SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Publications on Online Learning Technology for Mathematics and Science: Bibliometric Computational Mapping Analysis using VOSviewer

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ABSTRACT

This research aimed to explore the trends of research on online learning technology for mathematics and science. The data were obtained from Scopus database using the Publish or Perish application as a reference management tool. Subsequently, the computational mapping analysis was conducted using VOSviewer with a bibliometric approach. The keywords used as a guide for the search process were “technology” AND “online learning” AND “math” OR “science”. Over a span of ten years (2014 to 2023), a total of 458 relevant articles indexed by Scopus were identified. The results showed that research on online learning technology for mathematics and science were categorized into four terms, namely technology, online learning, mathematics, and science. The term "technology" fell within cluster 1, consisting of 149 links, a total link strength of 4936, and 324 occurrences. Online learning was categorized within cluster 2, comprising 149 links, a total link strength of 2921, and 181 occurrences. Mathematics was classified within cluster 4, with 138 links, a total link strength of 939, and 54 occurrences. Lastly, science was also categorized in cluster 4, with 129 links, a total link strength of 2420, and 167 occurrences. The data analysis revealed a fluctuation in research output on online learning technology for mathematics and science. The number of articles increased from 22 in 2014 to 25 in 2015, followed by a decrease to 17 in 2016, increased to 20, 21, 32, 40, 99, and 125 in 2017-2022, and finally decreased to 57 in 2023. These results were illustrated by VOS viewer analysis. The discussion presented can serve as a foundational point for future research on related topics.

Keywords:
Bibliometric analysis; Computational mapping analysis; Mathematics and science; Online learning technology; VOSviewer

1. Introduction

The field of online learning technology for mathematics and science has received a great deal of attention lately [1-10]. The pandemic of Covid-19 has accelerated the need for e-learning solutions, leading to the development of assessment instruments to evaluate the readiness of educational institutions for sustainable e-learning [11]. The COVID-19 pandemic had a profound impact on educational patterns leading to the closure of offline learning activities in educational institutions worldwide [12-14]. This situation necessitated a rapid transition from traditional face-to-face

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https://doi.org/10.37934/araset.58.2.4157

learning to online learning. As a result, online learning has subsequently evolved and become a global focus, with an emphasis on developing digital literacy to effectively handle future viral outbreaks [12].

Online learning relies on various network technology [15] that play a crucial role in determining its success, particularly in the field of mathematics and science, involving both abstract and practical concepts. Therefore, it is essential to employ appropriate technology to facilitate an effective online implementation. Technology tools can help reduce the abstraction of the subject matter, create engaging and innovative learning experiences, and stimulate active and creative learning activities [16]. This approach ensures a balanced educational outcome with the demands of the 4.0 era [17]. Consequently, a continuous development and research on technology in online learning are crucial to enhance its effectiveness in achieving educational goals.

To identify the development of online learning technology, experts often employ various existing research trends, including bibliometric analyses, which involve meta-analysis research containing bibliographic contents and article citations from journals and other scientific works. Bibliometric research has been conducted on various topics, including Google Classroom as learning media [18], the Zoom application [19], communication in online learning [20], and applied mathematics [21]. We hereby give a comprehensive collection of bibliometric articles, as indicated in Table 1, with references to earlier bibliometric studies and our investigations into earlier bibliometric analysis.

Table 1
Previous studies on bibliometric

Author	Title	Result	Ref
Huang *et al.,*	Progress on Pharmaceutical Sciences/Pharmacy Postgraduate Education: A Bibliometric Perspective	The study examined 485 bibliometric papers on pharmaceutical sciences and pharmacy education and found that both fields have been growing steadily, especially at US-based schools. In-school and residency education, interprofessional training, and COVID-19 therapeutic education are important research areas.	[22]
Barbosa & Galembeck	Mapping research on biochemistry education: A bibliometric analysis	The study utilized bibliometric analysis to analyse 66 years of biochemistry education research, providing insights into publication trends, key contributors, emerging topics, and potential research gaps.	[23]
Heradio *et al.,*	Virtual and remote labs in education: A bibliometric analysis	In order to identify important works and changing research interests, this paper analysed the literature up to 2015 and examined the usage of virtual and remote labs in education.	[24]
Shidiq *et al.,*	The use of simple spectrophotometer in STEM education: A bibliometric analysis	The study, which made use of the VOSviewer program, found that modified spectrophotometers are frequently used in the chemistry and STEM teaching, providing prospects for future research and addressing issues.	[25]
Zhang *et al.,*	Academia's responses to crisis: A bibliometric analysis of literature on online learning in higher education during COVID-19	With an emphasis on chemical and medical education, bibliometric analysis gives a thorough overview of online learning research at COVID-19, highlighting obstacles, cutting-edge pedagogies, and the uneven distribution of developing literature.	[26]
Hamidah *et al.,*	A bibliometric analysis of covid-19 research using VOSviewer	The extent of COVID-19 research was examined using the Scopus tool VOSviewer, which revealed a considerable increase in publications from 2019 to 2020.	[27]

