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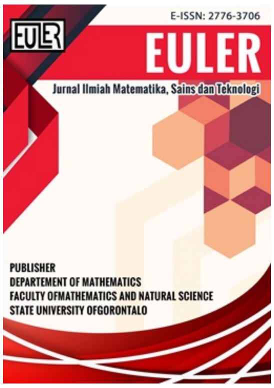

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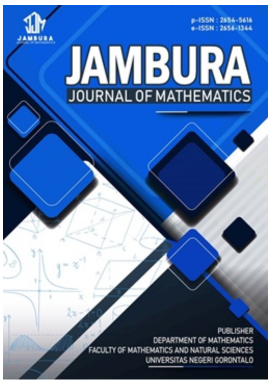

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Review Article

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Ethno-STEM Mobile Apps in Formal Education: A Systematic Review of Design Principles, Cultural Adaptation, and Learning Outcomes

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ABSTRACT. *This study presents a systematic literature review examining the development and educational impact of ethno-STEM mobile applications used in formal education. The review aims to synthesize evidence regarding three main aspects: design principles and technical features of ethno-STEM mobile apps, the integration and cultural adaptation of local knowledge, and the learning outcomes reported for students. The review followed the PRISMA 2020 framework to ensure transparency and methodological rigor in the identification, screening, and synthesis of relevant studies. Literature was retrieved from the SCOPUS database using Boolean keywords covering publications from 2016 to 2026. After a structured screening process involving document type filtering and content-based eligibility criteria, five studies were included in the final qualitative synthesis. The findings reveal that most ethno-STEM mobile applications are developed using Android platforms and instructional design frameworks such as ADDIE, emphasizing multimedia integration, interactive visualization, and guided inquiry structures. Cultural knowledge is incorporated through approaches such as ethnopedagogy, ethnomathematics, ethnoscience, and dual representation of indigenous and scientific knowledge systems. However, cultural validation processes are commonly limited to expert reviews and user evaluations rather than participatory collaboration with community knowledge holders. The reviewed studies report positive educational outcomes, including improvements in mathematical problem solving, creative thinking, scientific literacy, and student engagement. Nevertheless, most evaluations rely on short-term interventions and limited methodological rigor, with little evidence of long-term learning impacts or identity development. Overall, the findings suggest that ethno-STEM mobile applications show strong pedagogical potential but require more robust cultural validation frameworks and longitudinal evaluation to support sustainable and culturally responsive STEM learning.*

1. Introduction

The landscape of Science, Technology, Engineering, and Mathematics (STEM) education is inherently vast, encompassing disciplines that range from abstract computational algorithms to the meticulous measurement of human biology. Within the biological and health sciences, for instance, researchers frequently analyze complex physiological metrics, such as the distribution of android and gynoid fat mass, to understand metabolic and health risks across diverse demographic groups [1, 2]. Such rigorous STEM-based investigations highlight how physiological markers, including abdominal and visceral adiposity, can significantly vary depending on age, gender, and ethnic background, whether among collegiate athletes [3], individuals engaged in structured weight loss interventions [4], or specific populations like metabolically unhealthy normal-weight individuals [5]. Furthermore, variations in these biological distributions are critical determinants of cardiometabolic risk across ethnic groups, including Asian Indians and African Creoles [6, 7]. The intricate relationship between diverse human popula-

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tions and precise scientific measurement underscores a fundamental premise: STEM is deeply intertwined with the human and cultural contexts in which it operates. Understanding this intersection is crucial for developing educational paradigms that accurately reflect and respect the diverse realities of learners.

