



Trends and Patterns in Mathematics Education: A Bibliometric Study of Innovative Teaching Strategies in Mathematics Instruction

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Abstract

This study examined the trends and patterns of the innovative teaching strategies in mathematics instruction from a bibliometric perspective. A bibliometric analysis is a systematic approach that helps a researcher understand the global research trends in a specific field. To better understand the current trends, an analysis of the leading countries in innovation, the sources with the highest publications, and keywords with the most occurrences was conducted. The study made use of 295 articles which were extracted from the Scopus database. The year 2020 saw the highest rise in literature on innovative teaching strategies. The study's findings revealed that China is the leading country in terms of innovative teaching strategies in mathematical instruction, followed by Indonesia, Russia, India, and the United States. Applied Mathematics and Nonlinear Sciences emerged as the preeminent journal for innovative teaching strategies, with Education and Information Technologies, Sustainability and Eurasia Journal of Mathematics, Science and Technology Education exhibiting identical metrics. The term "co-occurrence" emphasised the significance of new pedagogical approaches and the importance of technological advancements in mathematics education. English as the only language and Scopus as the only database were highlighted as limitations of the study.

Keywords: Bibliometric Analysis, Innovation, Mathematics Instruction, Teaching Strategy, VOSviewer

Introduction

The educational system today is characterized by rapid societal shifts, where advancements occur swiftly, and the pervasive influence of information and communication permeates every facet of human existence. Numerous researchers, communities, and institutions emphasize the significance of adequately preparing educators to employ appropriate technologies and teaching methods in the realm of mathematics instruction (Marpa, 2021; Wardat et al., 2023; Weist, 2024). These innovations have fundamentally reshaped our perception of mathematics, the expectations of it, its practical applications, and, perhaps, the dynamics of learning and teaching the subject (Koparan, 2017).

Innovation is an important concept of mathematics learning process. DasGupta (2017) and Demyanenko (2020) defined innovation as the process of conceiving, creating, developing, or implementing novel or modified products, services, procedures, systems, organizational structures, or business models

with the aim of generating fresh value for students. This perspective closely aligns with that of Kovacs (2017) and Tribuanaswary et al. (2021), who posit that innovation encompasses the practical realization of ideas leading to the introduction of new products or services or the enhancement of existing ones. Other researchers added that the systematic rejuvenation and modernization of a particular domain, product, or service by introducing novel approaches, employing innovative techniques, or applying successful concepts to generate new value are all forms of innovation in education (Kovalenko et al., 2019; Khan et al. 2020). Consequently, innovation is defined as the process of converting opportunities into novel ideas and then applying these ideas widely in mathematics instruction.

Mathematics is a discipline focused on the organization, patterns, and connections. The progression in mathematics stems from humanity's ongoing quest to quantify, measure, calculate, and



predict events using logical reasoning (Ugwuanyi et al., 2023). Sharma (2021) characterized mathematics as the study of topics such as quantity, structure, space and change, while Metu et al. (2023) assert that mathematics comprises a foundational set of concepts, facts, principles, and operations that underpin the functioning of any human endeavour or technology which are key in mathematics instruction. According to Kiru et al. (2018), mathematics instruction is what transpires in the processes of teaching and learning mathematics, between the learner and the instructor, which has to do with what, why, when and how to teach that which is to be taught. It is a systematic method that integrates empirically supported instructional principles to proficiently and effectively impart essential mathematical concepts (Doabler et al., 2018). Effective mathematics instructor should teach for conceptual understanding and promote strategic competence through meaningful problem-solving investigations (VanDerHeyden & Allsopp, 2014). However, the method of teaching and learning of mathematics has been questioned by many scholars. In a study by Chand et al. (2021), ineffective mathematics curriculum was found to be one of the major causes of poor students' performance in mathematics. In a similar study by Ali and Jameel (2016) and Gnawali (2024), ineffective teaching methods and teacher strictness were the major causes of low academic grades in mathematics related contexts. While Owan and Agunwa (2012) attributed the reasons for poor mathematics achievement to include lack of motivation and understanding on the part of the students, they highlighted the inadequate teaching and learning materials was a major attribute of the poor recorded performances over the years. These finding calls for a shift from the traditional teaching methods to an interdisciplinary approach to education. It also questions the teaching strategies in use over the years during the process of teaching and learning of mathematics. To this end, it is imperative to examine the innovative methods in mathematics instruction which has been in use since the 21st century from the bibliometric perspective to better understand its trends and the patterns.

