

# Trends, challenges and opportunities for MOOCs in learning mathematics: a bibliometric analysis

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## ABSTRACT

This study examines the trends, challenges, and opportunities in the use of Massive Open Online Courses (MOOCs) within mathematics education. Employing a descriptive bibliometric approach, this research analyzed 1.800 publications indexed in Dimensions.ai from 2020 to 2025 using VOSviewer software to visualize and interpret keyword co-occurrence, citation patterns, and research networks. The results indicate a substantial growth in MOOC related mathematics studies from 2020 to 2022, followed by stabilization during 2023–2025, signaling the transition of MOOCs from emergency digital instruction toward a more structured and sustainable learning ecosystem. The visualization results identified four dominant thematic clusters: (1) pedagogical engagement and learning design, (2) data analytics and intelligent systems, (3) access, equity, and institutional policy, and (4) cognitive and affective learning outcomes. Despite significant progress in expanding global access to mathematical learning, persistent challenges remain particularly low course completion rates, limited adaptivity of mathematical content, and infrastructural disparities across regions. Nevertheless, the integration of AI-based personalization, learning analytics, and immersive technologies (VR/AR) provides promising directions for enhancing mathematical reasoning, engagement, and teacher professional development. Overall, this study contributes a comprehensive bibliometric overview and highlights the potential for MOOCs to evolve into adaptive, equitable, and data-informed digital learning ecosystems that advance the quality and inclusivity of mathematics education.

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## 1. INTRODUCTION

The rapid growth of digital technology has transformed the landscape of higher education and reshaped the way knowledge is produced, distributed, and consumed. The emergence of Massive Open Online Courses (MOOCs) has been one of the most influential innovations in open and distance education during the last decade, providing access to learning opportunities for millions of people worldwide (Zawacki-Richter et al., 2020). MOOCs represent a paradigm shift from traditional classroom-based learning to scalable, technology-driven ecosystems that emphasize accessibility, flexibility, and inclusivity (Alturkistani et al., 2020). This transformation aligns with global educational objectives that promote equitable access and lifelong learning, particularly in science, technology, engineering, and mathematics (STEM) disciplines.

In mathematics education, the integration of MOOCs has gained increasing attention due to the discipline's inherent emphasis on abstract reasoning and conceptual understanding (Guo et al., 2023). The ability of MOOCs to provide multimedia visualizations, interactive simulations, and automated feedback has made them particularly promising for addressing challenges in teaching complex mathematical concepts. However, despite their potential, MOOCs in mathematics still face significant pedagogical and technological limitations that affect learner engagement and persistence (Chen et al., 2020; Mohammad, 2021). Addressing these limitations requires a comprehensive understanding of the trends and research patterns that have shaped the development of mathematics MOOCs in recent years.

Previous research has explored various aspects of MOOCs, including learner motivation, engagement, and completion rates (Chaw & Tang, 2019; Milligan & Littlejohn, 2017). Studies have also analyzed instructional design strategies and learning analytics that improve student achievement and participation (Tang & Hew, 2022; Wang & Chen, 2025). Nevertheless, most of these investigations have focused on general education or computer science contexts, leaving a gap in the systematic examination of MOOCs specifically within mathematics education (Kornia et al., 2022). Consequently, the need arises for a focused bibliometric analysis that identifies dominant themes, research gaps, and potential opportunities related to MOOCs in mathematics learning. Mathematics is a discipline that relies heavily on sequential logic, cumulative understanding, and iterative feedback. Traditional online learning environments often fail to accommodate these characteristics effectively, leading to low completion and engagement rates in MOOCs (Abwatted & Miri, 2018; Mohammad, 2021). Learners frequently encounter cognitive overload or motivational fatigue when mathematical content is presented passively through videos and quizzes (Chen et al., 2020). Therefore, recent trends have emphasized adaptive instructional design, integration of AI-driven personalization, and data analytics to provide responsive, learner-centered pathways in mathematics MOOCs (Cao et al., 2022; Sun et al., 2024).