As scientific inquiry has advanced, so too has the technology used to gather data, analyze contexts, and deliver interventions, particularly through the proliferation of mobile applications. The ubiquity of smartphones, dominated by the Android operating system, has transformed both clinical practice and field research globally. Mobile applications are continuously deployed to overcome communication barriers in complex healthcare settings [8], to manage chronic conditions via securely connected Bluetooth-enabled platforms [9], and to facilitate large-scale health education initiatives, such as those targeting gestational diabetes awareness among women of reproductive age [10]. Furthermore, researchers increasingly rely on Android-based digital platforms for capturing critical socioeconomic and ethnographic data in remote or culturally diverse environments, demonstrating the platform's capacity for robust, real-time spatial and demographic analysis [11]. However, the successful implementation of these digital tools strongly depends on their usability and accessibility for varied user bases. Studies on the use of smartphone applications in qualitative research highlight both the significant advantages of real-time audiovisual data collection and the persistent challenges of the global digital divide [12]. Similarly, usability assessments of commercially available mobile applications reveal that marginalized and culturally diverse populations often experience frustration with poorly designed interfaces, emphasizing the critical need for participatory and user-centered design strategies [13].

The lessons learned from deploying digital technologies in the health and research sectors resonate deeply in formal education. The rapid integration of Digital Information and Communication Technologies (DICT) into educational environments, further accelerated by global shifts towards distance and hybrid learning, has mandated a reevaluation of how knowledge is constructed and delivered [14]. Educational technologies are no longer merely passive repositories of information; they are dynamic ecosystems that mediate the relationship between the learner, the subject matter, and the surrounding culture. Even within the intersection of visual anthropology and machine performance, scholarly explorations of autonomous androids and sensing technologies reveal that digital instruments actively produce technologically mediated subjects through complex sociocultural feedback loops [15]. This performative and socially embedded nature of technology provides a robust theoretical foundation for integrating ethnoscience into STEM curricula. Historically, formal STEM education has frequently privileged dominant Western epistemologies, inadvertently marginalizing indigenous and local knowledge systems. In response, culturally responsive pedagogy advocates for a decolonizing perspective that positions local ecological and cultural knowledge not as a mere supplement but as a legitimate and rigorous foundation for scientific inquiry. By leveraging the familiar and ubiquitous medium of mobile applications, educators can bridge the gap between abstract academic concepts and the everyday cultural realities of their students.

Within this transformative educational landscape, the development of ethno-STEM mobile applications has emerged as a particularly promising strategy, especially in mathematics and geometry. Mobile learning environments provide the flexibility required to support self-directed study while grounding mathematical principles in recognizable cultural artifacts. For example, integrating local wisdom into Android-based ethnopedagogical applications has been shown to effectively enhance elementary students' mathematical problem-solving skills by scaffolding fundamental steps, such as information gathering and problem posing

[16]. Similarly, for higher education levels, such as open university systems, mobile learning media infused with ethnomathematical models encourage active, independent learning unconstrained by physical classroom boundaries [17]. The visual capabilities of modern mobile devices further augment these educational efforts. Researchers have successfully utilized Android-based augmented reality (AR) technology to bring ethnomathematical contexts to life, demonstrating significant improvements in the creative thinking skills of junior high school students interacting with complex geometric concepts [18]. This immersive approach is echoed in the use of AR for ethno-geometry learning, where visualizing polyhedral shapes through local cultural lenses creates a highly interactive and engaging educational experience [19]. Moreover, cultural integration can extend beyond structural aesthetics to include moral and behavioral modeling; the use of traditional puppet characters within ethnomathematics applications has proven highly effective in simultaneously delivering mathematics instruction and character education, fostering values such as discipline and hard work across diverse student achievement levels [20].

Beyond mathematics, the principles of culturally responsive mobile design have been successfully applied across broader scientific disciplines. Authentic ethnoscience applications recognize that environmental and biological phenomena are deeply intertwined with community traditions and historical classifications. For instance, the development of mobile applications for soil science that concurrently display standard scientific taxonomies alongside indigenous Maya classifications exemplifies a dual-knowledge representation that honors local epistemic authority while meeting rigorous academic standards [21]. In secondary science education, the deployment of culturally themed Android applications that incorporate elements such as traditional instruments and local technologies serves as a practical catalyst for improving scientific literacy. By investigating the underlying physics and science of familiar cultural artifacts, students demonstrate marked increases in their ability to engage with and understand complex scientific phenomena [22]. Despite these promising individual case studies and the clear pedagogical potential of bridging cultural knowledge with mobile technology, the broader academic literature concerning ethno-STEM mobile applications remains noticeably fragmented. Current research often details highly localized interventions, yet there is a pervasive lack of transparency regarding the systematic instructional design frameworks, the specific mechanisms of software architecture, and the participatory processes required to ensure authentic cultural validation. Furthermore, while short-term usability and immediate cognitive gains are frequently reported, comprehensive evaluations of long-term educational impacts and STEM identity formation remain sparse. To address these critical gaps, there is an urgent need to synthesize the disparate empirical evidence across the fields of culturally responsive pedagogy, ethnoscience integration, and mobile learning. Therefore, this systematic literature review aims to rigorously examine the design principles, cultural adaptation strategies, and reported learning outcomes of ethno-STEM mobile applications implemented within formal education settings, ultimately providing a cohesive framework to guide the future development of equitable, technologically innovative, and culturally sustaining STEM learning environments.

