(JIML) JOURNAL OF INNOVATIVE MATHEMATICS LEARNING
Volume 8, No. 4, December 2025
P-ISSN 2621-4733
E-ISSN 2621-4741
https://dx.doi.org/10.22460/jiml.v8i4.p29460

DEVELOPMENT OF CULTURE-BASED ETNO-VR TEACHING MATERIALS TO FOSTER DEEP MATHEMATICAL CREATIVITY

Yusup Junaedi[1], Dwi Yulianto[2]

[1]Universitas La Tansa Mashiro, Jl. Soekarno-Hatta, Kab. Lebak, Indonesia.
yusufjuna4@gmail.com
[2]Universitas La Tansa Mashiro, Jl. Soekarno-Hatta, Kab. Lebak, Indonesia.
dwiyulianto554@gmail.com

ARTICLE INFO

Article history:

Received Sep 17, 2025
Revised Sep 17, 2025
Accepted Sep 18, 2025

Keywords:

Mathematical Creative Thinking
Etno-Virtual Reality
Culture-Based
Teaching Material

ABSTRACT

Ethnomathematics emphasizes the role of cultural context in shaping mathematical understanding, yet its integration with immersive technologies to enhance Deep Mathematical Creative Thinking (DMCT) in indigenous settings remains limited. This study aimed to develop and evaluate ETNO-VR, a virtual reality-based teaching material that incorporates Baduy cultural artifacts into junior high school geometry instruction to foster DMCT. Employing a design-based research framework following the 4-D model (Define, Design, Develop, Disseminate), the study involved three phases: expert validation, small-group trials, and quasi-experimental testing with 30 eighth-grade students. Instruments included content and construct validation using Aiken's V, practical feasibility assessment, and DMCT measurement across flexibility, elaboration, originality, and fluency. Results indicated that ETNO-VR achieved acceptable content validity (Aiken's V = 0.56–0.80) and very good practicality (mean = 3.48). Paired t-test analysis revealed a significant improvement in students' DMCT ($\Delta = 17.30$, $p < 0.001$, $d = 1.22$), with marked gains across all four indicators. ETNO-VR advances D'Ambrosio's ethnomathematics framework by embedding metacognitive scaffolding within culturally grounded spatial experiences, aligning with Indonesia's Merdeka Curriculum. This approach not only enhances students' creative mathematical reasoning but also contributes to the global discourse on culturally responsive mathematics education. Future research should examine scalability, cross-cultural adaptation, and AI-driven personalization of immersive ethnomathematics learning.

Corresponding Author:

Yusup Junaedi,
Department of Mathematics Education,
Universitas La Tansa Mashiro,
Jl. Soekarno-Hatta, Kab. Lebak, Indonesia
Email: yusufjuna4@gmail.com

How to Cite:

Junaedi, Y., & Yulianto, D. (2025). Development of Culture-Based Etno-VR Teaching Materials to Foster Deep Mathematical Creativity. *JIML*, 8(4), 692-710.

INTRODUCTION

In the context of 21st-century education marked by technological disruption and global competency demands, the Indonesian education system is challenged to foster higher-order thinking skills in a contextually relevant manner (González-Pérez & Ramírez-Montoya, 2022; Yulianto et al., 2024). One key competency is Mathematical Creative Thinking (MCT), which

enables students to generate original and adaptive solutions to complex problems (Hadar & Tirosh, 2019; Suherman & Vidákovich, 2022). Although the 2013 Curriculum emphasizes the importance of creative thinking in mathematics, its implementation in practice continues to face significant challenges. Studies have reported low MCT performance among Indonesian students, particularly in the areas of exploration and originality (Ansari et al., 2021; Tanujaya et al., 2021), as well as difficulties faced by teachers in designing open-ended instructional modules that support divergent thinking (Bulut Ates & Aktamis, 2024; Hamzah et al., 2022).

In fact, the development of MCT is closely linked to metacognitive awareness (Biwer et al., 2020) and students' emotional-cognitive engagement (Lidinillah et al., 2022). Therefore, integrating MCT into locally contextualized teaching materials is a crucial strategy for promoting higher-order thinking skills (HOTs), while simultaneously fostering the attributes of the *Profil Pelajar Pancasila,* namely collaboration, problem-solving, and civic-mindedness *(PISA 2022 Results (Volume* I), 2023; Ye et al., 2023). MCT refers to a cognitive ability that enables students to generate original, flexible, and elaborative solutions to context-based mathematical problems (Hadar & Tirosh, 2019; Ye et al., 2023). MCT integrates both divergent and convergent thinking processes, with four core indicators: fluency, flexibility, originality, and elaboration (Kozlowski et al., 2019; Mokhtar et al., 2020). In mathematics education practice, MCT is not solely demonstrated through correct answers, but rather through students' capacity to formulate novel approaches, propose alternative strategies, and reconstruct ideas reflectively (Kallia et al., 2021*; PISA 2022 Results (Volume* I), 2023).

