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A systematic review of technology integration into ethnomathematics in Indonesia

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Abstract

In the last decade, the integration of technology into ethnomathematics has significantly increased, particularly within the mathematics education sector. However, the systematic reviews that have been conducted did not focus on the type of technology and multimedia components and combinations technology that were integrated into ethnomathematics in Indonesia. This study aims to fill that gap by providing a systematic analysis of research trends from 2016 to 2025. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, the review identified 70 relevant articles that were carried out in Indonesia from ERIC, Scopus, Web of Science and Google Scholar. The articles were analyzed to identify the types of technologies integrated into ethnomathematics, the multimedia components and the component combinations. The findings showed that mobile learning applications, augmented reality, digital comics, e-books, and animation-based tools were mainly utilized. Text and images were among the multimedia components that were frequently integrated, whilst animation, video, audio and 3D were not frequently used. Sixteen combinations of multimedia components were identified, with the majority using two or four components. The findings show that there is a need for future research and development efforts focusing on expanding the use of multimedia components such as animation, 3D modelling, and interactive simulations in ethnomathematics-based teaching and learning activities. These multimedia tools enhance teachers' Technological Pedagogical Content Knowledge through the provision of sophisticated tools to represent cultural activities. Additionally their use aligns with the cognitive theory of multimedia learning which emphasise the use of dual–channel processing that bridge the gap between cultural activities and abstract mathematics concepts.

Keywords Ethnomathematics, Learning, Mathematics, Teaching, Technology, Systematic review

1 Introduction

The 21st century is characterised by globalisation and digitalisation, with rapid advancement in science and technology. The advancement of information technology has resulted in significant changes in the teaching and learning process in education [19]. Globally, every culture develops and uses mathematical ways, ideas and procedures that

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are used to solve real life problems [26, 94]. The mathematical ways, ideas and procedures developed by a culture are called ethnomathematics [99]. Mania and Alam [59] defined ethnomathematics as the art, style and method of understanding, explaining, managing and connection between mathematics and the environment (social and nature). The relationship between culture and mathematics is referred to as ethnomathematics [106]. The collection of general rules or norms that apply in a community, values and beliefs that are accepted by people who are in the same ethnic group is referred to as culture. Mathematics is viewed as a cultural product that is developed through a variety of activities, for instance, playing, placing, counting, measuring, explaining and designing.

Ethnomathematics called the Trivium Mathematics Curriculum comprise literacy, matheracy and technocracy [59, 98]. In the literacy approach students are required to combine and share school mathematics knowledge with their cultural background [59, 117]. Matheracy is the ability to use as well as interpret signs and codes and it supports students in reading and identifying artifacts in a specific culture. In the context of technocracy, students are required to use technology tools to solve mathematics problems and provide solutions in their everyday lives [25, 59].

Mathematics and scientific skills serve as a driving force for technological and economic development in the world [57]. Several technologies are being used in the modern society to solve daily and trivial problems during the Fourth Industrial Revolution (4IR) era. The diverse technologies related with the 4IR might be used to equip students with 21st century skills such as complex problem solving, critical thinking, collaboration, effective communication and self-direction required in an ever changing job market [3]. According to Gilbert and White [34] in response to the 4IR in Indonesia of particular concern to mathematics education was the integration of disruptive technology in education institutions including planned solutions connecting competency based education to meet the requirements of students, artificial intelligence (AI), augmented or virtual reality providing opportunities for greater accessibility, the internet of things bringing greater connectivity and communication, and big data. It is important for teachers to be knowledgeable about the innovative application of technology so that they would be able to equip the students with skills required for the evolving career and job landscape. There is a need for students to be in a position to use technological tools to determine the solution of a range of and different contextualized problems and situations proposed in the classrooms [24].

1.1 Ethnomathematics digital mathematics teaching and learning

Education including the teaching and learning of mathematics at various levels is a process of cultural transfiguration that results in changes in the culture of society and the globe [62]. Ethnomathematics is one method of teaching and learning both mathematics and culture [97]. Ethnomathematics fits well in the social constructivist theory where learners build mathematical understanding and knowledge through what they have learned and been exposed to in their day to day lives [16]. Digital technologies have become part of the learners' day-to-day lives and researchers have proposed the integration digital cultural-based media and resources into the teaching and learning of mathematics [11]. Multimedia learning types make use of technology, including educational media, electronic books, or e-books in the book creator application. The comic-based

mathematics teaching and learning media with ethno mathematics is one such example that amalgamates mathematics, culture, and technology [69].

Culture-based digital mathematics learning media and resources have been developed by researchers such as Fitrianingsih et al. [31] and Ayuningsih et al. [11]. The integration of culture and technology into mathematics teaching is anticipated to improve students' learning, motivation, thinking skills, curiosity and foster character of love for culture and nationality [93]. Visual-assisted learning activities integrated with ethnomathematics and technology makes abstract mathematics concepts simpler, specific, and easy to understand as well as providing visual experiences to learners [73]. With such growing body of literature, there is limited synthesis of types of multimedia technologies and components, hence, the need for a systematic review.

1.2 Technology and ethnomathematics integration in Indonesia

The current study focuses on Indonesia not just because it is a developing country, but because several important factors make it a great place to explore how to integrate technology into mathematics education. Indonesia has a long history of changing its curriculum since 1945, showing an educational system that is flexible and responsive to global efforts to include digital tools in learning [41]. However, Indonesia's recent PISA mathematics score of 366 is the lowest ever recorded [41], which points to the need for new strategies to improve students' understanding of mathematics and their problem-solving skills. In the era of the Fourth Industrial Revolution (4IR), with increasing mobile devices and digital learning platforms, technology can create engaging, relevant, and student-focused mathematics learning experiences. Studying Indonesia's situation can provide useful insights into how technology-supported education can help close persistent learning gaps in other developing countries around the world.

The implementation of technology in mathematics education is prevalent in Indonesia, with a prominent emphasis on using mathematics software such as Geogebra. The aim is to support and enhance students' achievements in mathematics learning which addresses the prevailing concern of low learning outcomes in mathematics.

Over the past decades, scholars have pointed out the potential of technology when paired with good teaching, to improve mathematics learning [41, 123]. According to Viberg et al. [123] recent reviews of research show that using digital technologies in mathematics education often doesn't meet expectations, as they rarely change learning experiences in significant ways. In many instances, technology is used just to support traditional teaching instead of encouraging creativity, relevance to real life, or a deeper understanding of concepts. This gap highlights the need to rethink how to integrate technology into culturally responsive methods, such as ethnomathematics-based technologies. These approaches rely on students' cultural backgrounds, indigenous knowledge, and local problem-solving techniques. By incorporating digital innovations into these cultural approaches, mathematics education can become more meaningful, inclusive, and connected to students' lives. This enables students to relate mathematical ideas to their experiences while encouraging critical thinking and creativity with technology.

Indonesia has a large and varied population with 1340 ethnic groups and 715 local languages [38]. According to Turmuzi et al. [118] Indonesia has varied, distinctive, and rich cultures that exposes it to the prospect of revolutionizing its educational system, particularly in mathematics education through relating the subject to students' day to

day activities and cultural norms. Research in Indonesia [39, 118] has revealed that there are components of ethnomathematics that can benefit the teaching and learning process of mathematics. For instance, Turmuzi et al. [118] highlighted that ethnomathematics improves achievement, enhances mathematical description, critical thinking skills as well as enabling a positive behavior toward mathematics.

Hidayat and Firmanti [41] examined 36 studies on technology use in Indonesian mathematics classrooms. The review was guided by the PRISMA framework and it categorized technology into four main types including hardware, general software, mathematical software, and online resources. PowerPoint and GeoGebra were the most commonly used tools. The findings showed that using technology improved students' problem-solving, spatial reasoning, and motivation. However, this study did not integrate technology into ethnomathematics.

Turmuzi et al. [118] reviewed 80 articles related to ethnomathematics published in Indonesian journals from 2016 to 2022, all indexed by SINTA. The findings showed a consistent increase in ethnomathematical research, especially after 2019. However, the reviewed studies did not include technology.

Riadi et al. [92] conducted a bibliometric analysis of ethnomathematics research in Indonesia using the Scopus database. Their study shows a steady increase in ethnomathematics publications since 2016. They emphasized the need for broader international cooperation, integration into curricula, and the use of digital tools to improve culturally relevant mathematics education.