The integration of learning analytics and intelligent systems has become a crucial element in understanding student behavior and enhancing course design (Ruth & Juan, 2021). By analyzing digital traces and engagement data, educators can identify learning patterns, predict performance, and deliver personalized feedback. Such data-informed pedagogy aligns with constructivist and connectivist perspectives, wherein learners actively build knowledge through interaction, reflection, and digital collaboration (Ficicli et al., 2016; Cohen & Holstein, 2018). In mathematics education, these approaches are essential for fostering problem-solving and reasoning skills, which are central to deep conceptual understanding.

Despite technological advancements, equity and accessibility remain critical issues in the global adoption of MOOCs. Studies have highlighted significant disparities in participation across countries, driven by differences in digital infrastructure, language, and institutional capacity (Kundu & Bej, 2020). While high-income regions such as China and the United States dominate MOOC research and development (Guo et al., 2023), developing nations continue to face structural barriers to implementation. This inequity not only limits access to quality mathematics education but also widens the digital divide in global learning ecosystems (Zawacki-Richter et al., 2020).

Moreover, the cognitive and affective dimensions of mathematics learning—such as confidence, attitude, and motivation—are often underrepresented in MOOC research (Baran et al., 2016). As mathematics is frequently perceived as a difficult and anxiety-inducing subject, MOOCs must address affective engagement alongside cognitive rigor. Integrating emotional design, gamification, and collaborative learning environments can enhance learner persistence and reduce attrition rates (Jeya & Hosam, 2019; Dodzi & Stefania, 2017). This multidimensional approach highlights the importance of balancing pedagogical, technological, and psychological factors in designing effective mathematics MOOCs.

Given these dynamics, bibliometric analysis provides a valuable methodological lens to trace the intellectual evolution, thematic structure, and emerging trends in this field. Visualization tools such as VOSviewer enable researchers to map keyword co-occurrences, co-authorship networks, and citation relationships that collectively illustrate the scientific development of MOOCs in mathematics education (Liu et al., 2015; Eck & Waltman, 2020). Through such mapping, it becomes possible to identify dominant research clusters, detect underexplored topics, and highlight potential areas for innovation.

Therefore, this study aims to provide a comprehensive overview of research developments in MOOCs within mathematics education from 2020 to 2025. Using bibliometric visualization through VOSviewer, the study analyzes patterns of publication, thematic clustering, and keyword relationships derived from the Dimensions.ai database. The analysis focuses on identifying dominant themes, persistent challenges, and future opportunities for enhancing mathematics learning through MOOCs. Ultimately, this research contributes to advancing scholarly understanding of how MOOCs can evolve into adaptive, data-informed, and equitable learning ecosystems for mathematics education in the digital era.

## 2. METHOD

This study employed a descriptive bibliometric research design to examine the intellectual structure, thematic evolution, and collaboration networks of research on Massive Open Online Courses (MOOCs) in mathematics education. The bibliometric approach was selected because it allows for an objective and systematic exploration of a large body of academic literature through quantitative indicators and visual network analysis (Eck & Waltman, 2020; Liu et al., 2015). By combining frequency-based mapping and relational visualization, this method provides a comprehensive overview of how research in this field has developed over time, across topics, and among countries.

### 2.1 Data Source and Search Procedure

The bibliometric dataset was retrieved from the Dimensions.ai database, one of the most extensive academic search platforms that index multidisciplinary publications, including open-access journals, conference proceedings, and book chapters. Dimensions.ai was chosen for its wide coverage of both international and regional research outputs, which is essential for mapping global participation in MOOC-related studies.

The data search was conducted in November 2025 using the keyword string “MOOC AND Mathematics”, applied to the Title, Abstract, and Full Text fields. The search period was restricted to 2020–2025 to capture the most recent trends following the global digital transition triggered by the COVID-19 pandemic. A total of 2,501 documents were identified and exported in CSV format, including key bibliographic information such as publication titles, abstracts, authors, source titles, years, countries, and citation counts.

### 2.2 Data Cleaning and Preparation

Prior to analysis, the dataset was refined to ensure accuracy and consistency. Duplicate entries and incomplete metadata were removed manually using Microsoft Excel. Non-English papers were retained only if they provided English abstracts, allowing for broader thematic inclusion. Author and institutional names were standardized to avoid fragmentation of records due to spelling or abbreviation inconsistencies.