Contextually, local studies highlight that the integration of MCT in classroom instruction remains limited, as evidenced by Indonesian students' performance on the PISA creative thinking assessment and the country's 115th ranking on the Global Creativity Index (Nusantara et al., 2021*; PISA 2022 Assessment and Analytical Framewo*rk, 2023; Yulianto et al., 2024). These findings underscore the urgent need for innovative instructional designs that not only foster mathematical creativity but also draw upon culturally and technologically contextualized learning environments. In response, this study adopts the MCT framework as the foundation for developing a mathematics learning intervention that is grounded in local cultural contexts and exploratory technologies, specifically through an ethnomathematics approach. Cultural motifs such as *tapis* and *batik* contain complex geometric elements that can be used to assess students' spatial flexibility and elaboration (Faiziyah et al., 2020; Kabuye Batiibwe, 2024). This strategy is not only cognitively relevant but also reinforces cultural literacy within the mathematics classroom (Suherman & Vidákovich, 2022). Accordingly, there is a pressing need for innovative assessment tools and digital learning materials that integrate MCT, local culture, and technologies such as Virtual Reality, to create meaningful and adaptive learning experiences tailored to the profiles of Indonesian students.

In the context of 21st-century mathematics education, the integration of ethnomathematics serves as a strategic approach to developing students' MCT skills in a contextualized manner (D'Ambrosio & Rosa, 2017; Hasanah et al., 2024). Ethnomathematics facilitates the exploration of mathematical concepts through local cultural practices, supporting idea elaboration, divergent thinking, and critical reflection. Within the framework of *Merdeka Belajar* and the Pancasila Student Profile, the development of culturally rooted teaching materials is highly relevant, particularly for fostering critical thinking and global diversity awareness. However, studies in Indonesia rarely develop teaching materials that systematically assess MCT or explicitly utilize specific cultural artifacts. *Leuit lenggang*, a traditional rice barn of the Baduy Dalam community, is a geometric artifact characterized by unique spatial structures involving estimation, symmetry, and transformation. This artifact reflects intuitive

mathematical practices embedded in local wisdom, yet it remains largely unexplored as a medium for mathematical instruction (Handoyo et al., 2022; Kusuma et al., 2024). In this study, the *leuit* serves as a contextual entry point for the development of STEM-ethnomathematics learning materials focused on three-dimensional geometry and volume estimation.

Figure 1. Cuboid Structure

Figure 2. Truncated Pyramid Structure

To address limitations in students' visualization and access, VR is introduced as an immersive learning medium capable of rendering *leuit* structures within a 3D digital environment. Research has shown that VR significantly enhances spatial representation, affective engagement, and conceptual understanding in geometry (Makri et al., 2021; Tene et al., 2024). Grounded in Vygotsky's social constructivism and Mayer's multimedia learning theory, VR integration enables direct interaction with abstract mathematical objects and supports adaptive feedback when combined with artificial intelligence. Although the effectiveness of VR has been demonstrated in topics such as fractions and linear equations (Akman & Çakır, 2023; Hsu, 2021), its application in developing ethnomathematics-based MCT at the primary education level in Indonesia remains largely unexplored and offers substantial potential for further investigation. VR has been recognized as a disruptive educational technology with strong potential for spatial and visual mathematics learning, particularly in topics such as analytic geometry, geometric transformations, and three-dimensional structures (Cooper et al., 2019; Hamilton et al., 2021; Hidajat, 2024). Research indicates that VR enhances conceptual engagement through immersive and exploratory learning experiences in dynamic 3D environments (Scurati et al., 2021). In the context of Indonesia's *Kurikulum Merdeka*, the integration of VR aligns with the principles of experiential learning and the STEAM approach (Marougkas et al., 2023), while addressing long-standing challenges in representing abstract mathematical concepts (Buchori & Osman, 2023).