Setiyo *et al.,*	The concise latest report on the advantages and disadvantages of pure biodiesel (B100) on engine performance: Literature review and bibliometric analysis	The benefits of B100, a diesel engine fuel, were shown by a bibliometric study of 127 papers, but it also calls for more research on engine sizes, raw materials, and testing conditions.	[28]
Soegoto *et al.,*	A bibliometric analysis of management bioenergy research using VOSviewer application	The study used VOSviewer to examine 180 articles on managing bioenergy from 2017 to 2021, identifying research topics, and recommending ways they may be combined with other areas of study.	[29]
Mudzakir *et al.,*	Oil palm empty fruit bunch waste pretreatment with benzotriazolium-based ionic liquids for cellulose conversion to glucose: Experiments with computational bibliometric analysis	In the study, the utilization of benzotriazolium salt-ionic liquids (ILs) as solvents in oil palm EFB waste processing is investigated using VOSviewer. This analysis reveals their maximum solubility and increased cellulose crystallinity and lignin content.	[30]
Santoso *et al.,*	Management information systems: bibliometric analysis and its effect on decision making.	With 120 administrative workers in Bandung, the study looked at how management information systems affected decision-making in archives. Results showed high levels of quality and efficacy, and bibliometric analysis revealed current trends in this field of study.	[31]
Nordin	Correlation between process engineering and special needs from bibliometric analysis perspectives.	VOSviewer, a process engineering tool for mapping analysis, experienced a decrease in publications on "process engineering special demands" between 2017 and 2021.	[32]
Bilad	Bibliometric analysis for understanding the correlation between chemistry and special needs education using VOSviewer indexed by Google.	An analysis of articles on chemistry and special education using VOSviewer and Publish or Perish showed a decline in publications in 2017 and a rise in 2021.	[33]
Riandi *et al.,*	Implementation of Biotechnology in Education towards Green Chemistry Teaching: A Bibliometrics Study and Research Trends	With journals being the most prevalent source, the study bibliometric analysis of research trends on biotechnology in education revealed four study concept potentials, underscoring the significance of teaching green chemistry in schools.	[34]
Nordin *et al.,*	A bibliometric analysis of computational mapping on publishing teaching science engineering using VOSviewer application and correlation.	A study that examined teaching, science, and engineering research using the VOSviewer and Perish applications found a significant drop because of pandemic conditions.	[35]
Wirzal & Putra	What is the correlation between chemical engineering and special needs education from the perspective of bibliometric analysis using VOSviewer indexed by google scholar?	Utilizing the VOSviewer software, a research study on the relationship between chemical engineering and special needs examined 800 pertinent papers between 2018 and 2022.	[36]
Nandiyanto & Al Husaeni	A bibliometric analysis of materials research in Indonesian journal using VOSviewer	A bibliometric assessment of research on Indonesian materials was conducted using VOSviewer, and the results showed that "acid" received the most attention from 2016 to 2021, with 43 publications and 8 foreign linkages.	[37]
Maryanti *et al.,*	Sustainable development goals (SDGs) in science education: Definition, literature review, and bibliometric analysis.	The bibliometric analysis, a vital instrument in science education, offers a thorough grasp of the subject, underscoring the important role it plays in facilitating research on the SDGs.	[38]