A bibliometric analysis is one of the systematic ways of evaluating enormous quantities of scientific material. It allows a researcher to unpack the historical complexities of a particular field of study, while revealing the key areas within that domain (Donthu et al., 2021; Kumar et al. 2023). Researchers can employ sophisticated bibliometric analytic tools to form bibliographic couplings, quantify the intensity of the

resulting linkages, analyse bibliometric networks, create bibliographic maps, and subsequently explore and visualise these maps (Karakus, 2019). According to Chen et al., (2017), Derviş (2019) Alsharif et al. (2020) and Abdullah et al. (2023), a bibliometric analysis is an approach which helps a researcher to understand the global research trends in a specific topic based on the outputs of past literatures.

Previous bibliometric study by Julius et al. (2025) focused on a general overview of mathematics education without specifically identifying the scientific data on innovative teaching strategies. The research of Irawan et al. (2024) investigated trends in computational thinking in mathematics learning, whereas this study focused on trends in innovative teaching practices. The recent bibliometric research by Ibragimov et al. (2024) is similar to the present study, but the study centered on developments in science education, whereas the current trend is on mathematics instruction. Yig (2022) conducted a study comparable to this present one. However, it only examined the top contributing journals from 2017 to 2021, but this study covered the period 2000 to 2024. With differences observed in previous literatures and teaching strategies in mathematics instruction found to be ineffective, it is important to examine the available scientific data to better understand the leading countries, the major sources of literature to determine the frequency and patterns of citations between publications, revealing the impact and influence of research and the word co-occurrence to determine the most important keywords.

Objectives:

1. To determine the leading countries in innovative teaching strategies research in mathematics instruction?
2. To find out the most important sources of literature in innovative teaching strategies research in mathematics instruction?
3. To explore the most important keywords in innovative teaching strategies research in mathematics instruction?

Methods

In a bibliographic study, data can be categorised into many attributes including keywords, subjects, countries, sources, titles, affiliations, among others (Ma et al. 2022; Metu et al., 2025). Bibliometric analysis utilises a wide range of databases such as Scopus, WOS, Google Scholar, Dimensions, OpenAlex, among others to collect, alter, and evaluate



bibliographic data. In this study, the Scopus database was the source for the data collection. In a comparison of data sources, Vieira and Gomes (2009) found that the Scopus database had the most comprehensive coverage of literatures compared to other data sources. Scopus was also found by Siguenza-Guzman et al. (2015) as a multidisciplinary database that offers superior coverage of identified journal articles. A total of 295 articles related to innovative teaching strategies were retrieved from the Scopus database (retrieved February 1, 2025). In this study, the coverage of data spanned from 2000 – 2024. The term “innovative teaching strategy* OR method*” AND “math* instruction* OR teaching*” were included in the search. This is aimed at retrieving

all the possible documents available in the Scopus database. The search also included only journal articles written in English. Data collected were analyzed using the VOSviewer software (v1.6.20). The software was deemed suitable for this study because of its low-dimensional visualisation, which accurately depicts the similarity between any two items (Van Eck et al., 2010; Hong et al., 2020; Wani, 2023). The nodes on the map signify elements, while the linkages denote interactions among these elements (Cheng et al., 2022; Lyu et al. 2024;). The lines connecting the nodes represent relationships, with the dimensions of each element determined by their occurrences. A distinct node was employed for various clusters to facilitate identification.