Iffah et al. [45] conducted a systematic literature review to examine the growth and trends of ethnomathematics research in Indonesia. The findings showed that ethnomathematics research in Indonesia started in 2016 and has grown since then. It recommended expanding research to other regions in Indonesia and different education levels while also incorporating digital media to update ethnomathematics-based teaching. The current review also includes all levels of education, from primary to higher, recognizing the potential of integrating technology into ethnomathematics with the aim of providing insights that are applicable to varied educational contexts. Table 1 is a summary of the systematic reviews carried out in Indonesia.

Table 1 Summary of the systematic reviews

Authors/year	Databases used	Focus of review	What was not covered
Hidayat and Firmanti [41]	Scopus, Web of Science	To dissect the impact of technology integration on student achievement, engagement, and attitudes towards mathematics, alongside identifying the challenges educators face in this integration process.	Did not focus on ethnomathematics, did not focus on technology integration into ethnomathematics
Turmuzi et al. [118]	SINTA	To determine trend in ethnomathematics in Indonesia, from the design to data analysis stages.	Did not focus on technology integration into ethnomathematics
Riadi et al. [92]	Scopus	To analyze the publication trends of ethnomathematics research in Indonesia.	Did not focus on technology integration into ethnomathematics
Iffah et al. [45]	ERIC, Scopus	Provide a clear picture of the development of ethnomathematics research in Indonesia in terms of research year, research methodology, regional distribution, level of education, types of cultural products and types of media.	Did not focus on technology integration into ethnomathematics

Sunzuma and Umbara [111] conducted a systematic review of how ethnomathematics-based technology has been integrated into Indonesian mathematics education over the past decade. It focused on how digital cultural media have been included in mathematics teaching and learning. The findings showed a significant rise in publications from 2016 to 2023, peaking in 2022. This increase reflects the growing interest in using technology to incorporate cultural contexts into mathematics education. The review emphasizes the potential of blending ethnomathematics with digital technology to create engaging, culturally rooted learning experiences that improve students' understanding and appreciation of mathematics.

Despite the growing interest in technology and ethnomathematics in Indonesia, few systematic studies [111] have examined how to integrate technology into ethnomathematics-based mathematics teaching and learning. The systematic review by Sunzuma and Umbara [111] did not focus on the types of technologies and multimedia tools used and it only used Google scholar database. In this study, a wide range of data sources including ERIC, Scopus, Web of Science and Google Scholar was utilised to provide a comprehensive analysis of the type and combinations of technologies integrated into ethnomathematics. This study fills the gap by analysing the technologies interact with ethnomathematics through the lenses of Technological Pedagogical Content Knowledge (TPACK) and cognitive theory of multimedia learning (CTML). Therefore, there is a need for a systematic review that focuses on the types and combinations of technologies involved in ethnomathematics.

2 Theoretical framework

The systematic review draws on two, the theoretical perspectives, Technological Pedagogical Content Knowledge (TPACK) and cognitive theory of multimedia learning (CTML) to explain the integration of technology into ethnomathematics in Indonesia.

Mishra and Koehler developed the TPACK framework basing it on the concept of pedagogical content knowledge (PCK) which was developed by Shulman. TPACK conceptualises knowledge as a dynamic integrated intersection of Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). To effectively teach with technology teachers should navigate the composite connection between what is taught (content), how it is taught (pedagogy) and the tools used to deliver the content (technology) in specific education context [66]. Technology integration is based on the TPACK framework, which emphasises the significance of integrating digital tools with subject content and teaching approaches such as ethnomathematics.

The cognitive theory of multimedia learning (CTML) developed by Mayer functions as an application of cognitive loads theory (CLT) in digital and multimedia environments [64]. According to Mayer [64] CTML comprise three assumptions which are the dual-channel assumption, the limited capacity assumption and the active processing assumption that help students to learn effectively. The dual-channel assumption states that students have two independent processing channels (audio and visual) each with a limited capacity. According to Mayer [64] and Sweller [116], the limited capacity assumption states that the students have limited cognitive capacity to represent and organize the information into the working memory. The third assumption states that learning is an active process of filtering, selecting, organizing, and integrating information based on existing knowledge. According to Mayer [65], the process of transferring knowledge

from the two channels (visual and audio) may be successful when information is incorporated with prior knowledge. As a result, when students are actively processing information, they make use prior knowledge to help the process. For instance, a student from Indonesia learning geometry concepts through the traditional patterns of Batik will process effectively the visual symmetry and geometric transformations they see if the teacher provides a simultaneous verbal explanation that connects the cultural decoration to the formal mathematics.

According to Mayer [64] the three assumptions have used to develop the CTML learning principles. These include multimedia principle (words and pictures), redundancy (avoid on-screen text that is redundant with narration), spatial and temporal contiguity principles (sync interrelated aspects visually and temporally), personalization principle (narrate in a conversational tone), signaling principle (highlight key information) and coherence principle (eliminate decorative elements). CTLM focuses on how the brain manages the simultaneous input of words and pictures which is relevant to technology integration. The multimedia principle outlines that students can learn better from pictures and words than from words only [64]. According to Sweller [116], CTL explains how human cognitive architecture process new information and construct knowledge in long-term memory. CTL is applicable to technology assisted learning [116] which includes the integration of technology into ethnomathematics.

TPACK and CTML provide an ample lens for explaining how technology is integrated into ethnomathematics in Indonesian. Whilst TPACK provides a structural understanding of specific knowledge essential for teachers to align cultural content knowledge with both digital tools and pedagogy, CTML makes sure that the digital tools are designed to maximize the students' cognitive processing of verbal and visual inputs. The frameworks explain how educators can bridge ethnomathematics with technology, nurturing deep knowledge construction in long term memory at the same time valuing the students' cognitive architecture.

The previous reviews have not examined the specific types of technologies and multimedia components that are used in ethnomathematics-based instruction, and because the quality of technology integration not merely its presence matters for improving learning outcomes, this review addresses the following questions.

(1) What are the technologies that have been integrated into ethnomathematics into the teaching and learning of mathematics?
(2) Which multimedia components and combinations are commonly integrated into ethnomathematics in the teaching and learning of mathematics?
(3) What impact has technology integration into ethnomathematics on students' learning outcomes?

3 Methodology

A systematic search was carried out on how technology was integrated into ethnomathematics in Indonesia using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) specification that allows transparent and complete reporting of systematic reviews [79].

3.1 Search procedure

Systematic reviews focusing wholly on published journal articles meet a more reliable quality standard than reviews that consist of varied sources [32, 36]. Studies carried out in Indonesia and published in peer-reviewed journals between the years 2016 and 2025 were included in the search process. The period 2016 to 2025 was chosen basing on literature that has revealed that numerous studies have been carried out on ethnomathematics in Indonesia since 2013 [39], especially in the context of the 4IR where technology is gaining prominence in mathematics education. Although ethnomathematics research in Indonesia has been documented since 2013, the year 2016 was selected as the starting point because it marks the period in which technology integration into ethnomathematics began to appear as a distinct research focus, coinciding with the emergence of the 4IR discourse in Indonesian education policy. In this systematic review, journal articles were searched from ERIC, Scopus, Web of Science and Google scholar. The articles were retrieved from the databases from 03/01/2026 to 05/01/2026. (see Table 2 for databases consulted, the search strings used and the dates on which the searches were conducted).

3.1.1 Inclusion and exclusion criteria

Articles were screened for technology integration in ethnomathematics, location, and date. Studies that were conducted in Indonesia between 2016 and 2025 were selected. Peer reviewed articles that did not focus on technology integration were not included in this study. Books, book chapters, systematic review articles and conference proceedings were excluded in order to maintain the highest quality and reliability standards. Due to the thorough review process that ensures the validity and credibility of findings, peer-reviewed journal articles are considered as the gold standard in academic research. Peer-reviewed articles are thoroughly evaluated by experts, maintaining high methodological and analytical standards that are crucial for robust systematic reviews. On the contrary, books and book chapters do not undergo similar processes of peer review like Peer-reviewed articles. Systematic review articles might be comprehensive, but can have