Nandiyanto & Al Husaeni	A bibliometric analysis of chemical engineering research using VOSviewer and its correlation with covid-19 pandemic condition.	Despite a decline in research since 2019, chemical engineering uses VOSviewer software for bibliometric analysis, which provides useful information on research trends and themes.	[39]
Al Husaeni	Computational bibliometric analysis of research on science and Islam with VOSviewer: Scopus database in 2012 to 2022.	In a study on science and Islamic research, VOSviewer was used for bibliometric analysis, which revealed drop-in research, particularly in Indonesia and Malaysia. This study also provided excellent reference materials for future research.	[40]
Al Husaeni	Bibliometric analysis of briquette research trends during the Covid-19 pandemic.	A review of 973 pertinent papers on briquettes was analysed using VOSviewer, bibliometric analysis, and data mapping; the results showed a decline in research over the previous three years as a result of the COVID-19 pandemic.	[41]
Ragadhita & Nandiyanto	Computational bibliometric analysis on publication of techno-economic education.	A study on science and Islamic research that employed data from the Scopus database from 2012 to 2022 and VOSviewer for bibliometric analysis found a reduction in research, mainly in Indonesia and Malaysia.	[42]
Al Husaeni	How to calculate bibliometric using VOSviewer with Publish or Perish (using Scopus data): science education keywords	With 200 documents from 2013 to 2023, VOSviewer is a potent tool for examining bibliometric data and offers simple, step-by-step insights into research advancements in scientific education.	[43]
Al Husaeni & Nandiyanto	Bibliometric computational mapping analysis of publications on mechanical engineering education using VOSviewer	A study that used VOSviewer to chart the development of nanopropolis research over the last ten years found a spike in research on nanoparticles, propoli and propolis.	[44]
Supriyadi & Dahlan	Constructionism and constructivism in computational thinking and mathematics education: bibliometric review	The study used bibliometric analysis to identify prolific authors and often-referenced researchers by looking at the rise in constructionism, constructivism, computational thinking, and mathematics education publications.	[45]
Supriyadi *et al.,*	Bibliometric analysis from local instruction theory research	The bibliometric analysis of 29 scientific papers on local instruction theory from 2009 to 2020 was conducted using the Scopus database, with Sriwijaya University having the highest level of scientific influence and Indonesia creating the most documents.	[46]
Supriyadi *et al.,*	Geometry in ethnomathematics research publication: bibliometric analysis	Despite continued difficulties, the bibliometric study of ethnomathematics research demonstrated its potential to improve learning interaction activities and conceptual comprehension in geometry.	[47]
Febriandi *et al.,*	Research on algebraic thinking in elementary school is reduced: a bibliometric analysis	VOSviewer, a bibliometric approach, was used to analyse 996 articles from 2012–2021, revealing a decline in research on algebraic thinking skills and providing valuable insights for future research.	[48]
Supriyadi *et al.,*	Global trend of ethnoscience research: a bibliometric analysis using Scopus database	An analysis of the Scopus database showed that ethnoscience research has significantly increased over the past 50 years, suggesting prospective directions for future study. This bibliometric study identified potential directions for ethnoscience research in the future.	[49]
Supriyadi *et al.,*	Didactical design research: a bibliometric analysis	By identifying research topics, authors, sources, countries, affiliations, and most-cited papers in DDR publications, Scopus offers bibliometric analysis. This analysis showed a large growth in DDR initiatives from 2015 to 2022.	[50]

Hayati *et al.,*	Computational bibliometric analysis on adaptive gamification using VOSviewer	A bibliometric investigation of adaptive gamification using the VOSviewer program showed a rise in research between 2019 and 2020 and a fall in 2021.	[51]
Nandiyanto *et al.,*	Particulate matter emission from combustion and non-combustion automotive engine process: review and computational bibliometric analysis on its source, sizes, and health and lung impact	This study discusses the growth trend of scientific publications on the topic of particulate matter identified based on several categories such as the most cited, publisher, author, country and affiliation.	[52]

Online learning technology for mathematics and science has been the subject of extensive research. However, there has been a limited extent of computational mapping analysis using a bibliometric approach specifically focused on understanding publication trends in online learning technology for mathematics and science using Scopus database and it becomes the novelty of this research. This is particularly true for bibliometric analyses conducted within the past ten years (2018-2023) using the VOSviewer application. This research was aimed to conduct a computational mapping using bibliometric analysis of Scopus indexed publications, utilizing the VOSviewer application. This research serves as a valuable reference for experts exploring online learning technology in the fields of mathematics and science.

2. Methodology

Data from articles in journals indexed by Scopus were used in this study. Scopus database was chosen based on the consideration of its rigorous peer-review process and its internationally recognized reputation in the scientific publication world. The retrieval of the Scopus database has also been carried out by several previous studies [33,34]. The publication data were obtained using the Publish or Perish reference management application, which could be downloaded and accessed freely from the website https://harzing.com/resources/publish-or-perish. The installation process and detailed usage of the application were explained by [35], while the data search procedure was elucidated by [36]. The collected data were subsequently used for a literature review on the selected topic. This research was conducted in several stages, as follows:

i. Utilizing the Publish or Perish application to gather Scopus indexed journal publications.
ii. Employing Microsoft Excel to process the bibliometric data obtained.
iii. Utilizing the VOSviewer application for computational mapping analysis of the collected publication data.
iv. Analysing the results from the computational mapping analysis.

The Publish or Perish application was employed to filter publications using the keywords “technology” AND “online learning” AND “math” OR “science”. The search was conducted in 08 July 2023, and the relevant publications were limited to the period from 2014 to 2023. The search results were saved in comma-separated value format (*.csv) and research information system (*.ris). These data were further analysed using VOSviewer for visualization and evaluation of trends through bibliometric mapping.