Results and Discussion

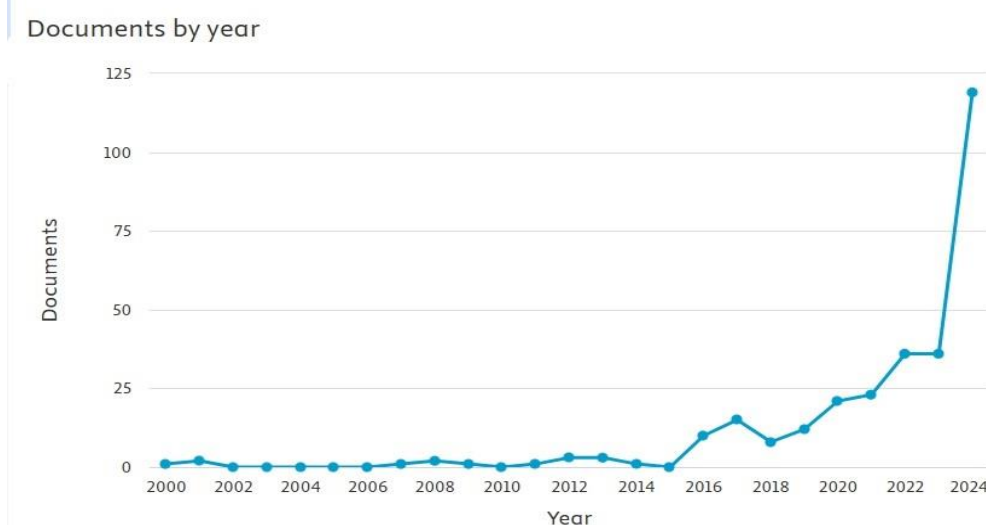


Figure 1. Frequencies of documents per year

The analysis of the documents from the Scopus database produced 295 articles. The retrieved data also showed document on innovative teaching strategies in mathematics instruction and their evolution from 2000 to 2024. The findings from figure 1 showed the rise in literature. The years 2000 to 2015 produced little result. Perhaps, the mathematics teachers relied so much on the

traditional teaching methods. Interest on innovation started to grow from the year 2016 with a dip in 2018. The trend has continued to rise with a remarkable increase in year 2024. This rise could be attributed to effort of researchers in an attempt to find the most suitable strategies to make mathematics learning more relevant and practical.

Analysis of the bibliometric coupling of countries

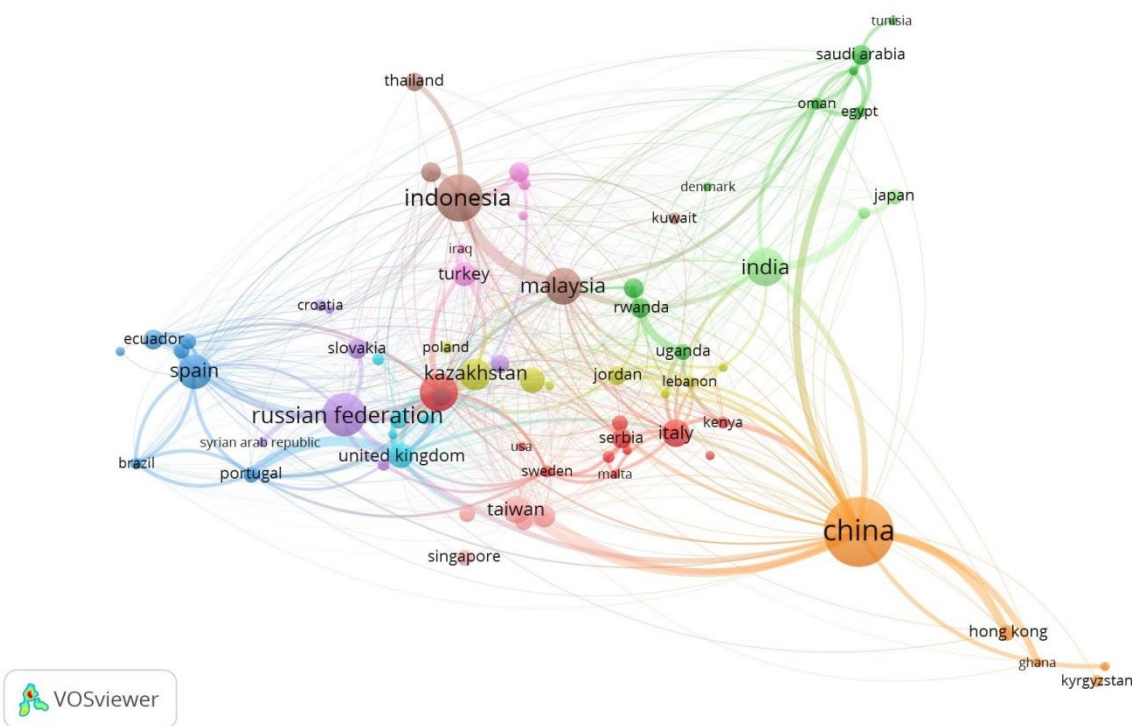


Figure 2. Analysis of Bibliographic Coupling of Countries

An analysis of bibliometric coupling of countries was conducted to determine the distribution of publications with respect to countries where the studies were conducted. The available data showed a total of 78 countries. All the countries were included in the bibliometric map. The authors considered all the countries relevant, hence the inclusion of all the available data. China came out top as the country with

the most publications followed by Indonesia, Russia, India and the United States. China did not appear to be surprising giving that the country has made significant investments in the area of research and development spending \$496 billion in 2024 (Avcioglu, 2025). This has brought about an increase in the number of mathematicians and scientists.