Table 2 Databases consulted, search strings and the dates

Database	Search string	Data per database
Web of Science	TS = (ethnomathematics OR ethnomathematical OR "cultural mathematics" OR " local mathematics" OR "culturally relevant mathematics" OR "indigenous mathematics") AND TS = (technology OR "educational technology" OR ICT OR "mobile learning" OR "e-learning" OR "virtual reality" OR "augmented reality" OR multimedia) AND TS = ("mathematics education" OR teaching OR learning)	03/01/2026
Scopus	TITLE-ABS-KEY (ethnomathematics OR ethnomathematical OR "cultural mathematics" OR " local mathematics" OR "culturally relevant mathematics" OR "indigenous mathematics") AND TITLE-ABS-KEY (technology OR "educational technology" OR ICT OR "mobile learning" OR "e-learning" OR "virtual reality" OR "augmented reality" OR multimedia) AND TITLE-ABS-KEY ("mathematics education" OR teaching OR learning)	04/01/2026
ERIC	((ethnomathematics OR ethnomathematical OR "cultural mathematics" OR " local mathematics" OR "culturally relevant mathematics" OR "indigenous mathematics") AND (technology OR ICT OR "educational technology" OR "mobile learning" OR "e-learning" OR "virtual reality" OR "augmented reality" OR multimedia) AND ("mathematics education" OR teaching OR learning)	04/01/2026
Google Scholar	(ethnomathematics OR ethnomathematical OR "cultural mathematics" OR " local mathematics" OR "culturally relevant mathematics" OR "indigenous mathematics")) AND (technology OR ICT OR "mobile learning" OR multimedia OR "virtual reality" OR "augmented reality") AND ("mathematics education")	05/01/2026

common characteristics with the studies included in the current review. Conference proceedings normally present preliminary findings that are not rigorous peer reviewed which affect their reliability. Therefore in this study a decision to focus on peer-reviewed journal articles ensures a high level of credibility and accuracy. The search was limited to English language articles because of resource and practical constraints in particular the thorough translation, validation and synthesis of non-English studies. The authors acknowledge that this might result in an English-language bias and may lead into exclusion of important Indonesian-language research, which is one of the limitations to be addressed further in the discussion. Only articles published in English were considered for further inclusion; this language criterion was applied during the initial title screening stage. The English-language articles were considered to ensure clarity and consistency in the review process. Through focusing on English language articles, potential language obstacles are minimized, permitting for a more streamlined analysis and synthesis of the literature.

Open-access articles that were fully retrievable were included to ensure verifiability and transparency of data extraction, making it possible for included studies to be independently checked for accuracy and replication purposes. Table 3 summarises the inclusion and exclusion criteria used to guide the selection of the articles for this review.

3.1.2 Screening process

The initial search yielded 794 articles from the four databases. After the initial screening process, 150 articles were excluded as they were duplicates, leaving 644 articles for further screening. From the 644 articles, 500 articles were excluded because they were not journal articles. The authors reviewed the full texts of the remaining 144 articles to determine whether they met the criteria. Sixty nine articles (focusing on ethnomathematics only (n = 46), focusing on mathematics and technology education only (n = 20) and systematic review (n = 3) were also excluded so 70 journal articles were included in the review. Figure 1 shows the PRISMA flow diagram beginning with the identification of articles, screening, eligibility, and inclusion processes [79]. Figure 1 illustrates the PRISMA flow diagram outlining the study selection process for the systematic review.

The articles included in the study were synthesized in an Excel spreadsheet with information on the authors' names, year of publication, technology, multimedia technology and multimedia component (see Table 4).

Given the heterogeneity of research designs across the reviewed studies, a meta-analysis was not conducted. This review adopts a qualitative thematic synthesis approach. Thematic analysis was carried out to categorize the themes connected to the research

Table 3 Inclusion and exclusion criteria

Criteria	Inclusion criteria	Exclusion criteria
Accessibility	Open access articles that can be retrieved.	Articles that were not open accessed that cannot be retrieved.
Publication date	Articles published between 2016 and 2025	Articles published prior to 2016 and after 2025
Focus of articles	Studies addressing technology and ethnomathematics at various educational level	Studies not addressing technology and ethnomathematics
Publication type	Journal articles	Books, book chapters, conference papers, or review article
Language of articles	Articles published in English	Articles not published in English

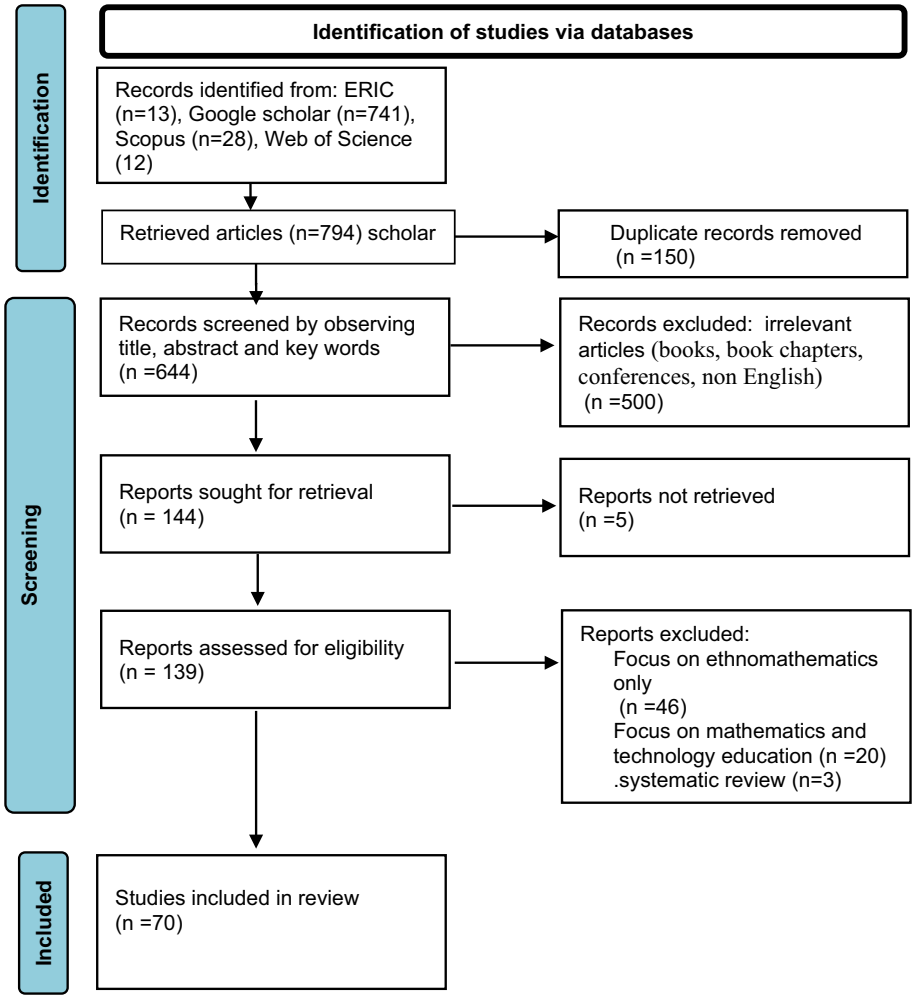

Fig. 1 Systematic review procedure

patterns in the study. After familiarization with the data, inductive coding was done to identify recurring concepts such as multimedia elements (text, image, video), mobile devices and augmented reality. The codes were grouped during axial coding into broader categories resulting into three themes: type of multimedia tool, type of technology tool and multimedia component. Regarding the outcome data, each outcome was assigned initial codes (motivation, reasoning, problem solving) to capture the core meaning. Similar codes were grouped into broader categories for example affective outcomes and cognitive outcomes. (See supplementary code book). Each study was treated as a unit of analysis ($n = 70$). Data were extracted and categorized into an excel sheet by two coders. To ensure reliability, 50% of articles were independently coded by a second coder. Inter-rater agreement was calculated using Cohen's kappa, yielding a coefficient of 0.797, indicating almost a perfect agreement. Disagreements were resolved through discussion until consensus was reached.

The Mixed Methods Appraisal Tool (MMAT) that has been used in numerous systematic reviews owing to its checked utility was used in this study to assess the methodological quality of the different study designs. Quality appraisal was carried out independently by the authors and final assessment for quality and the risk of bias was the result of the consensus. Although, the assessment enabled the authors to identify studies

Table 4 Type of multimedia tool, type of technology tool used and multimedia components