In this literature studies, we propose three research questions as follows.

RQ 1 : What design principles and technical features are used to build ethno-STEM mobile apps for formal education?
RQ 2 : How is local cultural knowledge integrated and adapted in these apps, and which methods are used to check cultural validity?
RQ 3 : What learning outcomes are reported for students using ethno-STEM apps, and how are those outcomes measured?

2. Methods

2.1. The Prisma Methods

This review was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework, which is widely used to strengthen transparency, methodological rigor, and reproducibility in systematic literature reviews. In line with PRISMA 2020, the review process was organized around clearly defined research questions, explicit eligibility criteria, a transparent search strategy, predetermined screening procedures, and systematic evidence extraction and synthesis. PRISMA 2020 was selected because it updates the earlier 2009 guideline and reflects major advances in review methodology, particularly in the reporting of search procedures, reviewer roles, synthesis methods, and data availability [23, 24]. Accordingly, this review documented the databases consulted, the search terms used, the inclusion and exclusion criteria, the study selection stages, and the procedures used to extract and synthesize evidence related to the design principles, cultural adaptation, and learning outcomes of ethno-STEM mobile applications in formal education. The initial search of the SCOPUS database which were then processed through a structured and traceable screening workflow based on the PRISMA checklist and flow diagram.

The study selection process followed the four PRISMA phases of identification, screening, eligibility, and inclusion. During the identification phase, records retrieved from the database were compiled and checked to remove duplicates. In the screening phase, titles and abstracts were examined against predefined criteria to exclude clearly irrelevant studies. Records that met the preliminary criteria were then subjected to full-text assessment during the eligibility phase, and the reasons for exclusion at this stage were documented to preserve an auditable and reproducible review trail. The final set of eligible studies constituted the basis for the qualitative synthesis addressing the three review questions. Consistent with PRISMA guidance, the review also specified how study characteristics were extracted and how findings were organized so that readers could assess the completeness, validity, and reproducibility of the synthesis process [23]. This emphasis on explicit reporting is reinforced by recent methodological studies showing that incomplete reporting of search and review procedures can undermine reproducibility and introduce avoidable bias [25, 26]. Recent extensions such as PRISMA-LSR and PRISMA-trAIce further indicate that the PRISMA framework remains adaptable to living and AI-assisted review contexts while preserving its core commitment to transparency and methodological accountability [27].

2.2. Literature Search Strategy

The literature search strategy was conducted using Boolean keywords in the SCOPUS database for the period 2016–2026, and the search was performed on January 30, 2026. Boolean keywords are a search technique used in literature retrieval, especially in academic databases, to combine or modify keywords using logical operators such as `AND`, `OR`, and `NOT`. The `AND` operator is used to narrow search results by displaying documents that contain all combined keywords, whereas `OR` broadens the results by displaying documents that contain at least one of the specified keywords. Meanwhile, the `NOT` operator is used to exclude certain keywords so that the search results become more specific. In research, particularly in a Systematic Literature Review (SLR), the use of Boolean operators is very important for constructing a systematic and transparent search strategy, enabling researchers to identify relevant literature more efficiently and reduce the likelihood of bias in the selection of research sources [24, 25]. In this article, the keywords used were `ethno* AND android*`, which yielded 43 documents.