Analysis of Bibliographic Coupling of Sources

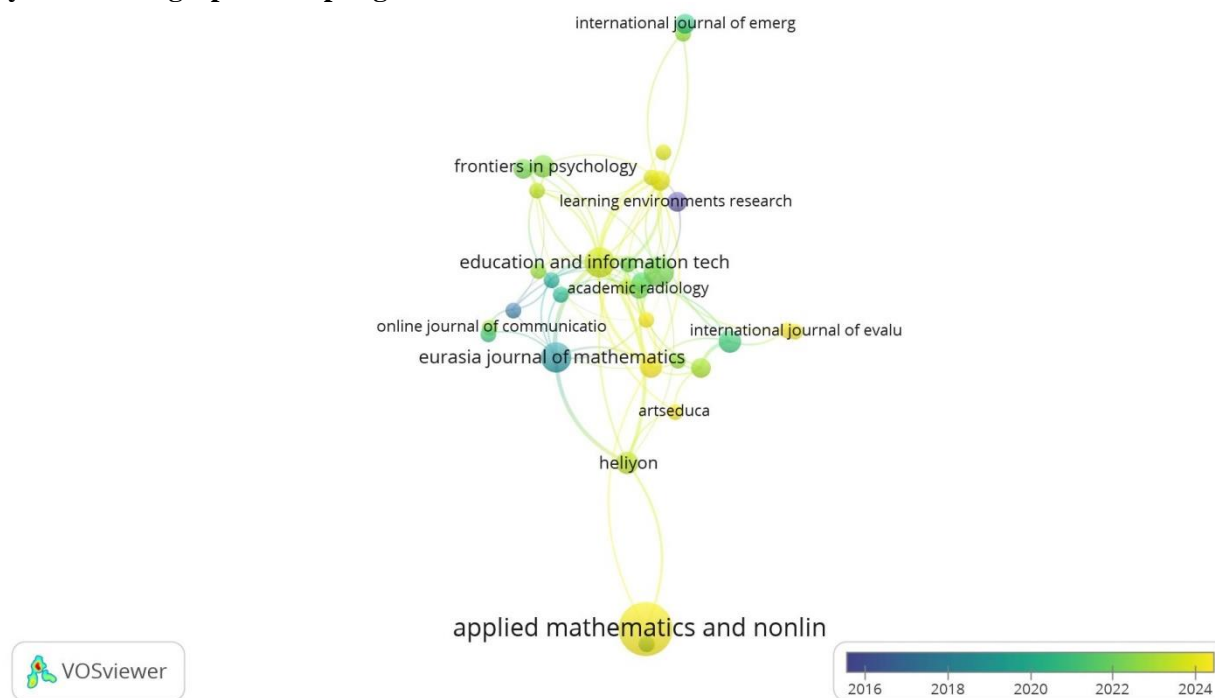


Figure 3: Bibliographic coupling of sources

The researchers conducted a bibliographic study of the source citations to determine which sources have the most publications on innovative teaching strategies in mathematics instruction. For this analysis, the researchers considered only sources with more than one publication. This is to include only the important contributors to the study. A total of 197 sources were retrieved from the database. By considering sources with more than one publication, only 43 sources met the

threshold. This represents only 21.8% of the total publication. Applied Mathematics and Nonlinear Sciences was the journal with the highest publication with a total of 22 articles (11.1%). Education and Information Technologies, Sustainability and Eurasia Journal of Mathematics, Science and Technology Education all had 7 articles each representing 3.55% of the total articles.