Author/year	Type of multimedia tool	Type of technology tool	Multimedia component
1. Nuryadi et al. [77]	Puppet ethnomathematics android application	Tablets, cell phone assisted application Web 2apk MS PowerPoint and I-spring	Image, text
2. Julianto et al. [51]	Mobile learning media integrated ethnomathematics	Mobile learning media	Text, image
3. Abdullah et al. [1]	Augmented Reality technology-assisted learning media with an ethnomathematical approach	Augmented Reality Smart phone	3D object, text
4. Darmayanti et al. [22, 23]	ethnomathematics based on Digital Book Creator.	Book creator application, laptops, computers, smart phones, e-book	text, image
5. Rohaeti et al. [96]	Visual Basic Application for Microsoft excel with ethnomathematical content	Visual Basic Application for Microsoft excel	Image, text
6. Darmayanti et al. [22, 23]	ethnomathematical e-book media	Book creator application, e-book	Text, video, audio, image
7. In'am et al. [47]	Ethnomathematical animation video	animated video	Video, audio, text, image, animation
8. Nuryadi et al. [75, 76]	Tedhak Siten's mobile learning tool	Adobe Flash CS6 software Android AIR worksheet, Adobe Air for Android software, Android, smart phones	Image, text
9. Marsudia et al. [61]	YouTube-based ethnomathematics learning tools	YouTube, corel video studio x10	Video, audio image
10. Sudirman et al. [107, 108]	local wisdom forms in Augmented Reality (AR) applications	Augmented Reality	3D, animation
11. Arthamevia et al. [7]	Digital Comics Learning Media based on ethnomathematics	Web comic (Pixton)	Image, text
12. Fitrianawati and Setiyawati [30]	digital Flipbook module	Digital flipbook module	audio, image, text,
13. Hidayah et al. [42]	Comics Learning Media through Instagram	laptops, pen tablets, mobile phones Krita Software, Photoshop, and the Instagram application	audio, image, text, video
14. Nuryadi et al. [75, 76]	mobile learning-based mathematics learning device with a realistic learning approach	Adobe Flash CS 6, Adobe Air for Android, Android	Text, image
15. Putri and Junaedi [89].	Ethnomathematics-based e-module	e- module, Microsoft Office 2016 software, and Canva for designing images.	Text, image
16. Sutarto et al. [115]	Ethnomathematics-based e-Module.	Smart phone, laptop, e- module	Text, image
17. Bintoro et al. [14]	ethnomathematics mobile module	Smart phone, laptop, mobile module	Text, image
18. Buchori et al. [17]	digital media of math game	Adobe Flash CS 6 Corel Draw, computer, mobile phone	Video, audio, image, text
19. Nursyahidah and Albab [78].	Ethno-mathematics of Traditional Cookie maker Assisted by GeoGebra	Geogebra applet, Google meet, whatsApp	3-D
20. Richardo et al. [93]	Ethnomathematics Augmented Reality	Augmented Reality	Audio, video, text, 3D, animation, image
21. Anggraeni et al. [5]	Search, Solve, Create, Share (SSCS) assisted by Microsoft Teams with ethnomathematics	Microsoft Teams	Video, audio, text, image

Table 4 (continued)

Author/year	Type of multimedia tool	Type of technology tool	Multimedia component
22. Nugroho et al. [71]	You Tube-based ethnomathematics learning media	You Tube	Video, audio, text, image
23. Cahyono and Ludwig [18].	digital technology-supported mathematical outdoor	Portal and mobile app, mobile technology	Text, image
24. Ilma et al. [46]	ethnomathematics-based interactive multime1dia	Computer	Text, image, video
25. Sari and Nursyahidah [78].	Interactive learning video	Laptop	Video, image, text, audio
26. Andang et al. [2]	Ethnomathematics-based digital teaching module	Android application	Text, image
27. Angellina and Kusuma [4]	Digital comic media	Projector, computer	Text, image
28. Rahayu et al. [91].	an ethnomathematics-based electronic student worksheet (e-LKPD)	electronic student worksheet (e-LKPD)	Text, image
29. Fikri et al. [29]	Website-Assisted Ethnomathematics-Based RME	On line platform	Video, image, text,
30. Gesty and Leonard [33]	ethnomathematics-based e-module	Smart phone and laptops	Video, image, text,
31. Hambali et al. [37]	ethnomathematics-based e-worksheet	Mobile devices	Text, image
32. Rizkiyani et al. [95]	digital comic media	digital comic book	Image text
33. Supriadi and Hanif [112]	Ethnomathematics mobile learning	mobile game platform.	Image text
34. Permatasari et al. [82]	Augmented Reality-based worksheet	Augmented Reality (AR) technology, namely using the Blender and Spark AR applications. Designing the worksheet using the Canva application,	Text, image
35. Ula et al. [120].	Ethnomathematics learning E-module	Canva application Flipbuilder application Interface devices, laptop and computers	Text, image, video
36. Sunantara et al. [110]	Ethnomathematics-based flipbooks	Power point presentation	Video, text, image, audio, sound
37. Munahefi et al. [67]	Augmented reality-based classroom learning media	Figma website, computer Augmented reality	Text, image
38. Astuti et al., [10]	3D Ethnomathematics Virtual reality Model	Computer, Virtual reality	Text, image, 3D objects
39. Sari et al. [103]	Ethno–RME-based digital worksheet, digital worksheet was created in an online open source website	computer or smartphone	Text, image
40. Salsabila et al. [101]	Augmented reality-based ethnomathematics learning media	Augmented reality	Text, image
41. Paramitha et al. [80]	ethnomathematics-AR-based media	Augmented reality	Text, image
42. Apricillia et al. [6]	ethnomathematics-based mobile learning media	laptops, cellphones, Construct, Canva, Adobe Illustrator, and itch.io	Text, images. Audio, simulation
43. Fendrik et al. [28]	Hybrid learning model based on ethnomathematics	Computers offline and online	Text, image
44. Assegaff and Bonyah [9]	ethnomathematics-based teaching materials through interactive games	Android-based cell phones	text, images, videos.
45. Sunantara et al. [110]	Assisted ethnomathematics-based module Canva application	Computer	Image and text, animation

Table 4 (continued)

Author/year	Type of multimedia tool	Type of technology tool	Multimedia component
46. Dewi et al. [27]	Ethnomathematics-based Augmented Reality	Augmented Reality	Image, text
47. Marheni et al. [60]	Ethnomathematics interactive e-module	smartphones, laptops, computers	images, text and videos.
48. Pratiwi et al. [87]	ethnomathematics monopoly media based on augmented reality	Canva application, augmented reality	Images, animated video, text,
49. Putra et al. [88]	AR ethnomathematics media	crafting the application using Unity 3D and Vuforia SDK, integrating 3D objects, 2D elements, and programming scripts.	Images, text, 3D objects
50. Pratama et al. [86]	e-module integrated with live worksheets	Canva application, computers, laptops, and cell phones	Image, text, audio and video
51. Hidayat et al. [40]	Digital Worksheet model based on Ethno-Modelling	CANVA, YouTube, and Live Worksheets	Image, text, audio and video
52. Arini et al. [8]	Ethno-Education Digital Book	Canva application, computers, laptops	Image, text, audio
53. Kumala et al. [54]	Educational Game Learning Media	computer mobile phone or laptop	Image, text
54. Yandani et al. [121]	ethnomathematics-based mathematics learning video media	Laptop .	Video, audio, image, text, animation
55. Sawitri et al. [104]	the digital mathematics pop-up book media		Images, text
56. Jampel and Antara [48]	E-Scrap book media	Augmented Reality	Text, image
57. Parwati et al. [81]	Ethnomathematics-Based e-evalution model	articulate storyline 3 application	Animation, image, text
58. Suryawan et al. [113]	Multimodal Digital Modules Based on Ethnomathematical Problems	Smartphones and computers	Video, image audio, text
59. Prabasari et al. [83]	Digital Comic Media	Annihilated video	Audio, video, image, text
60. Munawwaroh et al. [68]	Ethnomathematics-Based Flipbook Media		Text, image, visual simulations
61. Rosidin et al. [100]	E-Learning Ethnomathematics- online Scrabble game-based e-learning	Online	Text, image, video, simulation
62. Nuraini et al. [72]	ethnomathematics-based e module (flipbook)	You tube, Canva and Heyzine application	Audio, video, image, text
63. Novitasari et al. [70]	ethnomathematics-based visual novel game, named "EtnoMath		text, images, animations, and audio, simulations
64. Johar et al. [50]	ethnomathematics and technology-based realistic mathematics education	Google earth and geogebra	Text, images, video, 3D objects
65. Nursyahidah et al. [74]	Techno-Ethno-Realistic Mathematics Education (TE-RME)	animated video	Video
66. Raharjo et al. [90]	Culturally Themed E Comic Media	Electronic devices	Text, image, 3D objects
67. Pramulia et al. [85]	Augmented Reality-Based Ethnomathematics Comics	Smart phone, augmented reality	Text, image, 3D objects

Table 4 (continued)

Author/year	Type of multimedia tool	Type of technology tool	Multimedia component
68. Mandala et al. [58]	mobile augmented reality-based geometry learning games	Smartphone, tablet, Android Studio application, MS Publisher application augmented reality	Image, text, audio-visual 3D objects
69. Sumaji et al. [109]	ethnomathematics-based Geocube e-module	Smartphone	Text, image
70. Ulfa et al. [119]	Digital comic media		Text, image

of low methodological quality, their exclusion is not allowed hence the research findings have considered the risk of bias during interpretation.