The cleaned data was then imported into VOSviewer for visualization and mapping. Each publication served as a data unit representing the scientific contribution to the MOOC–mathematics research landscape.

### 2.3 Analytical Tools and Visualization Techniques

The bibliometric visualization and network analysis were conducted using VOSviewer version 1.6.x, developed by Van Eck and Waltman (2020). The software was used to create multiple types of network maps that represent relationships among items based on co-occurrence, co-authorship, and co-citation frequencies. The visualizations were generated through four complementary analyses:

1. Keyword Co-occurrence Network – to identify conceptual clusters and dominant research themes across publications.
2. Overlay Visualization by Year – to trace the temporal evolution of keywords and reveal emerging topics between 2020 and 2025.
3. Author Density Map – to highlight prolific authors and intellectual clusters contributing significantly to the field.
4. Country Collaboration and Density Maps – to illustrate international research cooperation and identify regions with high publication intensity.

Each visualization employed a distinct color-coding scheme: node size represents keyword or author frequency, while proximity between nodes indicates the strength of their co-occurrence relationship. These visual features collectively enabled both structural and temporal interpretation of the research landscape.

### 2.4 Analytical Indicators

Several bibliometric indicators were calculated to quantify productivity and influence:

1. Publication count per year, showing research growth patterns.
2. Citation count, reflecting the scholarly impact of publications.
3. Keyword co-occurrence frequency, measuring conceptual connections among research topics.
4. Author density and collaboration strength, assessing the prominence and cooperation of key scholars; and
5. Country co-authorship links, mapping international research networks.

These indicators provided quantitative support for the qualitative interpretation of the VOSviewer visualizations shown in Figures 1–5.

### 2.5 Interpretation Procedures

The analytical process combined quantitative mapping and qualitative interpretation. The visualization results were carefully examined to identify dominant clusters, emerging topics, and interconnections among keywords, authors, and countries. Each cluster identified by VOSviewer was interpreted as a thematic domain representing a

distinct stream of research. The evolution of color gradients in the overlay visualization was used to infer chronological shifts in research focus, whereas density maps helped identify the concentration of influential contributors and active regions. To enhance interpretive accuracy, the results were triangulated with insights from existing reviews and related studies on MOOCs and digital pedagogy (Kornia et al., 2022; Tang & Hew, 2022; Guo et al., 2023). This step ensured that visual patterns derived from VOSviewer were aligned with broader theoretical and pedagogical developments in mathematics education.

## 2.6 Validity, Reliability, and Ethical Considerations

Data collection and analysis adhered to transparent and replicable procedures. All included publications were peer-reviewed and verified from a single source to ensure consistency. The use of Dimensions.ai minimized database bias, while the analytical process in VOSviewer followed standardized normalization and clustering algorithms developed by Van Eck and Waltman (2020). No confidential or personal data were used in this study, and all sources were cited appropriately in compliance with research ethics and open science principles.

## 3. RESULTS AND DISCUSSION

### 3.1 General Overview of Publications

The bibliometric analysis identified 1.800 research outputs on MOOCs in mathematics education from 2020 to 2025, representing an upward trajectory in publication volume over the six-year period. This quantitative growth signals that MOOCs have matured from being an alternative learning model to a mainstream pedagogical discourse in higher and mathematics education. The rapid increase between 2020 and 2022 coincides with the global shift toward digital instruction during the COVID-19 pandemic (Table 1), when MOOCs became a primary channel for maintaining teaching continuity (Zawacki-Richter et al., 2020; Milligan & Littlejohn, 2017).

Table 1. Amount of publications per year (2020-2025)

Year	Amount of Pub
2020	252
2021	302
2022	451 (highest)
2023	322
2024	266
2025	207

These findings confirm the assertion by Tang and Hew (2022) that post-pandemic educational research has entered a phase of digital normalization, where online learning is not treated as emergency instruction but as an integral component of educational systems. Similarly, Kornia et al. (2022) emphasized that this transformation reshaped both access and pedagogy, positioning MOOCs as vehicles for innovation in mathematics teaching, especially in developing digital problem-solving competencies.