Analysis of Co-occurrence of keywords

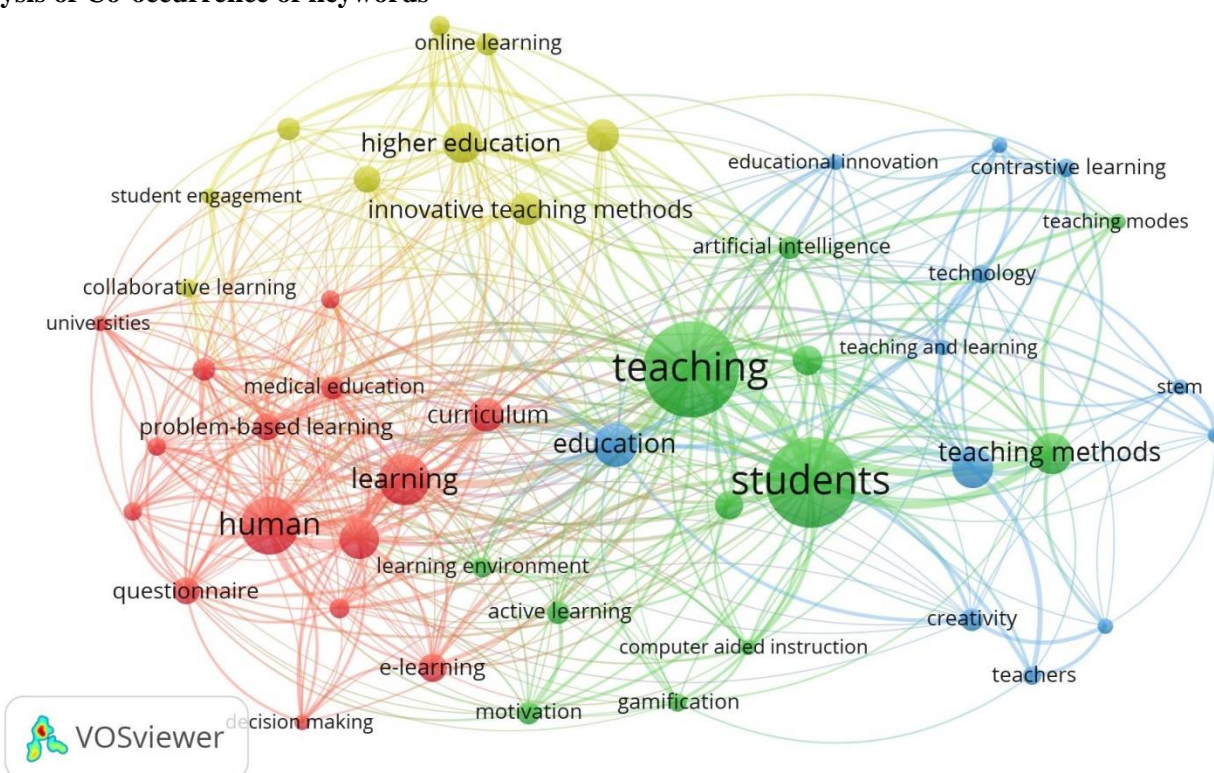


Figure 4: Co-occurrence of keywords

The analysis of the word co-occurrence was carried out to determine the most important keywords in innovative teaching strategies in mathematics instruction. A total of 1792 keywords were found in the study. By considering keywords with five or more occurrences, 1731 keywords were eliminated leaving only 61 keywords. Furthermore, the authors used thesaurus to clean up keywords that appeared twice in the analysis. Nine keywords were eliminated and only 52 keywords survived representing 2.9% of the total keywords found in the initial search.

The keywords are grouped in four clusters, each on a different colour of red, green, blue and yellow. The keywords on the red cluster includes decision making, e-learning, problem solving learning, procedures, surveys, among others. This shows a strong focus on educational research and learning approaches, demonstrating a growing interest in understanding successful teaching and learning strategies. It also highlights a shift in focus towards innovative and technologically advanced learning methodologies. The green cluster housing keywords such as teachers, students, learning environment, artificial intelligence among others suggests that teachers are realizing the

importance of creating effective and engaging learning experiences for the students through the use of technology. The presence of keywords such as educational innovation, technology, STEM education, and computational thinking in the blue cluster emphasizes the use of technology in the teaching and learning of mathematics. In the yellow cluster, distance learning, covid-19, collaborative learning, online learning, higher education, among other keywords were grouped together. This suggests that there was an increase to the use of innovation in higher education after the covid-19 pandemic, as many institutions turned to blended learning, online learning and collaborative learning.