This study responds to the persistent issue of low spatial literacy and limited access to physical manipulatives in schools by developing a lightweight, low-spec VR learning prototype accessible via basic devices and grounded in local ethnomathematical contexts (Uteuliev & Madyarov, 2022). The innovation draws on cultural elements such as batik patterns and traditional architectural structures as vehicles for spatial exploration, supported by scaffolding modules and interactive assessments. Despite its high potential, VR implementation faces practical constraints in three key areas: limited hardware availability, insufficient teacher technopedagogical literacy (TPACK), and the lack of culturally adaptive content (Diamah et al., 2022; Lee & Hwang, 2022). To address these issues, the proposed development strategy is inclusive and contextually grounded, combining problem-based learning with metacognitive scaffolding tailored to the infrastructure realities of non-urban educational settings. This study aims to contribute to the design of a VR-based mathematics learning model that is theoretically valid, culturally relevant, and technologically accessible. Ultimately, it seeks to foster students' creative thinking as a core component of deep, context-driven mathematical learning in the Indonesian education landscape.

The deep learning approach in education emphasizes meaningful, transformative learning that facilitates the transfer of knowledge to new contexts. Its implementation requires students'

metacognitive engagement (Téllez-Acuña et al., 2020) and the integration of new information with existing cognitive structures (Yulianto et al., 2024). In the context of primary education, such learning must be adapted through scaffolding and the zone of proximal development (Lukovic et al., 2022; Zaretsky, 2021). Research by Fan et al. (2023) and Anglin et al. (2008) demonstrates that Mindful Learning and Joyful Learning not only support academic achievement but also enhance students' creativity and self-regulation in exploration-based mathematics learning. Moreover, immersive technologies such as VR have been shown to improve spatial understanding and cognitive engagement (Østerlie et al., 2023). Integrating ethnomathematics into virtual design offers an authentic and culturally grounded context, as emphasized by D'Ambrosio & Rosa (2017), while digital experiential learning reinforces scaffolding through cognitive and social mediation. Accordingly, this study aims to develop a digital learning material based on Ethno-VR that is valid, practical, and effective in optimizing students' creative thinking skills. As illustrated in Figure 3, the Ethno-VR model is designed to synergize digital flexibility, the cultural context of the Baduy community, and immersive learning experiences as the foundation for a creative, reflective, and joyful mathematics learning environment.

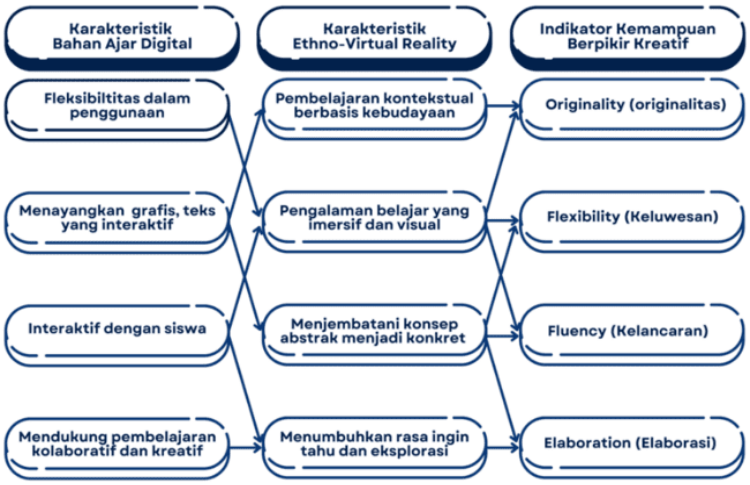

Figure 3. The Relationship Between Digital Teaching Materials, Ethno-VR, and Creative Thinking

Based on the figure above, it can be seen that the characteristics of digital teaching materials are closely related to Ethno-VR, providing a flexible, contextual, and immersive learning experience that has the potential to optimize students' creative thinking skills. Therefore, the objective of this study is to develop digital teaching materials based on Ethnomathematics-Virtual Reality within the context of Baduy culture that are valid, practical, and effective in enhancing creative thinking skills as an effort to strengthen deep learning.

METHOD

This study aims to develop a digital instructional material based on VR, integrated with the ethnomathematical content of Baduy culture, to enhance students' creative mathematical thinking skills through immersive, contextual, and culturally grounded learning experiences. The innovation responds to the challenges of 21st-century education by combining immersive technological approaches with the preservation of indigenous knowledge within a single, forward-thinking instructional ecosystem. The research adopts a Research and Development (R&D) methodology, employing a modified 4-D model (Thiagarajan et al., 1974) to accommodate local cultural elements and 3D visualization.