### 3.2 Publication Trends and Research Productivity

The annual publication trend demonstrates a steady increase in scholarly attention, peaking in 2022 and stabilizing thereafter. Such growth reflects global recognition of MOOCs' potential in supporting mathematical thinking, visualization, and reasoning. Early studies, such as Chen et al. (2020) and Mohammad (2021), mainly investigated the effectiveness and challenges of MOOC implementation in STEM learning environments. Later research expanded toward more integrative themes, including hybrid learning models, adaptive feedback, and cognitive scaffolding through intelligent systems (Cao et al., 2022; Sun et al., 2024).

The dominance of publications in journals such as *Computers & Education*, *British Journal of Educational Technology*, and *Education and Information Technologies* indicate that the MOOC–mathematics nexus is situated within the intersection of pedagogy, technology, and cognitive psychology. This reinforces earlier claims by Bhagat et al. (2021) that digital platforms can enhance mathematical reasoning when supported by interactive visualization and learner analytics.

### 3.3 Geographical Distribution and Collaboration

Analysis of geographical contribution (Figures 1) reveals that China, the United States, Spain, Australia, and Italy are the most productive and interconnected countries. China's centrality within the collaboration network supports findings by Guo et al. (2023), who highlighted the country's leadership in integrating MOOCs into national education strategies through platforms like XuetangX and iCourse.