The studies in general met the criteria of MMAT-checklist. Three qualitative studies met all MMAT criteria. Ten quantitative non-randomized studies, did not allow responding to criterion "Are the confounders accounted for in the design and analysis?" Two descriptive quantitative studies met all MMAT criteria, while two descriptive quantitative studies fail to respond to criterion "Is the statistical analysis appropriate to answer the research question?" Twenty three mixed-methods studies met all MMAT criteria, but thirty studies failed to respond to the criterion "Are divergences and inconsistencies between quantitative and qualitative results adequately.

addressed?, and out of the thirty, four studies failed to respond to the criterion "Are the outputs of the integration of qualitative and quantitative components.

adequately interpreted? (see Supplementary Tables ST2–ST5 for more details).

In summary, 40% of the articles $n = 28$ met 100% of the MMAT checklist, 54% of the articles ($n = 38$) met 80% of the MMAT checklist, representing high quality, 6% of the.

articles ($n = 4$) met 60% of the evaluated criteria, representing moderate quality.

4 Findings

4.1 Overview of studies included in the review

The 70 articles reported on the various ethnomathematics technology based teaching and learning media that have been used in mathematics in Indonesia. This highlights that Indonesia offer a rich source of ethnomathematical practices that can serve as valuable pedagogical tools for mathematic teaching and learning. Supporting this view, Bishop [15] reported that Asian cultures have made major contributions to the fundamentals of mathematics education.

Figure 2 shows the articles that were published between 2016 and 2025. In order to identify the publication trend, the articles were categorised into two groups: those published between 2016 and 2020 and those published in 2021 and later. The majority of the articles (93%) were published in 2021 or later and 7% were published between 2016 and 2020. There is an increase in research on technology integration into ethnomathematics from 2019 to 2022, followed by a decrease in 2023 and the highest number of articles was published in 2024. Those percentages indicate that research in technology integration in ethnomathematics is increasing, implying that the importance of using technology in ethnomathematics has been increasingly acknowledged as a pedagogical tool in mathematics education.

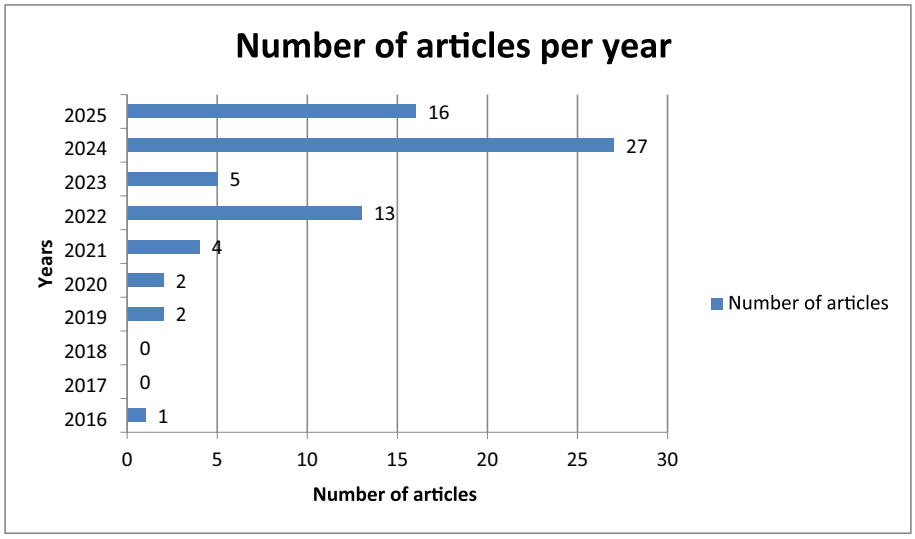

Fig. 2 Distribution of article by year

4.2 Type of technology, multimedia tool used

Different types of technologies have been integrated into ethnomathematics in the teaching and learning of mathematics in Indonesia. Basing on the findings of the systematic review the technologies have been classified as multimedia as the major theme with sub themes including type of multimedia tool, type of technology tool used and multimedia components used (see Table 4).

4.3 Type of multimedia tool integrated into ethnomathematics

Multimedia technology is an essential component of Information and Communication Technology (ICT) that focuses on how information can be presented and represented digitally, using various media, for example, video, audio, text, images and moving images [35]. Multimedia comprises the combination of various technologies that provide information in the best realistic sizes, packages and formats. Multimedia tool is an instructional resource that integrates multiple forms of media such.

as images, text animation or video to support teaching and learning. For instance, digital comics, e-modules, mobile learning apps and AR applications are the learning products used in instruction. Devices (computers, laptops, smartphone) and software (Canva, Unity 3D) including online platforms such as YouTube that enable the creation and use of multimedia are referred to as the technology tool. The individual media elements such as audio, video text and video that make up a multimedia tool are refer to as the multimedia component. Video refers to pre-recorded moving image content; animation refers to computer-generated motion graphics; simulation refers to interactive digital environments that respond to user input.

4.3.1 Digital modules and e-books

There is evidence of a growing use of various multimedia formats integrated into ethnomathematics in the teaching and learning of mathematics. The most common multimedia form was digital modules that include flipbooks, e-modules, digital books and electronic worksheets (e-LKPD). The resources were designed to promote interactive learning. Numerous studies developed e-ethnomathematics books and modules that

integrate cultural artefacts and local practices into mathematics education [2, 8, 13, 14, 22, 23, 30, 33, 48, 51, 60, 68, 72, 81, 89, 104, 109, 110, 113, 115, 120]. Likewise, digital worksheets and electronic teaching and learning materials have been used to support culturally contextualised mathematical problem solving [37, 40, 86, 91, 103]. Twenty six (37%) of the reviewed studies made use of the digital modules and e-books. The widespread use of digital modules and e-books reflects an easy use and an emphasis on promoting learner interaction with mathematics though culturally grounded digital content that supports engagement and conceptual understanding with local contexts.

4.3.2 Digital comics and visual storytelling media

Digital comics and visual storytelling media is another frequently used multimedia type which include culturally themed e-comics, web comics and comic-based instructional materials integrate ethnomathematical concepts. Studies such as Hidayah et al. [42], Angellina and Kusuma [4], Rizkiyani et al. [95], Arthamevia et al. [7], Prabasari et al. [83], Raharjo et al. [90], Ulfa et al. [119] and Pramulia et al. [85] illustrate how digital comic-based learning media make mathematics concepts more engaging by connecting them with visual representations and cultural stories. Eight (11%) of the reviewed studies used digital comics and visual storytelling multimedia. The use of stories and visual sequences shows a pedagogical shift towards contextualised learning, where mathematics concepts are understood through narrative engagements instead of isolated symbolic procedures.

4.3.3 Video-based multimedia

The use of video-based multimedia including interactive learning videos, animated video and YouTube-based instructional media was highlighted in the literature. The multimedia resources offer visual illustrations of mathematics concepts rooted in cultural activities. For instance, animated ethnomathematics learning videos [47, 74, 102, 121], while YouTube-based learning media [61, 71] were used to present culturally contextualised mathematics concepts. Video-based multimedia was used in six (8.6%) of the reviewed studies. Using video-based multimedia reflects an emphasis on dynamic and situated learning, where mathematics concepts are illustrated through culturally embedded processes instead of static representations.

4.3.4 Digital game-based multimedia

The use of digital game-based multimedia such as mobile games, educational games and interactive game-based environments in ethnomathematics has been increasing. For instance, digital mathematics games [9, 17, 54, 70], mobile game-based learning tools [100, 112] and augmented reality-based games [58]. Seven (10%) of the reviewed studies were on game-based multimedia. The use of digital game-based multimedia reflects a shift toward experiential and problem based learning environments where learners actively engage with mathematical concepts through ruled, challenges and feedback embedded in culturally meaningful contexts.

4.3.5 Virtual reality and augmented reality-based ethnomathematics learning media

Astuti et al. [10] developed a 3D Ethnomathematics virtual reality model. Augmented reality-based ethnomathematics learning media has been used in the teaching and

learning of mathematics by Abdullah et al. [1], Sudirman et al. [107, 108], Richardo et al. [93], Munahefi et al. [67], Salsabila et al. [101], Paramitha et al. [80], Dewi et al. [27], Pratiwi et al. [87] and Putra et al. [88]. Ten (14.3%) studies used VR and AR. The studies show that VR and AR are used to transform abstract mathematics concepts into immersive, manipulable experiences by situating them within culturally 3D environments.