2.3. Screening Criteria

Based on the 43 documents retrieved using the Boolean keywords above, a further screening process was conducted according to article type. Articles categorized as Conference Paper (15 documents), Review (2 documents), Conference Review (1 documents), Book (2 documents), and Book Chapter (1 document) were excluded from the set of studies to be reviewed. As a result, 22 documents remained for further processing. As a result, we have 5 documents to include in the review process. All process provided in Figure 1.

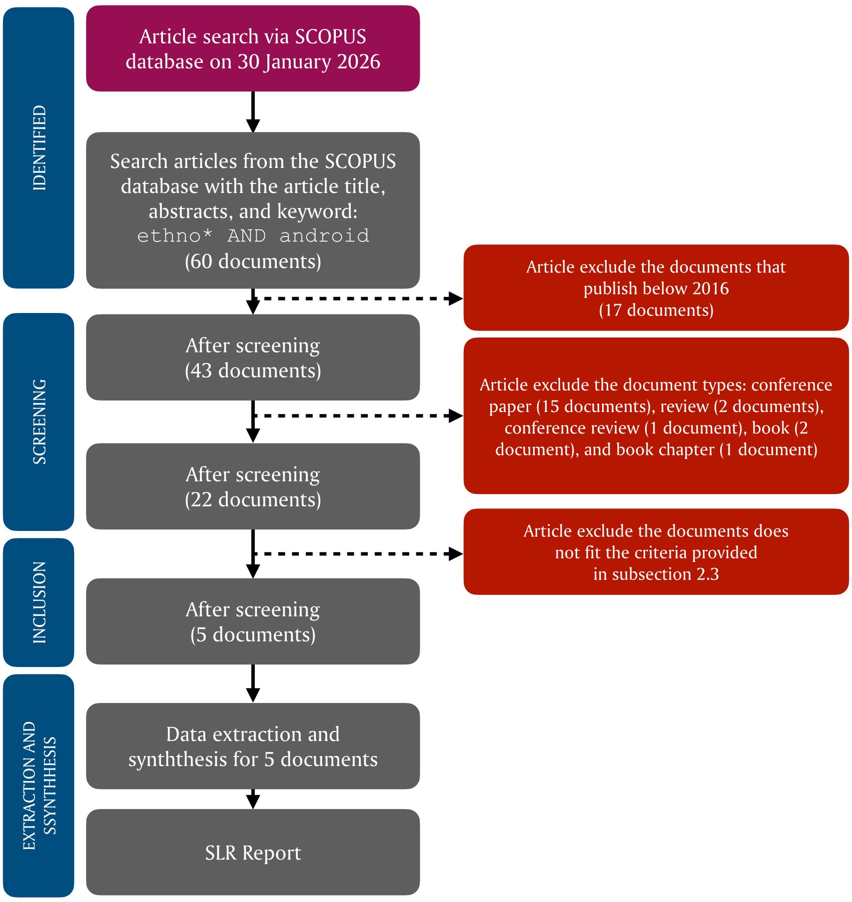


Figure 1. Flow diagram of the study selection process

The 22 remaining documents were then screened using content-based criteria aligned with the research questions of this review. First, the study had to focus on a mobile application used in a formal education context, such as primary, secondary, or higher education, because the review specifically examined ethno-STEM mobile apps implemented in structured learning environments. Second, the study had to describe the design principles, instructional structure, or technical features of the application, including aspects such as interface design,

Table 1. Summary of Design Principles and Technical Features Used to Build Ethno-STEM Mobile Apps for Formal Education

Learning focus	Education level	Development approach	Main technical features	Design orientation	Ref.
Culture-based mathematical problem solving	Elementary school	ADDIE	Android app, Java, audio, images, text	Guided inquiry steps: analyze, gather information, ask, solve	[16]
Ethno-geometry and creative thinking	Formal mathematics learning	ADDIE	Android-based AR, Unity	Interactive visualization of polyhedral concepts	[19]
Scientific literacy through ethno-STEM	Grade 8 secondary school	Quasi-experimental instructional use	RE-STEM Android app, thematic cultural modules	Investigation of science concepts through local culture	[22]
Geometry and creative thinking	Junior high school	ADDIE	Android-based AR multimedia	Visualization of geometry in ethnomathematical context	[18]
Soil knowledge and indigenous classification	Multi-user educational/ professional audience	App development study	Android app, Java, seven menu sections, maps, user roles	Role-based access and dual scientific-indigenous representation	[21]