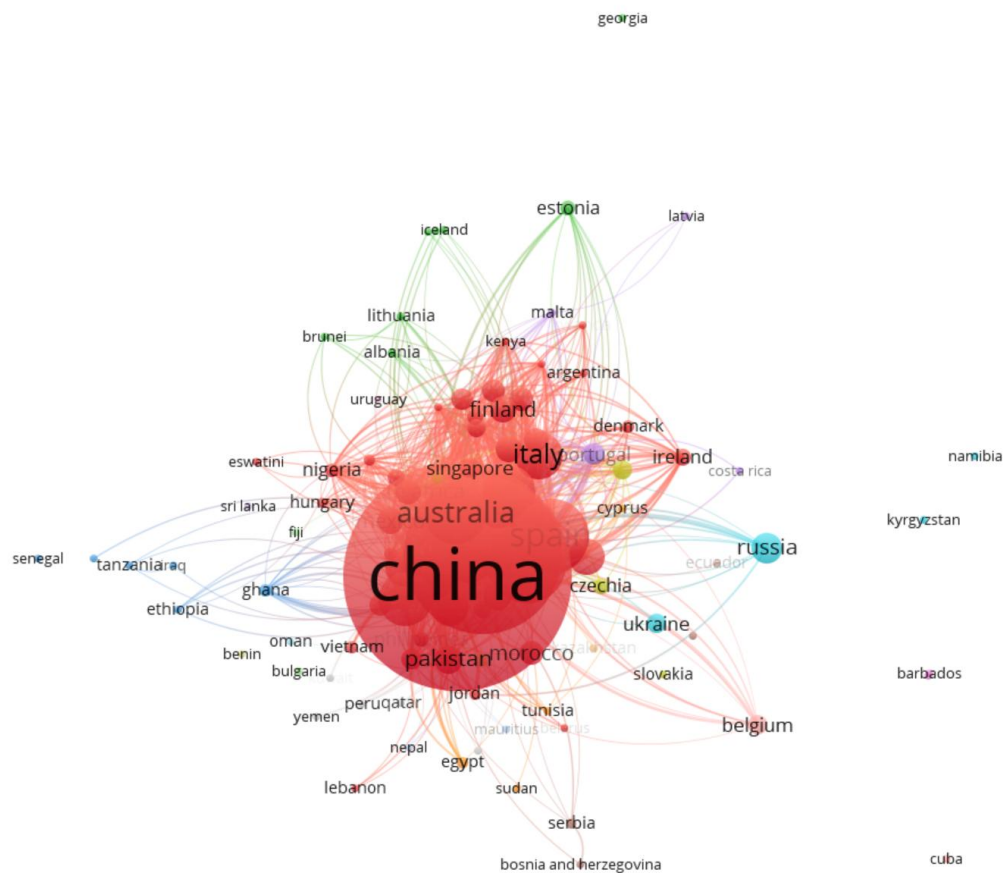


Figure 1. Analysis of geographical contribution

Similarly, European countries such as Spain and Italy have focused on pedagogical innovation and open educational practices, often emphasizing inclusivity and teacher development (Ruth & Juan, 2021). The presence of Australia as a collaboration hub reflects its commitment to international MOOC partnerships, particularly in mathematics and STEM education. However, the relatively sparse representation from African and Southeast Asian regions aligns with Kundu and Bej (2020), who documented persistent inequities in global MOOC participation and research production. These disparities underscore the need for more cross-regional and multilingual initiatives to achieve the inclusive ideals of open education.

### 3.4 Keyword Co-occurrence and Conceptual Structure

The VOSviewer keyword co-occurrence network (Figure 2) highlights four conceptual clusters.



in digital contexts (Koehler & Mishra, 2009). The convergence of mathematics education and professional development in this cluster suggests that MOOCs are gradually becoming part of teacher training ecosystems and evolution from student-oriented models to community-based and participatory professional learning environments.

The blue cluster, located on the left side of the map, is characterized by terms such as *algorithm*, *dataset*, *machine learning*, *accuracy*, and *prediction*. This area represents the computational and data-driven dimension of MOOC research, where scholars employ learning analytics, artificial intelligence (AI), and predictive modeling to analyze learner behavior, assess performance, and personalize instruction (Cao et al., 2022; Sun et al., 2024).

These studies mark the integration of educational data science into MOOC research. Keywords such as *deep learning*, *network*, *big data*, and *cloud computing* indicate the application of advanced analytical frameworks to process large-scale learning data. For instance, predictive algorithms are increasingly used to forecast dropout probabilities or to identify patterns in problem-solving behavior among mathematics learners (Guo et al., 2023).

However, while this computational approach enhances precision in understanding learning processes, several studies caution against over-reliance on metrics without considering contextual and pedagogical dimensions (Milligan & Littlejohn, 2017). Thus, current trends point toward hybrid research models that integrate algorithmic precision with human-centered design, supporting the broader shift from performance optimization toward adaptive, meaningful learning.

The dense linkages among clusters reveal significant interdisciplinary integration. The intersection between the red and green clusters, for instance, connects *satisfaction* and *use* with *MOOC* and *professional development*, indicating that learner experience and pedagogical design are mutually reinforcing. Similarly, the overlap between the blue and red clusters particularly through terms like *algorithm*, *performance*, and *self-efficacy*—shows the growing importance of data-informed personalization in addressing affective barriers and supporting learner persistence.

This interconnectedness confirms the observation by Kornia et al. (2022) that current MOOC scholarship in mathematics education increasingly embodies a “human–data” duality: data analytics informs personalized instruction, while learner agency and engagement remain central to pedagogical success. The overall map demonstrates that the field has moved from disciplinary silos toward a networked paradigm, where pedagogy, psychology, and computation coexist in shaping the future of digital mathematics learning.

### 3.5 Temporal Evolution of Research Themes

The overlay visualization (Figure 2) offers insights into how research foci have evolved over time. Studies from 2020–2021 were dominated by system-based keywords such as *algorithm*, *performance*, and *feature*, mirroring early interest in AI-assisted MOOC design (Eck & Waltman, 2020). During this phase, researchers sought to enhance MOOCs’ efficiency through computational approaches and data modeling.

From 2022 onward, the thematic focus expanded toward *attitude*, *acceptance*, *relationship*, and *motivation*. This reflects a paradigm shift from technology-driven to learner-driven inquiry. For example, Baran et al. (2016) and Tang and Hew (2022) reported that understanding students’ emotional and motivational factors became crucial for sustaining participation and improving course completion rates.

