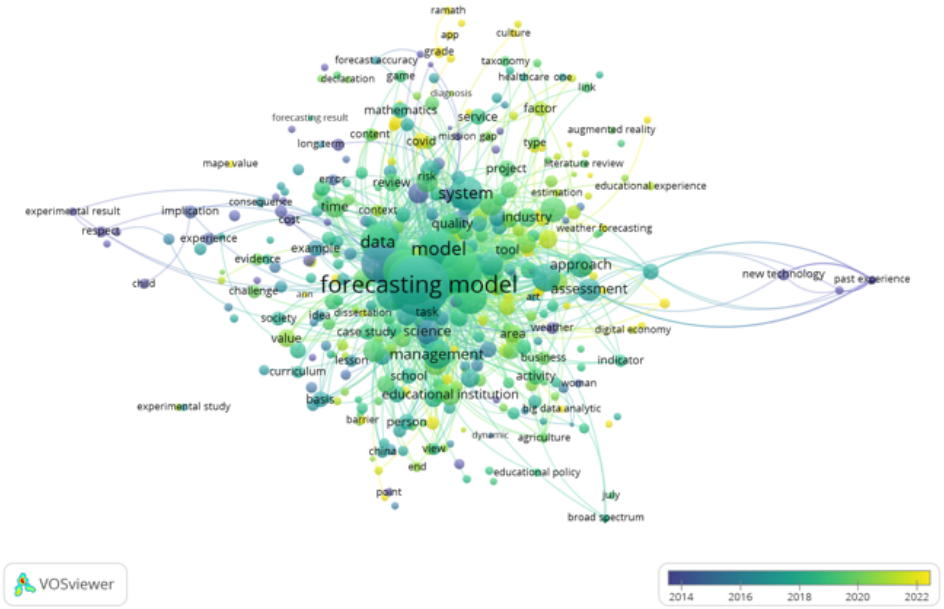

Figure 3: Overlay Visualization.

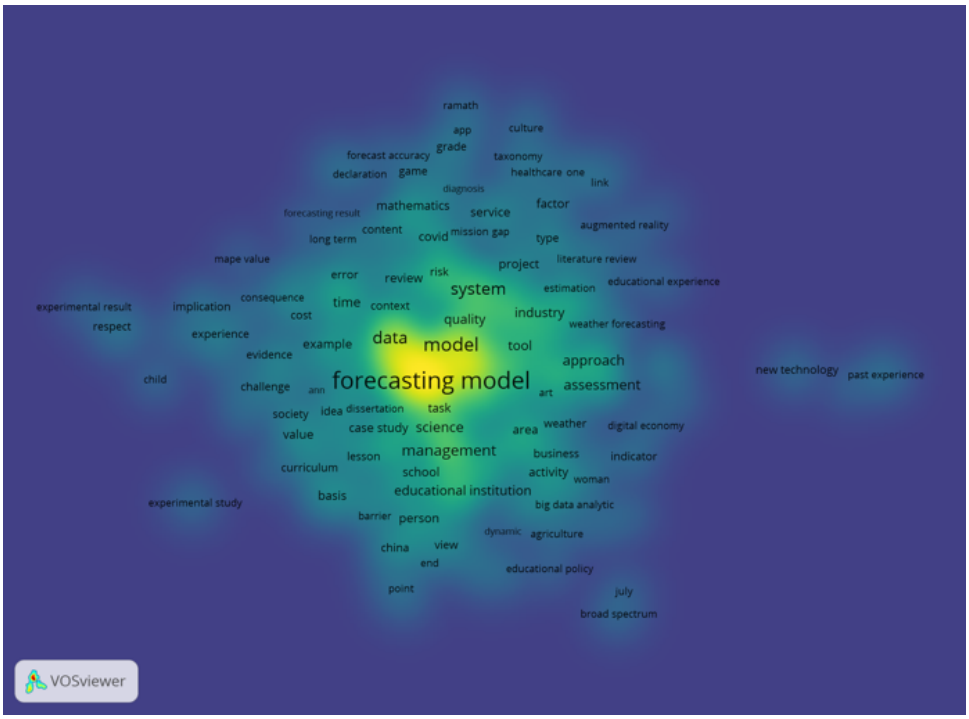

Figure 4: Density Visualization.

like those between “forecasting model” and “educational policy” or “digital economy.” The focus on recent terms like “digital economy” and “big data analytics” reflects current trends, while practical terms like “school” and “lesson” underscore the direct

applications of these findings in educational contexts, showing the research's evolution and ongoing relevance to educational practices.

Table 3: Top ten countries with the highest number of publications.

Countries	Documents	Citations
United States	249	6511
China	142	1014
Rusia Federation	53	247
Germany	51	1440
United Kingdom	32	794
Australia	30	927
India	28	164
Canada	21	794
Taiwan	17	180
Italy	17	325

Table 3 displays "The Top Ten Countries with the Highest Number of Publications" from a bibliometric analysis titled "Forecasting Methods and Models in Science Education," using the Scopus database. It lists countries by publication count and citation numbers. The United States leads with 249 documents and 6,511 citations, underscoring its prominent role in this research area. China follows with 142 documents and 1,014 citations, showing strong international influence. Germany's 51 documents garnered 1,440 citations, highlighting the impactful nature of its research. Other nations like Russia, the United Kingdom, Australia, India, Canada, Taiwan, and Italy demonstrate the global relevance of forecasting in science education. The inclusion of India and Taiwan emphasizes the involvement of developing countries and the broad applicability of this research. Overall, the table reflects a diverse geographical spread in research, indicating robust international collaboration and knowledge exchange in science education forecasting.

Figure 6 illustrates the bibliographic coupling, using countries as the unit of analysis. The study also established certain limitations for the analysis, such as requiring a minimum of five documents from a country to be considered a limiting factor.

4. CONCLUSION

The conclusion of this article emphasizes the importance of forecasting methods in addressing evolving educational needs and shaping future educational policies. The

comprehensive bibliometric analysis from 2004 to 2024 highlights the necessity of integrating advanced forecasting models into educational strategies to enrich scientific understanding and prepare educational systems for future challenges. The conclusion calls for ongoing research and collaboration to enhance the use of forecasting methods in education, highlighting their significant impact on science education.

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