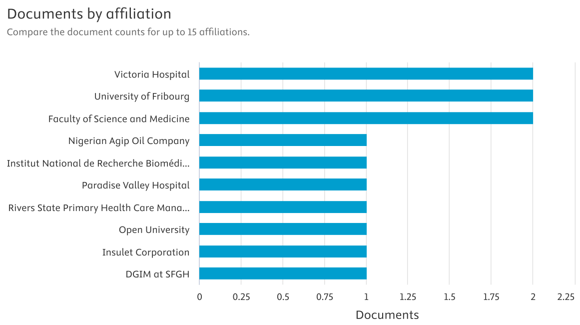
learning architecture, content organization, navigation, interactivity, multimedia integration, or platform functionality, in order to address RQ1. Third, the study had to demonstrate how local cultural knowledge, indigenous knowledge, ethnoscience, or culturally grounded content was incorporated into the application, including the way such knowledge was adapted, represented, or contextualized for educational use, in order to address RQ2.

In addition, the study had to report some form of cultural validation, expert review, user evaluation, or adaptation process showing that the cultural content included in the application was assessed for relevance, appropriateness, or authenticity. To address RQ3, the study also needed to present learning outcomes or educational impacts associated with the use of the app, such as improvements in achievement, conceptual understanding, motivation, engagement, scientific literacy, problem-solving, or attitudes toward learning, along with the methods used to measure those outcomes. Studies were excluded if they did not focus on a mobile app, were not situated in formal education, lacked explicit ethno-STEM or cultural integration elements, did not provide information on app design or technical features, or did not report educational outcomes relevant to the review objectives.

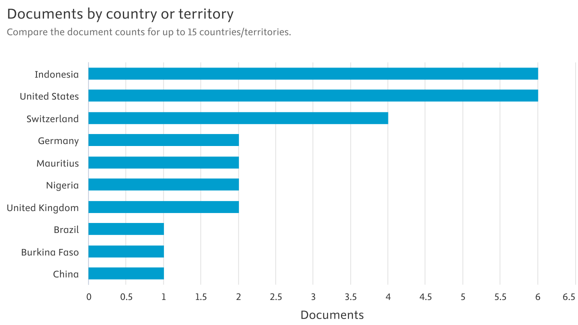
3. Results and Discussion

3.1. Statistical Description

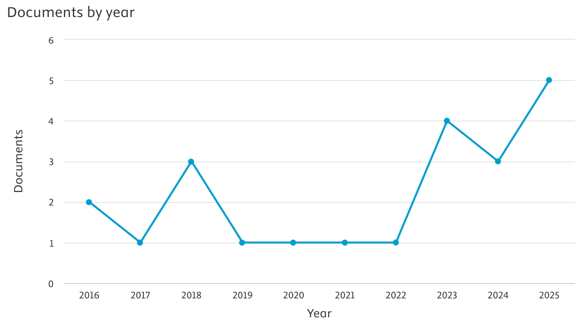
The statistical description of the reviewed articles is based on the graphical data presented in Figure 2(a)-(e). This data presents the condition when the documents have not filtered yet. These graphs illustrate the distribution of documents by affiliation, country, year, and country. Top of published documents are provided by Victoria Hospital, University of Fribourg, and Faculty of Science and Medicine which each affiliation has two documents as shown in Figure 2(a). Moreover, Indonesia and United States becomes the top countries that published the relevant documents with 6 published articles followed respectively by Switzerland, Germany, Mauritius, Nigeria, United Kingdom, Brazil, Burkina Faso, and China, see Figure 2(b). By considering the results provided by Figure 2(c), most documents are published in 2025 with 5 documents which proof this topic is popular nowadays. Most of them are published by Hunma et al. [6]