Recent publications (2023–2025) increasingly integrate academic self-efficacy and digital literacy concepts that highlight MOOCs’ role in empowering learners to take ownership of their learning. This aligns with the perspective of Kornia et al. (2022), who argued that digital transformation in mathematics education must emphasize self-regulated learning and human–machine interaction rather than mere platform usage.

### 3.7 Author and Country Density Patterns

The author’s density map (Figure 3) identifies Arthur Tatnall, Yan Li, Christoph Meinel, and Martin Ebner as the most prolific contributors. Their collaborations span Europe and Asia, bridging theoretical and applied research on digital pedagogy. This finding corroborates the observation by Liu et al. (2015) that scholarly influence in educational technology often concentrates within interlinked research communities rather than geographical boundaries.

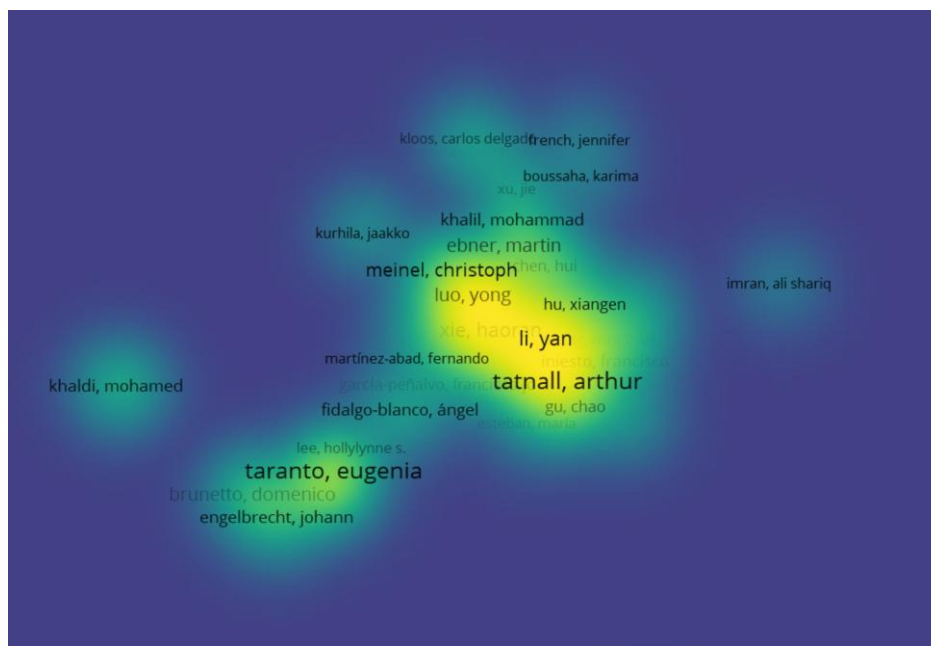


Figure 3. Author's density map

The country density visualization (Figure 1) shows high concentrations in China, Spain, Italy, and Australia, aligning with previous studies indicating that government-led initiatives and institutional investment strongly determine national research productivity (Guo et al., 2023). Nevertheless, the underrepresentation of developing regions highlights structural inequities in global knowledge production (Kundu & Bej, 2020), calling for more participatory and open-access collaboration.

### 3.8 Integrated Discussion and Theoretical Implications

Synthesizing the above findings, three major insights emerge. First, MOOC mathematics research has evolved toward a human-centered paradigm, moving beyond access and technology toward learner experience, engagement, and emotion. This aligns with constructivist and connectivist learning theories, where knowledge emerges through interaction and reflection (Ficicli et al., 2016; Cohen & Holstein, 2018). Second, the integration of AI, analytics, and adaptive feedback redefines MOOCs as intelligent learning ecosystems capable of diagnosing misconceptions and supporting metacognitive growth (Cao et al., 2022; Bhagat et al., 2021). Third, the growing focus on teacher education and professional development through MOOCs points to their long-term sustainability as tools for pedagogical transformation, particularly in the era of TPACK-oriented instruction (Ruth & Juan, 2021; Kornia et al., 2022).