4.3.6 Mobile learning based applications

Different multimedia tools were identified in the systematic review, probably due to the advanced development in multimedia technology in mathematics education. These include mobile learning based applications that were developed by Nuryadi et al. [75, 76], Rohaeti et al. [96], Julianto et al. [51] and Apricillia et al. [6], whilst Nuryadi et al. [77] developed a puppet ethnomathematics android application. Mobile learning based applications were used in six (8.6%) of the reviewed studies. In these studies mobile learning applications are used to extend ethnomathematics beyond the classroom by enabling flexible, context-aware learning that aligns with learners' everyday digital practices.

4.3.7 Other multimedia technologies

Other multimedia technologies were used such as ethnomathematics and technology-based realistic mathematics education [50], hybrid learning model based on ethnomathematics [28], digital technology-supported mathematical outdoor [18], ethnomathematics-based interactive multimedia [46] and ethno-mathematics of traditional cookie maker assisted by geogebra [78]. Anggraeni et al. [5] used the model of Search, Solve, Create, Share (SSCS) assisted by Microsoft Teams with ethnomathematical variations in terms of adversity quotient to analyse the patterns of students' mathematical critical thinking ability. Six (8.6%) of the reviewed studies used other multimedia technologies. The studies show that ethnomathematics is increasingly being integrated into broader pedagogical models and digital ecosystems rather than treated as a standalone tool, combining instructional approaches with technology to shape how rather than treated as a standalone tool, combining instructional approaches with technology to shape how learning is structured and experienced.

4.4 Type of technology tool and platform used

4.4.1 Virtual reality (VR) and augmented reality (AR) technology

VR and AR technologies were used to develop interactive, 3D visualisations of cultural and mathematical concepts. Those technologies were use in thirteen studies by Mandala et al. [58], Permatasari et al. [82], Astuti et al. [10], Abdullah et al. [1], Sudirman et al. [107], Richardo et al. [93], Munahefi et al. [67], Salsabila et al. [101], Paramitha et al. [80], Dewi et al. [27], Jampel and Antara [48], Pratiwi et al. [87] and Putra et al. [88] to develop multimedia tools that were integrated into ethnomathematics. Development tools such as Vuforia, Unity 3D and Spark AR were also used [88].

4.4.2 Mobile devices and application

Android-based applications, smartphones, tablets, cell phones, computers and laptops were used as the platforms to deliver ethnomathematics learning resources. Forty-five (64.3%) mobile devices and applications (tablets (2), cell phones and smartphones (19),

computers (15), mobile devices (9)) were used in the reviewed studies. Mobile platforms enable learners to access and engage with mathematics content anywhere and at anytime.

4.4.3 Web based and online platforms

Online tools, for instance, GeoGebra, Microsoft Teams, YouTube, Google Meet, instagram and WhatsApp were used to deliver asynchronous and synchronous ethnomathematics-based instruction [5, 42, 50, 71, 78]. Figma website and web comic were used by Munahefi et al. [67] and Arthamevia et al. [7]. These platforms also facilitate collaborative learning and interactive engagement.

4.4.4 Multimedia development and design tools

Design and authoring tools such as book creator, Photoshop, Corel Draw, Canva, PowerPoint, I-spring, Krita Software, Microsoft Office 2016 software, Visual Basic Application for Microsoft excel and Adobe Flash CS 6 were used to develop culturally contextualised teaching and learning media [13, 17, 23, 42, 72, 75, 77, 89, 96]. Nine studies used such tools to support multimedia integration, including text, images, video, audio, simulations and animation.

4.5 Multimedia component

As indicated in Table 3, various multimedia components were identified. These included 3D, animation, video, audio, text, images and annotation with various multimedia tools combining two or more components. The integration of 3D into ethnomathematics was reported by Nursyahidah and Albab [78], Richardo et al. [93], Sudirman et al. [107, 108] and Abdullah et al. [1]. Animation was also embedded as a component the multimedia [47, 93, 107, 108]. The distribution of the multimedia components in the reviewed articles is illustrated in Fig. 3.

As indicated in Fig. 3, the analysis shows that text (33%) and images (33%) are the major multimedia component being integrated with ethnomathematics whilst other components such as audio (11%), video (13%) are fairly integrated with ethnomathematics.

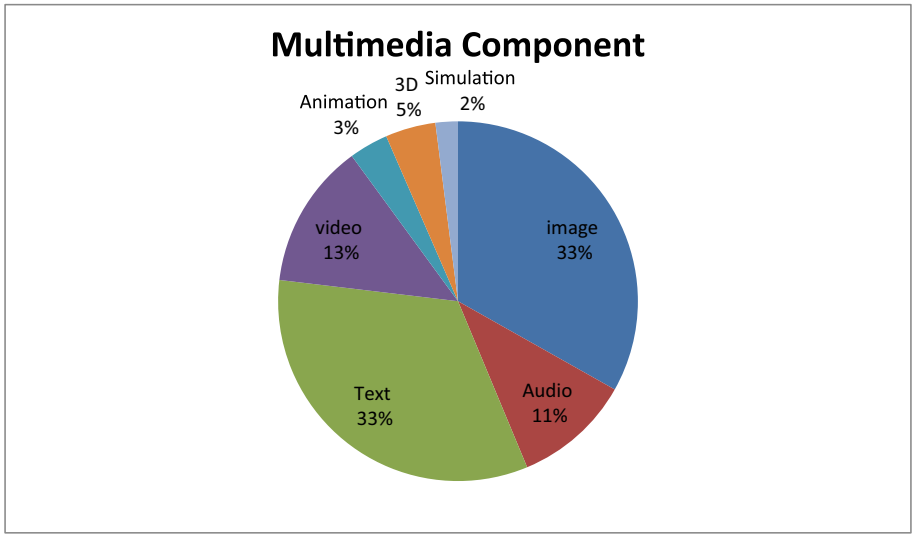

Fig. 3 Multimedia components

However, simulation, animation and 3D technologies with 2%, 3% and 5% respectively are least incorporated into ethnomathematics technology based media. This underrepresentation may reflect the relatively higher technical demands of producing animation and 3D content, which require specialized software skills and hardware infrastructure that may not be widely available among Indonesian educators and researchers.

Figure 4 represents the distribution and frequency of multimedia component combinations integrated into ethnomathematics in the reviewed articles in mathematics education in Indonesia. These multimedia components were combined into sixteen combinations as shown in Fig. 4. The combinations of the multimedia components integrated into ethnomathematics ranges from one to seven. Videos (C1) and 3D (C2) were used in some cases without any other component. These combinations resulted from the multimedia components used in each article. For example, combination 3 (C 3) represents the combination of text and image used in the reviewed articles. The combination of the two components, C3 (text, image) was widely utilized in the reviewed articles. Twenty seven articles made use of such a combination. The combination of two components was also used only once in C 4 (3D, text) and C 5 (3D, animation). The combination of three was utilized once in C 6 (text, audio, and video), C 7 (image, audio, video) and C8 (text image and simulation), five C 9 (text image and video), three C 10 (text image and animation), four C 11 (text image and 3D). The combination of four was used thirteen times in C 12 (text, image, audio, video), once in C13 (text, image, audio, simulation) and C14 (text, image, video, 3D), whilst the combination of five C 15 (text, image, audio, animation, simulation) and seven C 16 (text, image, audio, video, animation, 3D, simulation) were each used once. Most of the articles used two and four combinations of multimedia components as shown in Fig. 4. Tools with five and seven components were very few.

4.5.1 Trend of multimedia components

Figure 5 represents trend in the use of multimedia components from 2016 to 2025. Figure 5 shows that images and text remained constantly prevailing throughout the period, the use of video and audio appears sporadically, which may indicate selective use based on context or need. Animation, simulation and 3-D components make only irregular