3. Results

3.1 Publication of Data Search Results

The search conducted using the Publish or Perish application and Scopus database yielded a total of 458 publications that met the research criteria. The obtained metadata encompassed author names, titles, years, and citation counts. A sample of the publication data used in the VOSviewer analysis is presented in Table 2. This sample specifically includes the top 20 most-cited publications. The total citation count for the publications was 1912, with an average of 19.12 citations per year, an average of 95.6 citations per article, and an average of 4.16 authors. The high citations depicted in the data are due to the fact that in the last ten years, the development of educational implementation has increasingly led to online or blended learning with supporting technology, especially in the fields of mathematics and science.

Table 2
Publication data for online learning technology in mathematics and science

No.	Authors	Title	Year	Citations	Ref
1	Bernard *et al.,*	"A meta-analysis of blended learning and technology use in higher education: From the general to the applied"	2014	369	[53]
2	Paul & Jefferson	"A comparative analysis of student performance in an online vs. face-to-face environmental science course from 2009 to 2016"	2019	145	[54]
3	Chen *et al.,*	"A hybrid recommendation algorithm adapted in e-learning environments"	2014	141	[55]
4	Hansen & Reich	"Democratizing education? Examining access and usage patterns in massive open online courses"	2015	140	[56]
5	Mayer	"Thirty years of research on online learning"	2019	122	[57]
6	Sindiani *et al.,*	"Distance education during the COVID-19 outbreak: a cross-sectional study among medical students in north of Jordan"	2020	100	[58]
7	Mamun *et al.,*	"Instructional design of scaffolded online learning modules for self-directed and inquiry-based learning environments"	2020	82	[59]
8	Rapanta *et al.,*	"Balancing technology, pedagogy and the new normal: post-pandemic challenges for higher education"	2021	79	[60]
9	Kizilcec *et al.,*	"Scaling up behavioural science interventions in online education"	2020	74	[61]
10	Moazami *et al.,*	"Comparing two methods of education (virtual versus traditional) on learning of Iranian dental students: a post-test only design study"	2014	72	[62]
11	Qazi *et al.,*	"Conventional to online education during COVID-19 pandemic: do develop and underdeveloped nations cope alike"	2020	69	[63]
12	Al-Salman & Haider	"Jordanian university students' views on emergency online learning during covid-19"	2021	64	[64]
13	Hoic-Bozic *et al.,*	"Recommender system and web 2.0 tools to enhance a blended learning model"	2016	64	[65]
14	Hwang *et al.,*	"Effects of a social regulation-based online learning framework on students' learning achievements and behaviours in mathematics"	2021	61	[66]
15	Perrotta & Selwyn	"Deep learning goes to school: toward a relational understanding of AI in education"	2020	60	[67]
16	Mead *et al.,*	"Immersive, interactive virtual field trips promote science learning"	2019	60	[68]
17	Chen *et al.,*	"Exploring design elements for online STEM courses: active learning, engagement & assessment design"	2018	57	[69]
18	Bonk *et al.,*	"Understanding the self-directed online learning preferences, goals, achievements, and challenges of MIT open courseware subscribers"	2015	57	[70]

19	Chakraborty & Nafukho	"Strengthening student engagement: what do students want in online courses?"	2014	49	[71]
20	Debnath & Bardhan	"India nudges to contain COVID-19 pandemic: a reactive public policy analysis using machine-learning based topic modelling"	2020	47	[72]

3.2 Development of Research in Online Learning Technology for Mathematics and Science

The development of research in online learning technology for mathematics and science based on publications indexed by Scopus is shown in Table 3. The total number of publications in the field of online learning technology for mathematics and science was 458 (shown in the Table 2), with 22 publications in 2014, 25 in 2015, 17 in 2016, 20 in 2017, 21 in 2018, 32 in 2019, 40 in 2020, 99 in 2021, 125 in 2022, and 57 in 2023. Figure 1 provides an overview of the distribution of research on online learning technology for mathematics and science.

Table 3
Development of research in online learning technology for mathematics and science

Year of Publication	Number of Publications
2014	22
2015	25
2016	17
2017	20
2018	21
2019	32
2020	40
2021	99
2022	125
2023	57
Total	458
Average	127.5

Figure 1 reveals a notable trend in research on online learning technology for mathematics and science over the past ten years. In general, the trend is increasing, except in 2016 and 2023. In 2016, the number of publications decreased by 8, from 25 in 2015 to 17 in 2016. Also, in 2023, the number decreased from 125 to 57. However, this positive trend did not persist, as the number drastically increased in 2022. Trends show that research related to online learning technology for mathematics and science is still in a great demand. This is because, in 2023, journal publication calculations were only counted for half a year, so there is still a chance to increase again.