Conclusion

Innovative teaching strategy is particularly important in any learning environment particularly in mathematics instruction. With a focus on technologies, teachers will be able to meet the unique needs of each individual. This bibliometric study has shown various trends and patterns in mathematics education research. The surge in literature in the 2024 shows that educators are beginning to realize that innovative teaching



strategy could be key to unlocking students understanding of mathematics concepts which could bring about an increase in academic achievement. The findings of the study revealed that China is the leading country in innovative strategies in mathematics followed by Indonesia, Russia, India and the United States. Applied Mathematics and Nonlinear Sciences stood out as the most sourced journals when it comes to innovative teaching strategies with the next four journals all sharing the same metric. The word co-occurrence also highlighted the importance of innovative teaching strategies and role technology has played in mathematics instruction.

The study has some limitations. Scopus was the only database used in this present study for data retrieval. Future researchers can look into other databases not considered by the authors so as to make comparison. Only texts in English language were considered in this study. An inclusion of studies done in other languages might yield a different result. The current study also considered only article publications for data analysis. Future researchers may include other sources of data to draw conclusion. It was therefore recommended that online learning be integrated into the school curriculum as it will promote the use of various innovative tools in the learning process.

References

- Abdullah, K. H., Roslan, M. F., Ishak, N. S., Ilias, M., & Dani, R. (2023). Unearthing hidden research opportunities through bibliometric analysis: a review. *Asian Journal of Research in Education and Social Sciences*, 5(1), 251-262. <https://doi.org/10.55057/ajress.2023.5.1.23>
- Ali, H.H & Jameel, H.T. (2016). Causes of poor performance in mathematics from teachers, parents and student's perspective. *American Scientific Research Journal for Engineering, Technology, and Sciences*, 15(1), 122-136. <https://bit.ly/4bexOCE>
- Alsharif, A.H., Salleh, N.Z. & Baharun, R. (2020). Research trends of neuromarketing: a bibliometric analysis. *Journal of Theoretical and Applied Information Technology*, 98(15), 2948-2962. <http://bit.ly/4d1qY4r>
- Avcioglu Mucathithan (2025). China's spending on research and development surpassed \$496B in 2024. Retrieved from <https://bit.ly/4hUAdoA>
- Chand, S., Chaudhary, K., Prasad, A., & Chand, V. (2021). Perceived causes of students' poor performance in mathematics: a case study at Ba and Tavua secondary schools. *Frontiers in Applied Mathematics and Statistics*, 7, 614408. <https://doi.org/10.3389/fams.2021.614408>
- Chen, W., Liu, W., Geng, Y., Brown, M. T., Gao, C., & Wu, R. (2017). Recent progress on emery research: a bibliometric analysis. *Renewable and Sustainable Energy Reviews*, 73, 1051-1060. <https://doi.org/10.1016/j.rser.2017.02.041>
- Cheng, K., Guo, Q., Shen, Z., Yang, W., Wang, Y., Sun, Z., & Wu, H. (2022). Bibliometric analysis of global research on cancer photodynamic therapy: focus on nano-related research. *Frontiers in Pharmacology*, 13, 1-19. <https://doi.org/10.3389/fphar.2022.927219>
- DasGupta, R. (2017). Fostering innovation and entrepreneurship. *Technology and Innovation*, 19(1), 345-348. <http://dx.doi.org/10.21300/19.1.2017.345>
- Demyanenko, N. (2020). Educational innovation studies as a complex system. *Interdisciplinary Studies of Complex Systems*, (16), 87-101. <https://doi.org/10.31392/iscs.2020.16.087>
- Derviş, H. (2019). Bibliometric analysis using bibliometrix an R package. *Journal of Scientometric Research*, 8(3), 156-160. <https://dx.doi.org/10.5530/jscires.8.3.32>
- Doabler, C. T., Nelson, N. J., Kennedy, P. C., Stoolmiller, M., Fien, H., Clarke, B., Gearin, B., Smolkowski, K., & Baker, S. K. (2018). Investigating the longitudinal effects of a core mathematics program on evidence-based teaching practices in mathematics. *Learning Disability Quarterly*, 41(3), 144-158. <https://doi.org/10.1177/0731948718756040>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: an overview and guidelines. *Journal of Business Research*, 133, 285-296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Gnawali, Y. P. (2024). Causes of poor performance in mathematics at school education examination (SEE). *Ganeshman Darpan*, 9(1), 71-78. <http://dx.doi.org/10.3126/gd.v9i1.68537>
- Hong, R., Liu, H., Xiang, C., Song, Y., & Lv, C. (2020). Visualization and analysis of mapping knowledge domain of oxidation studies of sulfide ores. *Environmental Science and Pollution Research*, 27, 5809-5824. <https://doi.org/10.1007/s11356-019-07226-z>
- Ibragimov, G. I., Murkshtis, M., Zaitseva, N. A.,