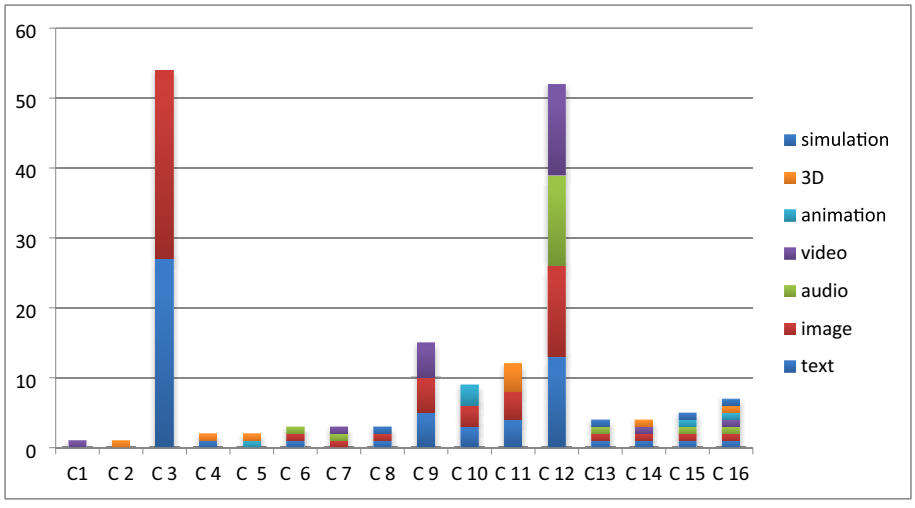

Fig. 4 Multimedia component combinations

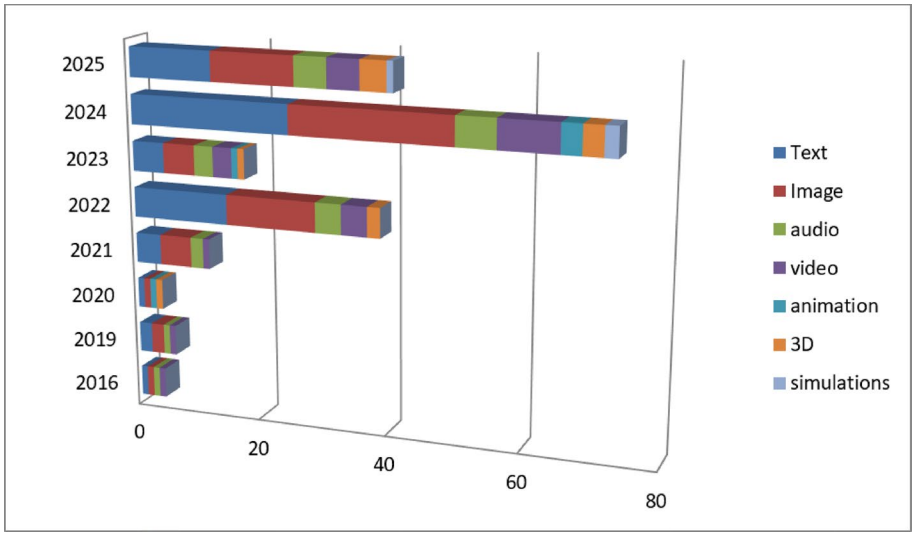

Fig. 5 Multimedia component based on year of publication

appearances, implying that they were introduced slowly as digital capacity increased. This pattern may suggest that as new multimedia technologies are increasingly becoming more available, teachers and content developers are more likely to use them in teaching and learning activities.

Supplementary Table S6 illustrates a categorization of type of technology and multimedia component used in the reviewed studies in mathematics education in Indonesia, with representative references.

4.6 The impact of integrating technology into ethnomathematics on learning outcomes

Based on the nature of the reviewed studies on their impact on students' learning outcomes, findings were categorized under four sections; academic performance and learning outcome, cognitive and problem solving skill development, affective engagement and learning motivation and conceptual understanding and mathematical competence. (see supplementary table S7 The impact of integrating technology into ethnomathematics on learning outcomes)

4.7 Academic performance and learning outcome

It is worth noting that due to Indonesia's recent PISA mathematics students' low performance and their struggle in identifying problems and using mathematical tools to solve them, improving students' academic achievement has been a major goal. The findings show that ethnomathematics-based multimedia tools contribute positively to students' academic performance, especially when they integrate interactive and multimodal features. For instance, YouTube-based tools [61], augmented reality tools [67, 82] and game-based e-learning platforms [100] demonstrate improvements in learning outcomes. Similarly, multimodal digital modules and flipbook-based e-modules [72, 104] enhance performance by combining textual, visual and interactive components that support retention. However, the absence of significant effects [77] might imply that the mere presence of technology does guarantee improved achievement; instead effectiveness depends on pedagogical alignment, usability and the depth of the cultural integration.

4.8 Cognitive and problem solving skill development

Ahead of the students' performance, the reviewed studies reported a positive impact of ethnomathematics-based multimedia tools to higher-order cognitive skills. The recent COVID pandemic revealed that the world's knowledge of mathematics is so far not at its best hence requires citizens who can think critically to solve societal problems. Globally with Indonesia included, there is a need for quality education that includes higher-order cognitive skills. In response to this, some of the reviewed studies showed a positive contribution of ethnomathematics-based multimedia tools to higher-order cognitive skills such as problem solving, creativity critical thinking, and reasoning. VR and AR technologies [58, 67] enhance spatial reasoning which is a major element of mathematical cognition. Interactive e-modules, AR tools and mobile learning applications [27, 51, 89] promote analytical thinking by situating mathematics problems within familiar cultural contexts. Multimedia tools involving game-based environments [70, 100] and GeoGebra-based ethnomathematics activities [78] support inquiry-based learning and enables students to construct and test mathematical concepts.

4.9 Affective engagement and learning motivation

Some of the reviewed studies reported positive impact of technology integration into ethnomathematics in promoting increased learner engagement, interest and motivation. Digital worksheets and e-modules [33, 91] were found to be engaging, user friendly which enables continual learner involvement. Immersive learning environments that capture students' attention were created through interactive platforms, for example, visually rich media like pop-up and digital comics books [42, 104] and AR applications [1, 88]. Such tools make the learning of mathematics meaningful and enjoyable through embedding it in cultural activities and real-life contexts. Increased engagement and motivation are connected to improved perseverance and eagerness to solve difficult mathematics tasks, implying that multimedia tools play a dual cognitive-affective role in learning.

4.10 Conceptual understanding

Indonesian students show limited mathematics basic skills, they lack knowledge application an interpretation in broader and complex context [52]. This might suggest that such students struggle to absorb and process challenging mathematics concepts which necessitated for improved learning methodologies. A key contribution of integration technology into ethnomathematics is the ability to enhance conceptual understanding. Digital tools for example e-modules, AR/VR applications, game-based learning environments and interactive videos [10, 23, 85] enable the visualization of abstract mathematics concepts, making them more accessible to students. Such learn mathematical concepts through culturally relevant examples, in a way thus connecting mathematics taught in classroom to the real world. In addition approaches such as TE- RME and RME [29, 74] put more emphasis on contextual problem-solving that strengthens students' capability to apply mathematics concepts in real world situations. The findings on improvement in mathematical connections, competence and literacy may suggest that integrating technology into ethnomathematics promote deep, transferable understanding.

5 Discussion

The gradual rise in research on technology integration into ethnomathematics from 2019 to 2022 can be attributed to the COVID-19 pandemic, which led to the all-embracing adoption of technology-based learning systems worldwide, including in Indonesia because it was no longer possible to have face-to-face teaching and learning activities. The decrease in research in 2023 is probably due to the improvement in the COVID-19 situation, which altered the learning process from online to blended learning. The finding contradicts Yuen et al. [122] who reported a demand for digital teaching resources to accommodate differentiated instruction as well as to support remote learning during the post pandemic era. The use of technology enhance ethnomathematics instruction enables all students including those in remote and resource constrained areas to access to culturally contextualized mathematics learning [12] even during the pandemic. However, in Indonesia digital divide characterised by unequal distribution of technology infrastructure and lack of culturally authentic resources in non-English languages may worsen educational inequities in some environments [20]. This might reveal some tensions stemming from embracing technology in internationally unequal educational systems. In spite of the of the growing use technology enhanced ethnomathematics multimedia in Indonesia, limited studies has focused on how digital divide affect the equitable implementation and learning outcomes across various educational levels and settings.

According to Khalid et al. [53] digital learning multimedia tools might broaden the reach of ethnomathematics into new-fangled learning environments. Such tools enable cultural artifacts to explored dynamically, connecting culture with modern.

technology. The findings of this review show that regarding the integration of technology into ethnomathematics, there is an increased use of multimedia technological tools. The finding is in line with Li et al. [56] who indicated a continued increase in the use of a variety of technology-based learning tools in education.

The findings showed that digital modules and e-books contributed 37% of the reviewed studies, which is more than a third of the reviewed studies. This might be due to their flexibility and their compatibility with laptops, computers and smartphones that are commonly used in homes and schools. Some of the reviewed studies (14.3%) showed that immersive and interactive technologies such as VR and AR were integrated into ethnomathematics. This might be due to their ability to create stimulating and immersive environment. The findings are in line with previous review by Zekeik et al. [124]. However, Zekeik et al. [124] also highlighted challenges related to the complexity of AR and VR that might contribute to its limited use in education. Mayer [65] pointed out that if well designed multimedia tools enhance learning through engaging the dual channels in the mind. However if they are complex they overload the students' cognitive ability, making it difficult to process and retain information. As a result it is important to ensure that cognitive load is properly managed during instructional design in digital multimedia learning environments [126].