Overall, these findings suggest that MOOCs in mathematics education have transitioned from technological novelty to pedagogical necessity. However, challenges persist chief among them being low retention, uneven access, and limited contextual adaptation. Future studies should explore the integration of immersive and AI-based personalization (e.g., metaverse learning environments) to foster deeper cognitive engagement, equitable access, and affective inclusion. Such directions would position MOOCs not merely as tools for learning mathematics, but as ecosystems that democratize mathematical understanding across contexts and cultures.

## 4. CONCLUSION

This bibliometric study provides a comprehensive overview of the evolution of research on Massive Open Online Courses (MOOCs) in mathematics education from 2020 to 2025, integrating quantitative mapping with qualitative interpretation. Using VOSviewer to visualize co-occurrence, author, and country networks, the analysis reveals that the field has undergone a significant transformation from initial explorations of technology implementation to more nuanced, learner-centered and pedagogically grounded approaches. The increasing complexity and interdisciplinarity of the research landscape indicate that MOOCs are no longer perceived merely as technological innovations, but as integrated pedagogical ecosystems that link data analytics, affective learning, and professional development.

The findings highlight three central trends. First, research has shifted from system-oriented inquiry (focused on algorithms and data modeling) to human-centered perspectives, exploring learners' attitudes, motivation, and self-efficacy. This transition underscores a growing concern for engagement, personalization, and

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effective well-being in digital mathematics learning. Second, the integration of AI, learning analytics, and adaptive technologies has introduced new opportunities for individualized learning pathways, enabling real-time feedback and cognitive scaffolding in mathematics MOOCs. Third, the emergence of studies on teacher professional development and digital pedagogy demonstrates that MOOCs are increasingly being used not only as student learning spaces but also as platforms for teacher empowerment and continuous professional learning.

Nevertheless, several challenges remain. The geographical concentration of research in countries such as China, the United States, and Europe underscores an ongoing imbalance in global participation. Structural barriers including disparities in digital infrastructure, linguistic diversity, and access to publication networks continue to limit contributions from developing regions. Moreover, while data-driven personalization is advancing rapidly, the ethical, contextual, and cultural dimensions of its application in mathematics education require deeper exploration to avoid perpetuating bias and inequality. Addressing these issues demands collaborative frameworks that integrate open access, multilingual dissemination, and south–south cooperation in MOOC design and research. The next phase of research should focus on designing humanized MOOCs environments that balance artificial intelligence with empathy, analytics with agency, and efficiency with inclusion. Such transformation will not only advance theoretical understandings of digital learning but also strengthen the role of MOOCs as catalysts for mathematical literacy, teacher innovation, and educational democratization in the digital era.

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## REFERENCES

- Abwatted, M., & Miri, B. (2018). Exploring student engagement in mathematics MOOCs: Barriers and enablers. *Journal of Educational Technology Systems*, 47(4), 517–538. <https://doi.org/10.1177/0047239518795467>
- Alturkistani, A., Greenhalgh, T., Brindley, D., & Majeed, A. (2020). Massive Open Online Courses (MOOCs): Systematic review of theories and educational outcomes in medical education. *BMJ Open*, 10(2), e033992. <https://doi.org/10.1136/bmjopen-2019-033992>
- Baran, E., Correia, A.-P., & Thompson, A. (2016). Transforming online teaching practice: Critical analysis of the literature on the role of teacher presence in MOOCs. *Computers & Education*, 102, 202–216. <https://doi.org/10.1016/j.compedu.2016.08.003>
- Bhagat, K. K., Yang, F.-Y., Cheng, C.-H., Zhang, Y., & Liou, W.-K. (2021). Using eye-tracking to investigate students' attention and learning in AR-based mathematics education. *Educational Technology Research and Development*, 69(6), 2997–3016. <https://doi.org/10.1007/s11423-021-10030-7>
- Cao, L., Li, X., & Sun, Y. (2022). Adaptive learning in MOOCs: A bibliometric and conceptual analysis. *Interactive Learning Environments*, 30(4), 692–709. <https://doi.org/10.1080/10494820.2021.1888583>
- Chaw, L. Y., & Tang, C. M. (2019). What makes MOOCs successful? An empirical study on learner retention and engagement. *Education and Information Technologies*, 24(3), 2311–2330. <https://doi.org/10.1007/s10639-019-09881-8>
- Chen, X., Breslow, L., & DeBoer, J. (2020). Analyzing productive learning behaviors in MOOCs: A learning analytics approach. *Computers & Education*, 150, 103879. <https://doi.org/10.1016/j.compedu.2020.103879>
- Cohen, A., & Holstein, J. (2018). The role of learner interaction in MOOCs: A connectivist perspective. *International Review of Research in Open and Distributed Learning*, 19(3), 37–54. <https://doi.org/10.19173/irrodl.v19i3.3491>
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340. <https://doi.org/10.2307/249008>
- Eck, N. J. van, & Waltman, L. (2020). *VOSviewer manual (Version 1.6.x): Visualizing bibliometric networks*. Leiden University.
- Ficieli, I., Cukurova, M., & Spector, J. M. (2016). Connectivist approaches to online learning in STEM education: A review of challenges and affordances. *British Journal of Educational Technology*, 47(6), 1322–1338. <https://doi.org/10.1111/bjet.12402>
- Guo, Y., Li, Z., & Huang, X. (2023). MOOCs and digital transformation in higher education: A review of Chinese experiences. *Smart Learning Environments*, 10(1), 22. <https://doi.org/10.1186/s40561-023-00209-0>
- Jeya, M., & Hosam, A. (2019). Gamification and motivation in mathematics MOOCs: A systematic review. *Education and Information Technologies*, 24(6), 3479–3498. <https://doi.org/10.1007/s10639-019-09929-7>
- Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, 9(1), 60–70.