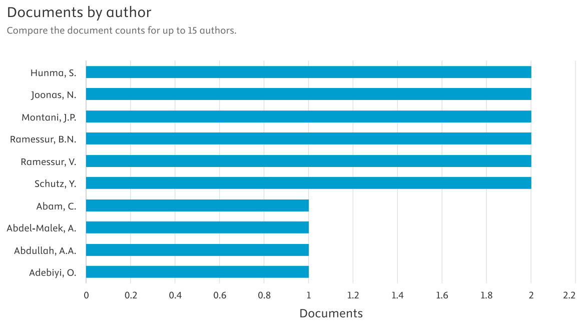
(a) Documents by affiliation



(b) Documents by country



(c) Documents by year



(d) Documents by author

Figure 2. Distribution of documents

3.2. RQ 1 : What design principles and technical features are used to build ethno-STEM mobile apps for formal education?

A consistent thematic pattern across the directly relevant studies is the dominance of Android-based design, development-research workflows, and instructionally structured multimedia features. Three of the strongest studies explicitly used the ADDIE model to guide development, namely the culture-based EBS Apps for elementary mathematics [16], the augmented reality ethno-geometry media for polyhedral learning [19], and the ethnomathematics augmented reality multimedia for junior high school geometry [18]. This repeated use of ADDIE suggests that ethno-STEM mobile app development in formal education is being approached not merely as software production, but as instructional design in which analysis of learner needs, content structuring, implementation, and evaluation are closely integrated. Technically, the reviewed studies also show a preference for accessible platforms and familiar programming environments. Isrokatun et al. [16] developed their application in Java, while Susanto et al. [19] used Unity to build Android-based augmented reality media. In the supplementary soil-information app, Gallegos et al. [21] also used Java and organized the app through seven menu sections and differentiated user access, indicating that role-based information architecture is a feasible design choice when mobile apps are intended to serve multiple educational or semi-educational audiences.

The reviewed apps also reveal a clear preference for interactive visualization and guided learning sequences rather than static content delivery. In Isrokatun et al. [16], the application was designed around steps such as analyzing, gathering information, asking questions, and solving problems, which indicates that the app architecture itself was used to scaffold mathematical reasoning. In Richardo et al. [18] and Susanto et al. [19], augmented reality was used to support geometry and ethno-geometry learning, showing that immersive visualization is viewed as particularly useful for abstract spatial concepts that benefit from concrete and culturally contextualized representation. Subali et al. [22] likewise showed that the RE-STEM

Table 2. Summary of Integration and Adaptation of Local Cultural Knowledge and the Methods Used to Check Cultural Validity

Cultural knowledge source	Mode of integration	Validation actors	Validation evidence	Main observation	Ref.
Local wisdom / ethnopedagogy	Embedded in culture-based mathematical situations	Material experts, media experts, local content experts, students	Expert validation, questionnaires, interviews	Strongest explicit local-content validation in the file	[16]
Yogyakarta ethnomathematics	Contextualized AR multimedia for geometry	Expert validators, mathematics teachers, students	Validity scores, practicality percentages	Cultural context linked to geometry learning design	[18]
Polyhedral ethnogeometry	AR-based representation of geometry concepts	Users through tests and questionnaires	Feasibility, practicality, effectiveness	Cultural content tied to visual and conceptual learning	[19]
Indonesian ethnoscience themes	Four cultural themes used as science learning resources	Classroom implementation with students	Learning gains during app-supported instruction	Culture functions as inquiry resource, not mere decoration	[22]
Maya and WRB soil classification	Parallel scientific and indigenous labeling	Students, teachers, agronomists	Favorable user evaluation	Illustrates dual-knowledge representation in app design	[21]

App was organized around multiple cultural themes that functioned as learning resources for scientific investigation. Taken together, these findings suggest that the prevailing design principle in this literature is not technological novelty alone, but the alignment of mobile features with specific cognitive demands such as problem solving, creative thinking, and scientific literacy. At the same time, the evidence base still shows limited attention to more advanced technical features such as adaptive feedback, learning analytics, personalization, or sustained teacher dashboards. This indicates that current ethno-STEM mobile apps are generally designed as pedagogically enriched learning media rather than as fully data-driven intelligent learning systems, and their scalability may still be shaped by broader inequalities in access to digital infrastructure and educational technology investment [14].