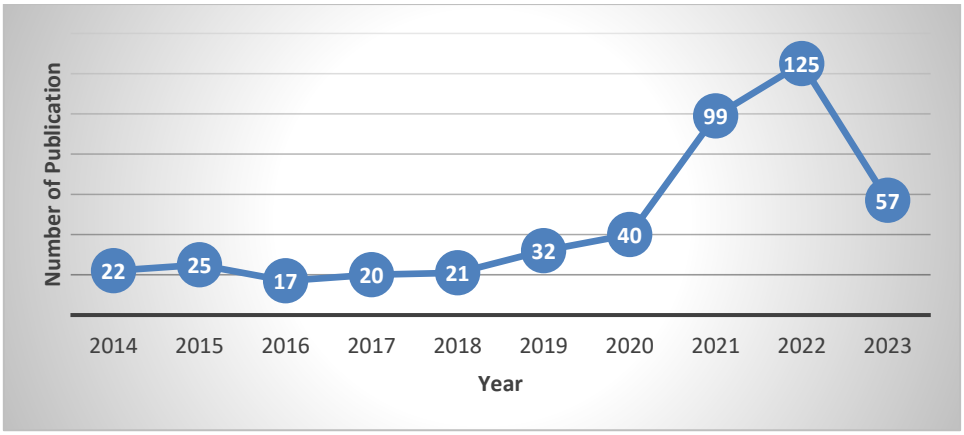

Fig. 1. Level of development of research on online learning technology for mathematics and science

3.3 Visualization of the Field of Online Learning Technology for Mathematics and Science using VOSviewer

The research data were analysed using computational mapping with VOSviewer. The analysis identified 150 distinct items, which were subsequently categorized into four clusters as follows:

i. Cluster 1, consists of 44 items marked in red. Cluster 1 includes algorithm, application, artificial intelligence, blended learning, classroom, collaborative learning, college student, combination, communication technology, computer science, concept, content, development, education, effect, environment, framework, guidance, ict, idea, importance, improvement, inquiry, internet, investigation, knowledge, learning, learning environment, learning experience, learning management system, learning process, lms, management system, module, motivation, rapid development, skill, social medium, student learning, system, teacher, technology, topic, dan web.
ii. Cluster 2, consists of 42 items marked in green. Cluster 2 includes adoption, attitude, college, covid, cross sectional study, difficulty, discipline, distance, distance education, distance learning, e learning, educational institution, faculty, health, higher education, higher education institute, information technology, issue, lecture, lecturer, lockdown, medical science, online education, online learning, online teaching, pandemic, present study, program, self-efficacy, social science, solution, stakeholder, study, teaching, technique, technology acceptance model, traditional face, transition, undergraduate student, university, university student, dan world.
iii. Cluster 3, consists of 36 items marked in blue. Cluster 3 includes assessment, assignment, collaboration, communication, creation, digital technology, evaluation, experience, flexibility, focus, future research, government, guideline, innovation, instruction, instructor, integration, interaction, interview, learner, lesson, methodology, nature, online course, online learning environment, pedagogy, perspective, professional development, project, quality, recommendation, reflection, strength, team, theory, dan video.
iv. Cluster 4, consists of 28 items marked in yellow. Cluster 4 includes academic performance, access, active learning, analytic, approach, behaviour, class, course, educational technology, educator, engineering, face, gap, gender, implication, intervention,

mathematics, online, online class, online environment, online learning platform, opportunity, person, platform, science, society, stem, dan student.

Cluster visualization demonstrates the interrelationship between terms. Each term was labelled with a differently coloured circle, with the size of circle reflecting the frequency of the term occurrence [39]. In other words, the more frequently the word occurs, the greater the circle appeared in the titles and abstracts, indicating a positive correlation between the term occurrence [37]. The mapping results were presented through three visualization components, namely network (Figure 2), overlay (Figure 3), and density (Figure 4).

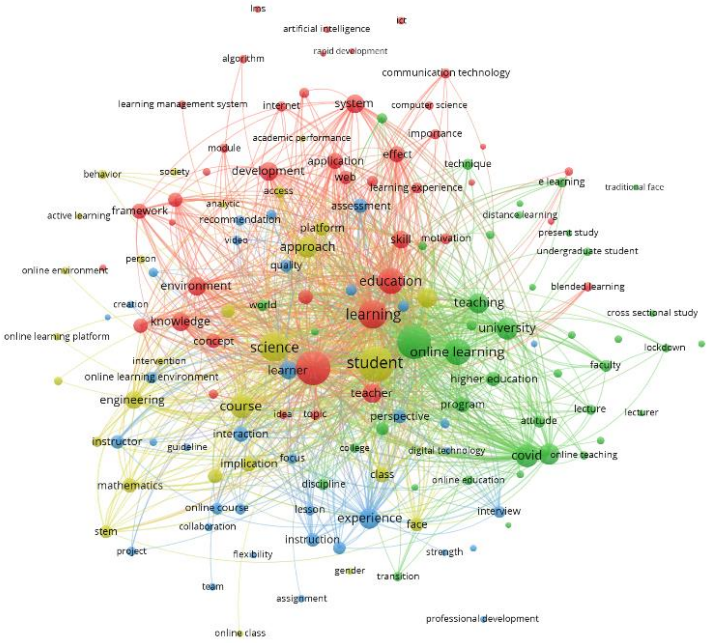

Fig. 2. Network visualization of the research keywords "technology" AND "online learning" AND "math" OR "science"