- Kornia, R. H., Komikesari, H., & Saregar, A. (2022). A bibliometric analysis of digital learning in mathematics education during the COVID-19 pandemic. *Education and Information Technologies*, 27(7), 9479–9502. <https://doi.org/10.1007/s10639-022-11012-9>
- Kundu, A., & Bej, T. (2020). Blended learning in higher education: Challenges and opportunities in the post-COVID-19 era. *Asian Association of Open Universities Journal*, 15(3), 331–350. <https://doi.org/10.1108/AAOUJ-09-2020-0079>
- Liu, W., Hu, G., & Tang, L. (2015). Mapping knowledge domains of MOOCs research: A bibliometric analysis. *Computers & Education*, 91, 1–12. <https://doi.org/10.1016/j.compedu.2015.09.010>
- Milligan, C., & Littlejohn, A. (2017). Why study on a MOOC? The motives of students and professionals. *International Review of Research in Open and Distributed Learning*, 18(2), 92–102. <https://doi.org/10.19173/irrodl.v18i2.3033>
- Mohammad, H. (2021). Understanding learners' behavioral intention in mathematics MOOCs: An extended TAM approach. *International Journal of Emerging Technologies in Learning*, 16(3), 158–174. <https://doi.org/10.3991/ijet.v16i03.19479>
- Ruth, A., & Juan, C. (2021). MOOCs for teacher professional development: Opportunities and challenges. *International Journal of Educational Technology in Higher Education*, 18(1), 62. <https://doi.org/10.1186/s41239-021-00310-4>
- Sun, Y., Cao, L., & Li, X. (2024). Data-driven personalization in MOOCs: Trends, challenges, and future directions. *Computers & Education: X*, 13, 100155. <https://doi.org/10.1016/j.caeo.2024.100155>
- Tang, C. M., & Hew, K. F. (2022). Emerging research trends in MOOCs: A review of the last decade. *Computers & Education*, 182, 104466. <https://doi.org/10.1016/j.compedu.2022.104466>
- Wang, F., & Chen, J. (2025). The evolution of learning analytics in MOOCs: A systematic review and future perspectives. *Frontiers in Education*, 10, 121–139. <https://doi.org/10.3389/educ.2025.00371>
- Zawacki-Richter, O., Bozkurt, A., Alturki, U., & Aldraiweesh, A. (2020). What research says about MOOCs – An overview of recent publications (2014–2019). *International Review of Research in Open and Distributed Learning*, 21(3), 1–16. <https://doi.org/10.19173/irrodl.v21i3.4691>