- Kosheleva, Y. P., Sadykova, A. R., & Shindryaeva, N. N. (2023). Research trends on learning environment in science education. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(11), em2351. <https://doi.org/10.29333/ejmste/13680>
- Irawan, E., Rosjanuardi, R., & Prabawanto, S. (2024). Research trends of computational thinking in mathematics learning: a bibliometric analysis from 2009 to 2023. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(3), em2417. <https://doi.org/10.29333/ejmste/14343>
- Julius, R., Halim, M. S. A., Hadi, N. A., Alias, A. N., Khalid, M. H. M., Mahfodz, Z., & Ramli, F. F. (2021). Bibliometric analysis of research in mathematics education using Scopus database. *Eurasia Journal of Mathematics, Science and Technology Education*, 17(12). <https://doi.org/10.29333/ejmste/11329>
- Khan, M. T., Khan, T. I., & Khan, S. (2020). Innovation & its diffusion in business: *Concept, Stages & Procedural Practices*. *SJESR*, 3(4), 174-186. [https://doi.org/10.36902/sjesr-vol3-iss4-2020\(174-186\)](https://doi.org/10.36902/sjesr-vol3-iss4-2020(174-186))
- Kiru, E. W., Doabler, C. T., Sorrells, A. M., & Cooc, N. A. (2018). A synthesis of technology-mediated mathematics interventions for students with or at risk for mathematics learning disabilities. *Journal of Special Education Technology*, 33(2), 111-123. <https://doi.org/10.1177/0162643417745835>
- Karakus, M., Ersozlu, A., & Clark, A. C. (2019). Augmented reality research in education: a bibliometric study. *Eurasia Journal of Mathematics, Science and Technology Education*, 15(10), 1-12. <https://doi.org/10.29333/ejmste/103904>
- Koparan, T. (2017). Analysis of teaching materials developed by prospective mathematics teachers and their views on material development. *Malaysian Online Journal of Educational Technology*, 5(4), 8-28. <https://mojet.net/index.php/mojet/article/view/111>
- Kovacs, H. (2017). Learning and teaching in innovation: why it is important for education in 21st century. *Neveléstudomány/ Oktatás-Kutatás-Innováció*, 5(2), 45-60. <https://doi.org/10.21549/NTNY.18.2017.2.4>
- Kovalenko, K. E., Bakhvalov, S. Y., Zekiy, A. O., Vikulina, V. V., Tinkov, S. A., & Tkacheva, T. V. (2019). Key indicators of innovation activity of Russia (from 2011 to 2017). *Journal of Entrepreneurship Education*, 22(3), 1-7. <https://bit.ly/43cFkw6>
- Kumar, M., George, R. J., & Anisha, P.S. (2023). Bibliometric analysis for medical research. *Indian Journal of Psychological Medicine*, 45(3), 277-282. <https://doi.org/10.1177/02537176221103617>
- Lyu, Y., Li, W., Guo, Q., & Wu, H. (2024). Mapping knowledge landscapes and emerging trends of marburg virus: a text-mining study. *Heliyon*, 10(8), e29691. <https://doi.org/10.1016/j.heliyon.2024.e29691>
- Ma, C., Xu, Q., & Li, B. (2022). Comparative study on intelligent education research among countries based on bibliographic coupling analysis. *Library Hi Tech*, 40(3), 786-804.
- Marpa, E. P. (2021). Technology in the teaching of mathematics: an analysis of teachers' attitudes during the covid-19 pandemic. *International Journal on Studies in Education (IJonSE)*, 3(2), 91-102. <https://doi.org/10.46328/ijonse.36>
- Metu, C.A., Marbán, J.M., & Espina, E. (2025). Growth mindset in mathematics: a bibliometric analysis. *Journal of Research and Advances in Mathematics Education*, 10(1), 1-14. <https://doi.org/10.23917/jramathedu.v10i1.6482>
- Metu, C.A., Ugwuanyi, C.C, Nwoye, M.N., Odo, I.O. & Nwachukwu, W.C. (2023). Unlocking students areas of difficulties in mathematics through the teachers creativity fostering behaviours. *International Journal of Research and Innovation in Social Science (IJRISS)*, 7(9), 389-396. <https://dx.doi.org/10.47772/IJRISS.2023.70932>
- Owan, V. J., & Agunwa, J. N. (2012). Principals' administrative competence and teachers' work performance in secondary schools in calabar education zone of Cross River state, Nigeria. *Online Submission*, 7(1), 20-28. <http://dx.doi.org/10.2139/ssrn.3221784>
- Sharma, P. (2021). Importance and application of mathematics in everyday life. *International Journal for Research in Applied Science and Engineering Technology*, 9(11), 868-879. <https://doi.org/10.22214/ijraset.2021.38869>
- Siguenza-Guzman, L., Saquicela, V., Avila-Ordóñez, E., Vandewalle, J., & Cattysse, D. (2015). Literature review of data mining applications in