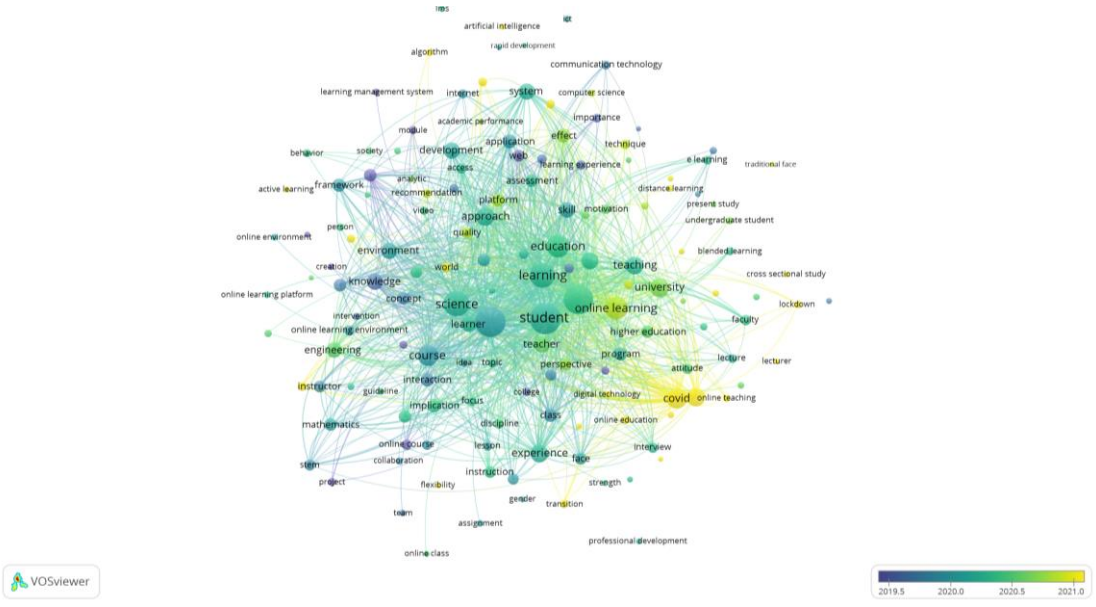

Fig. 3. Overlay visualization of the research keywords "technology" AND "online learning" AND "math" OR "science"

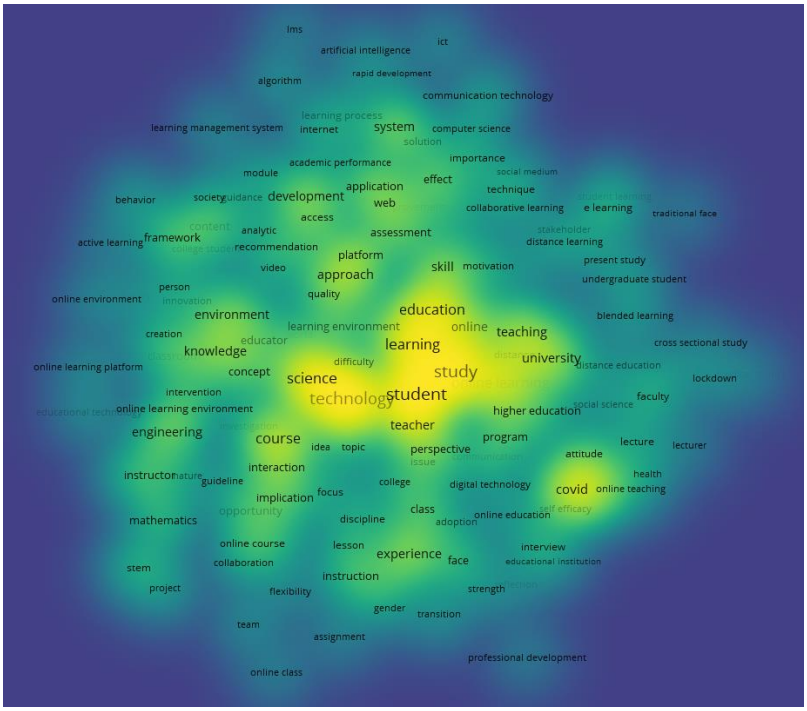

Fig. 4. Density visualization of the research keywords "technology" AND "online learning" AND "math" OR "science"

Figure 2 shows the relationships between terms within each cluster depicted through a connected network. These clusters, derived from the previous analysis, can be linked to the research topic of online learning technology for mathematics and science. Based on the examination of clusters in the network visualization, research in this area could be categorized into four distinct terms. The first term pertained to technology, which fell within cluster 1, with 149 links, a total link strength of 4936, and 324 occurrences (Figure 5).