For the teachers to be able to use such technologies there is a need for ample training, comprehensible instructional design, as well as continues professional development to take advantage of the potential of VR and AR in enhancing the teaching and learning of mathematics using cultural activities. From the TPACK's perspective, teachers must know how to use digital tools (technological knowledge) and understand the cultural

aspect of mathematics (content knowledge) and use immersive pedagogies (pedagogical knowledge) to create conducive learning environments.

Regarding the type of technology tool and platform used, the findings showed that technology integration into ethnomathematics is characterized convergence immersive environments, online platforms, mobile technologies and multimedia design tools. The dominance of mobile devices might imply that affordability, accessibility and ease to use are significant factors in integrating technology into ethnomathematics. The growing use of AR, VR and web-based platforms shows an emerging transition towards, more interactive, immersive and technologically advanced forms of ethnomathematics instruction. From the TPACK's perspective teachers' technological knowledge influences their perceived use and usefulness of technology [49].

According to Mayer [65] merging visual and verbal information enhances learning efficiency. Hence, more efficient learning is likely to be observed when using technological presentations with multimedia components (images, animations text, videos, and graphs). Taken together, the findings suggest that while technology integration into ethnomathematics in Indonesia has grown rapidly in volume, it remains predominantly surface-level, relying on familiar and low-complexity multimedia components (text and image) rather than leveraging the full potential of interactive and immersive technologies. In this review text and images dominated multimedia component usage with 33% each, while animation, simulation, and 3D objects each appeared in fewer than 6% of studies. The dominant use of text and images suggests that most of the studies aimed to simplify abstract mathematics concepts for students by combining explanations with visual cultural representations such cultural objects, geometric designs or patterns. The limited use of animation, simulation, and 3D objects might be stemming from the technological complexity or cognitive overload. Mayer [65] pointed out that learning is enhanced when irrelevant sound, images and words are excluded or minimized. Hence, it is possible that the reviewed studies focused on simple text-image combinations that are easier for students to process cognitively given that they already have challenges in solving mathematical concepts. From the TPACK perspective, text and images requires lower levels of technological expertise and infrastructure, which is more practical to situations where teachers have limited technological knowledge or limited access to advanced digital tools. In contrast, animation, simulation, and 3D objects require sophisticated technological knowledge, software skills and instructional device competencies to integrate into ethnomathematics. Additionally, this could be due to the contextual realities in numerous developing educational systems where hardware availability, internet connectivity and access to advanced multimedia software remain uneven. As a result educators may select multimedia components that are affordable, culturally adaptive, pedagogically effective and accessible to the learners' different environments.

The majority of studies employed combinations of two or four multimedia components. The finding is in line with Mayer [64, 65] who suggested students understand concepts better when information is presented through both visual and verbal communication rather than text alone.

5.1 The impact of integrating technology into ethnomathematics on learning outcomes

The evidence on improving the academic achievement of Indonesian students in mathematics education through technology integration into ethnomathematics is apparent.

The research on underperformance of students in mathematics in Indonesia are persistent attributable to lack of context-specific methods [44, 59]. In the current review the findings showed positive impacts on students' academic achievement and learning outcomes. This finding is in line with previous studies on the use technology and ethnomathematics [63]. However, the heterogeneity of outcome measures across studies prevents definitive conclusions, highlighting the need for more standardized assessment approaches to support thorough assessment and accountability as noted by Prahmana et al. [84].

The findings suggest that integrating technology to ethnomathematics showed potential in enhancing mathematics understanding, especially, when cultural aspects are meaningfully integrated into the digital learning design. The finding is in line with previous studies on the use of ethnomaathematics-based digital tools [63]. From a global perspective, Shimizu and Kang [105] noted that many mathematical mistakes emanate from disassociations between instruction and cultural context. Such a disconnection result in poor achievement in mathematics in Indonesia [43]. Cultural examples act as cognitive anchors that help students to build new understanding upon their prior knowledge. Students' conceptual understanding is strengthened by making abstract mathematical content more meaningful and relevant [125]. From a CMTL perspective, the findings showed a significant impact of students' prior knowledge on learning outcomes which is in line with Mayer [64].

Regarding skills development, the effect of technology integration into ethnomathematics was examined on higher-order cognitive skills such as problem solving, creativity critical thinking, and reasoning. Students' cognitive skills including problem-solving skills, indicative of conceptual understanding and applied mathematical reasoning in real-life contexts, improved following technology integration into ethnomathematics. This is important because quality education is promoted by addressing 21st-century skills that are crucial in the 4IR.

Affective factors contribute to the success of technology integration into ethnomathematics, as noted by Surya et al. [114], they emphasised on emotional engagement, which is supported in this review, which shows that students were engaged, motivated and interested during the learning process. Students develop emotional attachment to the mathematics when their culture activities are used in lessons which sustain motivation even in difficult tasks, transforming mathematics into an individual and shared experience. In summary, the findings are in line with Cesar et al. [21] who reported that digital teaching materials that are embedded in cultural values can improve both affective and cognitive engagement in mathematics teaching and learning.

6 Conclusion

This systematic review of 70 peer-reviewed articles published between 2016 and 2025 found revealed that technology integration into ethnmathematics has great potential to improve the teaching and learning of mathematics in Indonesia. The findings revealed that such integration helps students to understand mathematics concepts, improve their academic achievement and promote student motivation and engagement and helps develop cognitive skills.

In light of the findings of the reviewed studies, it was concluded that the integration of technology into ethnomathematics in Indonesia requires support from curriculum

developers, teacher educators and researchers. For curriculum developers we recommend the development of curriculum guidelines that integrate richer multimedia design into ethnomathematics curriculum frameworks. This will improve the flexibility of incorporating cultural examples into mathematics teaching by the teachers, which is in line with worldwide education standards.

For curriculum developers and educators, the review findings suggesting positive effects of technology integration into ethnomathematics on student engagement and achievement deserve its planned and continuous integration into the mathematics. The integration ought to move beyond surface inclusion of technology and cultural components toward logical alignment with formal mathematics goals [12]. Effective integration requires the development of culturally rooted pedagogical content knowledge integrated with technological content knowledge to bridge between the formal mathematics and the cultural knowledge.

The successful integration of technology into ethnomathematics depends mainly on teachers' understanding and how they implement it. Effective integration of technology into ethnomathematics instruction starts with teachers' reflection and a clear understanding of its pedagogical purpose [55]. To effectively integrate technology into ethnomathematics there is a need for teachers to be trained in ethnomathematics and technology including multimedia technology. Therefore, there is a need for the teacher educators to develop TPACK-focused professional development programs targeting AR, animation, and simulation tools. For the researchers we recommend that they prioritize the development and empirical testing of ethnomathematics-based learning media that utilize higher-order multimedia components.

Several studies used small samples ranging from single class or schools or limited geographic districts, raising issues about generalizability among various educational situations and student population Future research should focus on long-term intervention such as longitudinal studies using diverse and larger samples to investigate the integration of technology into ethnomathematics. In addition comparative experimental studies examining the differential effects of multimedia component combinations such as text+image vs. text+image+animation+simulation on mathematics learning outcomes in ethnomathematics contexts can be carried out. Design-based research studies developing and iteratively refining high-complexity multimedia tools (AR, 3D, simulation) for specific ethnomathematics topics and testing their usability across diverse regional contexts in Indonesia are also important. There is also a need for survey-based studies investigating the barriers that prevent Indonesian educators from adopting more complex multimedia technologies, including infrastructure, training, and institutional support factors.

7 Limitation

Various limitations of the systematic review should be acknowledged. This study was limited to Indonesia limiting the generalizability of the systematic review and limiting the transferability of findings to other cultural and educational settings, implying more research could have been carried out on technology integration into ethnomathematics in other countries. The scope of the current study was confined to articles published between 2016 and 2025, this excludes earlier publications. Even though this focus guaranteed relevance to current developments, it might have limited a complete

understanding of technology integration into ethnomathematics in Indonesia. The exclusion of non-English articles might have limited the diversity of findings in Indonesia and crucial studies that might have provided more insights could have been overlooked. In addition, while the heterogeneity of research methods and designs and outcomes provided a broad view, it as well imply that formal meta-analysis was not possible because of the methodological differences that restricted the strength of the conclusions.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1007/s44217-026-01905-z.

Supplementary Material 1.

Author contributions
All authors have sufficiently contributed to the study and agreed with the results and conclusions.

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Data availability
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Declarations

Ethics approval and consent to participate
Not applicable. The study is a systematic review based on published literature and publicly available data, hence, did not involve animals, human participants or primary data collection.

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