3.3. RQ 2 : How is local cultural knowledge integrated and adapted in these apps, and which methods are used to check cultural validity?

The findings indicate that local cultural knowledge was integrated into mobile apps through several overlapping approaches, namely ethnopedagogy, ethnomathematics, ethnogeometry, ethnoscience, and the parallel representation of indigenous and scientific knowledge systems. In Isrokatun et al. [16], cultural content was framed through local wisdom and ethnopedagogy in a mathematics-oriented Android application for elementary learners. In Richardo et al. [18], the ethnomathematical context of Yogyakarta was used to ground geometry learning for junior high school students, while Susanto et al. [19] focused on polyhedral ethno-geometry materials. Subali et al. [22] integrated four themes of Indonesian culture—tarutu, tin-telephone, calung, and bird whistle—as learning resources within the RE-STEM App, thereby positioning culture not as decorative background but as the conceptual entry point for scientific investigation. A particularly interesting adjacent example is Gallegos et al. [21], who presented soil information using both WRB scientific classification and Maya

Table 3. Summary of Learning Outcomes Reported for Students Using Ethno-STEM Apps and How Those Outcomes Were Measured

Outcome domain	Students / context	Measurement approach	Main result	Evidence strength	Ref.
Mathematical problem solving and engagement	Third grade elementary students	Questionnaires and interviews	Students were engaged and found the app helpful for problem solving	Moderate; positive but mainly perception-based classroom trial	[16]
Scientific literacy	102 grade 8 students in a rural secondary school	One-group pretest-posttest quasi-experiment	Scientific literacy improved by 61.33% in the medium category	Stronger within this file because of larger sample and pre/post design	[22]
Creative thinking in geometry	Junior high school students	Validity test, practicality test, one-sample t-test	Effective in improving creative thinking; $t = 9.92 > 1.74$	Moderate to strong for development research	[18]
Mathematical creative thinking	Students using ethno-geometry AR media	Written exams, documentation, paired-samples t-test, questionnaires	Effective and favorably evaluated by users	Moderate; improvement shown but design details are limited in the abstract	[19]
User evaluation of culturally grounded soil app	Students, teachers, agronomists	Favorable evaluation of app use	Positive appraisal of app usefulness	Peripheral for formal learning outcomes	[21]

soil classification. Although this study was not centered on classroom learning outcomes, it shows that cultural adaptation in mobile design can also take the form of dual-knowledge representation, where local naming systems and disciplinary taxonomies are placed side by side rather than hierarchically separated.

However, the methods used to establish cultural validity were more limited and more technocratic than participatory. The strongest evidence in the file points to expert-based validation involving material experts, media experts, teachers, and local content reviewers. Isrokatun et al. [16] explicitly reported validity testing by experts in material, media suitability, and local content, which is one of the clearest examples of formal cultural review. Richardo et al. [18] reported four expert validators and four mathematics teachers, with strong validity and practicality scores, while Susanto et al. [19] evaluated feasibility, practicality, and effectiveness through tests and questionnaires. Gallegos et al. [21] also reported favorable evaluations from students, teachers, and agronomists. These findings suggest that cultural adaptation is generally checked through educational expert review and user response, rather than through deeper co-design with community knowledge holders, elders, or cultural practitioners. As a result, the literature demonstrates serious attention to relevance and appropriateness, but it still tends to operationalize “cultural validity” as expert confirmation and usability evidence rather than as a broader collaborative process of negotiating representation, authenticity, and local epistemic authority.

3.4. RQ 3 : What learning outcomes are reported for students using ethno-STEM apps, and how are those outcomes measured?

Across the directly relevant studies, the reported learning outcomes were uniformly positive, but they were concentrated in a relatively narrow set of domains: mathematical problem solving, creative thinking, scientific literacy, and student engagement. Isrokatun et al. [16] found that elementary students were engaged with the EBS Apps and considered the app helpful for practicing information gathering, problem posing, and problem solving. Subali et al. [22] reported that students' scientific literacy increased by 61.33% in the medium category after learning with the RE-STEM App in a grade 8 rural secondary school context. Richardo et al. [18] concluded that their Android-based ethnomathematics augmented reality multimedia was effective in improving creative thinking skills, and Susanto et al. [19] similarly reported that Android-based augmented reality media improved students' mathematical creative thinking in ethno-geometry learning. In addition to these cognitive gains, several studies also reported positive affective or usability responses, such as favorable questionnaire results, high practicality ratings, and student perceptions that the apps were enjoyable, interactive, and useful.