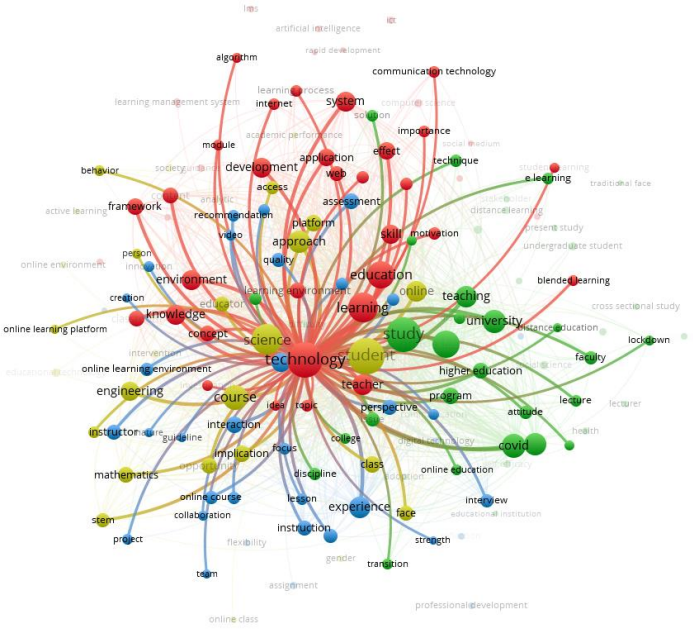

Fig. 5. Network visualization of the term of technology

The second term corresponded to online learning, which was categorized within cluster 2, with 149 links, a total link strength of 2921, and 181 occurrences (Figure 6).

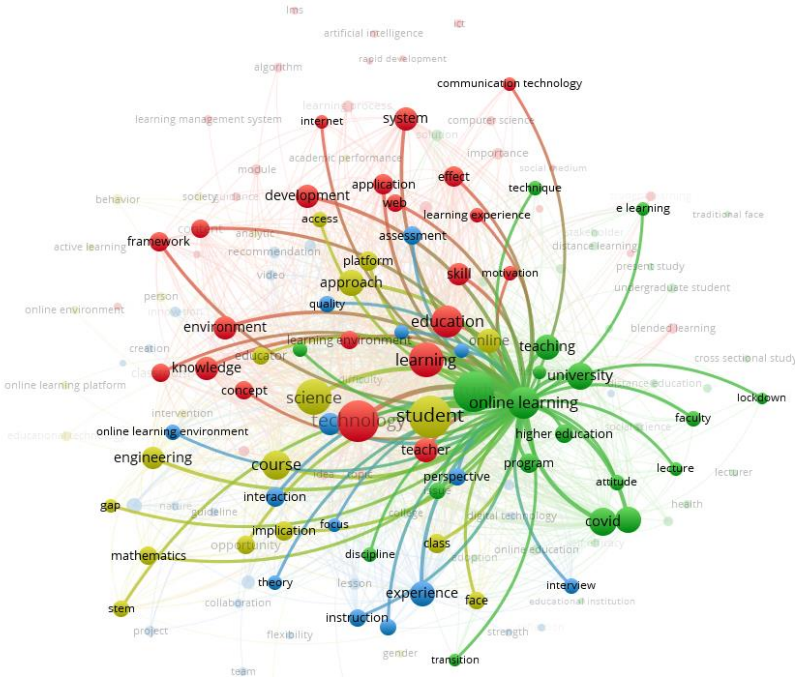

Fig. 6. Network visualization of the term of online learning

The third term was mathematics, categorized within cluster 4, with 138 links, a total link strength of 939, and 54 occurrences (Figure 7). The fourth term was related to science, which also fell within cluster 4, with 129 links, a total link strength of 2420, and 167 occurrences (Figure 8).