- academic libraries. *The Journal of Academic Librarianship*, 41(4), 499-510. <https://doi.org/10.1016/j.acalib.2015.06.007>
- Tribuanaswary, T., Rahmadani, P., & Dara Damanik, E. S. (2021). The new innovation of learning strategy during pandemic for state islamic university of north sumatera students. *Jurnal Pendidikan Nusantara*, 1(1), 36-43. <http://doi.org/10.55080/jpn.v1i1.1>
- Ugwuanyi, C. C., Metu, C. A., Nzeakor, E. C. Odo, I. O., Okeke, A. M. , Osakwe, I. J., Onah, E. N., Shiaki, O. B. & Ugwuanyi, C. S. (2023). Teachers' self-regulation and sociability as predictors of students' academic achievement in bearing and distances. *European Chemical Bulletin*, 12(8), 7928-7937, <https://bit.ly/3TkIKHc>
- Van Eck, N. J., Waltman, L., Dekker, R., & Van Den Berg, J. (2010). A comparison of two techniques for bibliometric mapping: multidimensional scaling and VOS. *Journal of the American Society for Information Science and Technology*, 61(12), 2405-2416. <https://doi.org/10.1002/asi.21421>
- VanDerHeyden, A., & Allsopp, D. (2014). Innovation configuration for mathematics. Document No. IC-6): Retrieved from University of Florida, Collaboration for Effective Educator, Development, Accountability, and Reform Centre website: <http://cedar.education.ufl.edu/tools/innovation-configuration>
- Vieira, E. S., & Gomes, J. A. (2009). A comparison of scopus and web of science for a typical university. *Scientometrics*, 81, 587-600. <https://doi.org/10.1007/s11192-009-2178-0>
- Wani, N. S. (2023). Compassionate capitalism: an analysis of its trends and themes. *International Journal of Financial Management and Economics*, 6(1), 51-57. <https://doi.org/10.33545/26179210.2023.v6.i1.167>
- Wardat, Y., Tashtoush, M. A., AlAli, R., & Jarrah, A. M. (2023). ChatGPT: a revolutionary tool for teaching and learning mathematics. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(7), 1-18. <https://doi.org/10.29333/ejmste/13272>
- Wiest, L. R. (2024). The role of computers in mathematics teaching and learning. In *Using information technology in mathematics education* (pp. 41-55). CRC Press.
- Yig, K. G. (2022). Research trends in mathematics education: a quantitative content analysis of major journals 2017-2021. *Journal of Pedagogical Research*, 6(3), 137-153. <https://doi.org/10.33902/JPR.202215529>
- Zheng, Q., Xu, J., Liu, M., Ji, K., Zhang, Y., Wu, S., Li, T., Yuan, K., Ma, Z., Ma, Z., Tian, J., & Li, J. (2025). Mapping the research landscape: a comprehensive bibliometric review of global warming and human health. *International Journal of Climatology*, 45(5), 1-13. <https://doi.org/10.1002/joc.8761>