The measurement approaches used to generate these findings varied, but most studies relied on short-term intervention designs, expert validation, and post-development effectiveness testing rather than longitudinal or comparative evaluation. Subali et al. [22] used a one-group pretest-posttest quasi-experimental design with 102 students, making it the clearest example of a larger empirical intervention in the file. Richardo et al. [18] used validity and practicality assessments alongside a one-sample t-test, while Susanto et al. [19] used written exams, documentation, questionnaire analysis, and a paired-samples t-test. Isrokatun et al. [16] relied on questionnaires and interview guidelines to document students' engagement and perceived usefulness. The pattern across these studies indicates that ethno-STEM mobile apps are most strongly supported as tools for improving immediate classroom performance and participation in specific subject areas, especially mathematics and science. At the same time, the evidence remains methodologically uneven: only a few studies reported sample sizes in detail, only one offered a more explicit quasi-experimental structure, and none in the file provided longitudinal evidence of retention, transfer, or broader cultural identity outcomes. Thus, the current literature supports the pedagogical promise of ethno-STEM mobile apps, but the strength of evidence is greater for short-term instructional effectiveness than for long-term educational transformation.

4. Conclusion

This systematic literature review examined the current state of research on ethno-STEM mobile applications used in formal education by synthesizing evidence related to design principles, cultural adaptation strategies, and reported learning outcomes. The findings demonstrate that the development of ethno-STEM mobile apps is strongly influenced by instructional design frameworks and accessible mobile technologies. Most applications are Android-based and are developed using structured instructional models such as ADDIE, emphasizing interactive multimedia elements, guided inquiry sequences, and visual representations of abstract STEM concepts. These design characteristics indicate that developers generally approach ethno-STEM mobile apps as pedagogically oriented learning tools rather than purely technological products. The review also highlights that cultural knowledge is incorporated into mobile learning environments through various approaches, including ethnopedagogy, ethnomathematics, ethnoscience, and the parallel presentation of indigenous and scientific knowledge systems. In many cases, cultural contexts function as entry points for scientific investigation or mathematical reasoning, demonstrating the potential of culturally grounded learning environments to connect disciplinary concepts with students' sociocultural experiences. However, the methods used to ensure cultural validity remain relatively limited. Most studies rely on expert validation, teacher feedback, or user questionnaires rather than participatory co-design processes involving community knowledge holders or cultural practitioners. This suggests that while efforts to ensure cultural relevance are present, deeper collaborative models of cultural validation are still underdeveloped in the current literature. In terms of educational outcomes, the reviewed studies consistently report positive effects of ethno-STEM mobile apps on students' learning. Improvements are primarily observed in areas such as mathematical problem solving, creative thinking, scientific literacy, and student engagement. These outcomes suggest that integrating culturally contextualized knowledge within interactive mobile platforms can support meaningful STEM learning experiences. Nevertheless, the strength of the evidence remains uneven, as many studies employ small sample sizes, short-term intervention designs, or perception-based evaluations. Longitudinal studies and more rigorous experimental research are still needed to understand the sustained impact of ethno-STEM mobile learning on academic achievement, cultural identity development, and broader STEM participation. Overall, the current body of literature demonstrates promising potential for ethno-STEM mobile applications to support culturally responsive STEM education. Future research should prioritize stronger methodological designs, participatory cultural validation processes, and comprehensive evaluation frameworks that capture both cognitive and sociocultural learning outcomes. Strengthening these aspects will help advance the development of scalable and culturally sustaining ethno-STEM learning technologies in formal education contexts.

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Data availability. All data are obtained from SCOPUS database which are filtered using PRISMA methods.

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