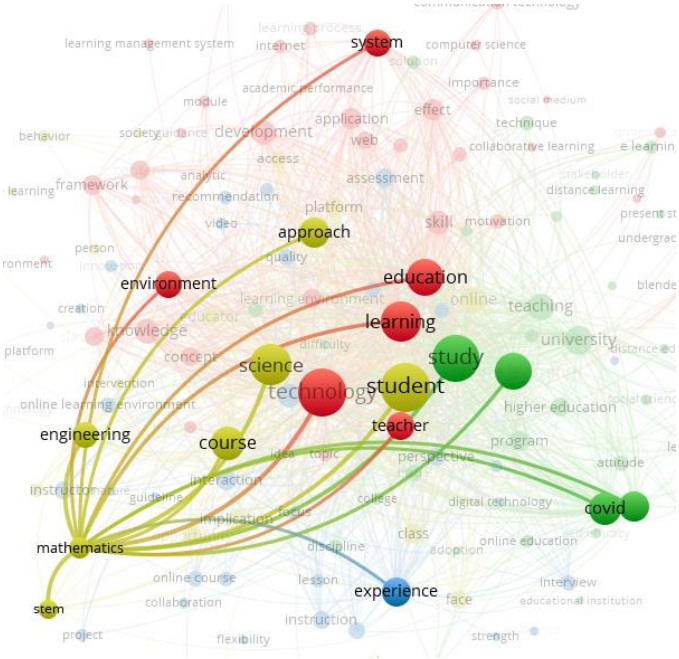

Fig. 7. Network visualization of the term of mathematics

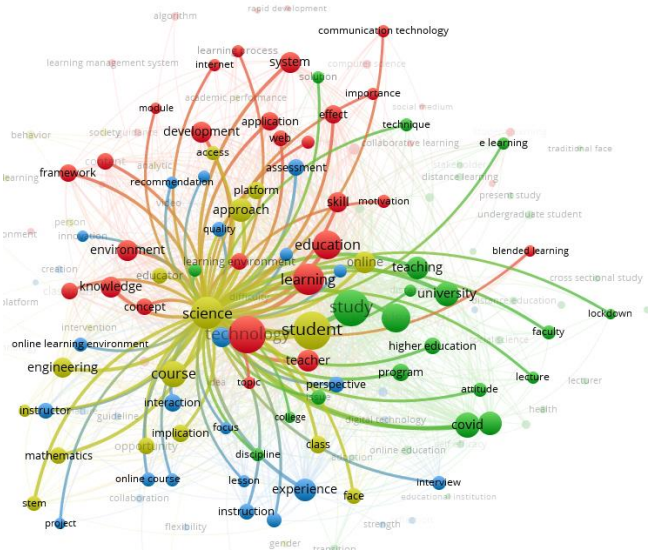

Fig. 8. Network visualization of the term of science

Each of the visualized figures describes different aspects. Figure 3 depicts the overlay visualization, which represents the novelty of research related to terms [37,39]. Figure 3 shows that research on online learning technology for mathematics and science was most prevalent between 2017 and 2022, indicating that new research in this field was relatively common due to its enduring popularity.

Figure 4 depicts density visualization, representing the frequency of term occurrence. Brighter colours and larger circle diameters indicate a more frequent occurrence [37,39,73-75]. In other words, the wider the circle and the more vibrant the colour, the more frequently the term was researched, and vice versa. Figure 4 shows that terms, such as science, education, learning, student, teacher, teaching, university, online learning environment, and covid exhibited a high frequency of occurrence.

Figures 5, 6, 7 and 8 demonstrate the relationships between fields and other terms. Figure 5 describes the relationships between technology and other terms, including science, student, course, idea, topic, teacher, learning, education, online, idea, concept, knowledge, online education, learning environment, blended learning, etc. Figure 6 shows the relationship between online learning and other fields, including student, teaching, university, higher education, program, covid, learning, education, online, science, course, engineering, mathematics, application, web, application, etc. Figure 7 depicts the relationship between mathematics and other fields, including stem, engineering, approach, course, science, student, study, covid, experience, etc. Lastly, Figure 8 shows the relationship between science and other fields, including technology, student, learning, education, online, teacher, course, online learning environment, engineering, mathematics, knowledge, learning environment, study, teaching, online, etc.

The mapping results from the collected publication data indicated that the keywords “technology” AND “online learning” AND “math” OR “science” has been done a lot and still has the opportunity to be conducted. The biggest opportunity is seen in the math keyword which seems to still have a narrow area [76-80]. Research was also generally carried out separately in certain terms. This presents opportunities for further explorations on online learning technology for mathematics and science.

4. Conclusions

This research aimed to carry out a computational mapping-based bibliometric analysis to explore the field of online learning technology for mathematics and science. The analysis utilized publication data obtained from Scopus through the Publish or Perish application, focusing on the titles and abstracts. A total of 458 relevant articles, published between 2014 and 2023, were identified from the search results. The analysis revealed an increasing trend in research on online learning technology for mathematics and science from 2016 to 2023, with the exception of the year 2016 and 2023. The highest number of publications occurred in 2022. This suggests that research in this field still has considerable opportunities for further explorations as well as potential connections with other related terms.

Acknowledgement
This research was not funded by any grant.

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