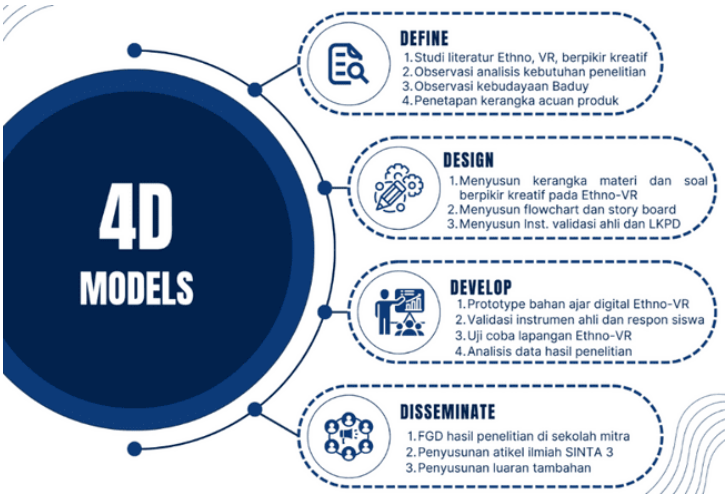

Figure 4. 4D Research Model

The development of the instructional media followed a structured ADDIE-based framework comprising four stages. In the Define stage, needs analysis, learner characteristics assessment, and curriculum review were conducted, focusing on identifying connections between mathematical content and Baduy ethnomathematics, including geometric motifs in traditional weaving, symmetrical structures in vernacular architecture, and nature-based measurement systems. During the Design stage, a prototype of the VR-based instructional media was created to integrate these cultural elements within the context of solid geometry, emphasizing principles of 3D visualization, interactivity, and alignment with pedagogical standards. The Develop stage involved expert validation by content specialists, media experts, and local cultural authorities, who evaluated content accuracy, cultural relevance, and the quality of visual representation. Participants were selected via purposive sampling to ensure diversity in background and learning ability. Practicality tests were conducted with a small group of eighth-grade students across varying proficiency levels (high, medium, low), while effectiveness tests were implemented in a full experimental class at SMPN 1 Banjarsari, Lebak Regency, measuring the media's impact on students' creative mathematical thinking using standardized instruments and appropriate statistical analyses. Finally, in the Disseminate stage, the finalized media were prepared for broader implementation in schools with similar cultural contexts, accompanied by a dissemination plan that included content adaptation strategies and teacher training modules.

The research instruments included: (1) expert validation sheets (assessing content, language, presentation, and cultural relevance), (2) practicality questionnaires completed by students and lecturers, and (3) an MCT test based on four core indicators: fluency, flexibility, elaboration, and originality. Data were analyzed using quantitative descriptive techniques. Content validity was assessed using Aiken's V formula, with $V > 0.5$ considered valid. Instrument reliability was tested using Cronbach's alpha, with $\alpha \geq 0.6$ indicating acceptable reliability (Susanta et al., 2023). The validity of the instructional material was determined based on mean expert ratings, covering content, construction, language, and visual presentation. A four-point Likert scale was used for expert assessments, with results categorized as highly valid, valid, or less valid. Practicality was evaluated through user response questionnaires (teachers and students), using a four-point Likert scale ranging from very impractical (1.00–1.80) to very practical (3.41–4.00). Interpretations were supported by frequency distribution analysis and visual data presentation. To measure effectiveness, the MCT test was administered in both pre-test and post-test formats, covering the four creativity indicators derived from Guilford's theory and the Ministry of Education's guidelines. Effectiveness was assessed by comparing pre- and post-test scores using descriptive statistics (mean, standard deviation, minimum, and maximum scores), and further confirmed using inferential statistics (e.g., paired t-test) to determine statistically

significant improvements. A minimum success criterion was established, requiring at least 60% of students to reach a high-score category (67–100), based on score conversion and distribution aligned with national competency standards and 21st-century skill evaluation practices.

RESULTS AND DISCUSSION

Results

This section presents the research findings and discussion concerning the development of digital learning materials based on Ethnomathematics-Virtual Reality (ETNO-VR), contextualized within the Baduy culture. The results are presented sequentially, covering curriculum analysis, identification of media development needs, design processes, expert validation, and the practical and pedagogical effectiveness of the product. The discussion emphasizes how the integration of local cultural artifacts within a virtual environment can enhance students' understanding of mathematical concepts, foster creative mathematical thinking skills, and support deep learning. All findings are critically analyzed, linking content validity, practical implementation, and pedagogical relevance, thereby providing an empirical foundation for the development of innovative, contextualized, interactive, and transformative learning media. The developed ETNO-VR product can be accessed at https://shorturl.at/l9qMq, providing direct insight into its structure, features, and interactive capabilities.

1. Define Stage

The curriculum analysis was conducted through an in-depth review of the lesson plans (*Rencana Pelaksanaan Pembelajaran* or RPP) for eighth-grade mathematics at SMPN 1 Banjarsari, Lebak Regency, specifically focusing on the topic of polyhedral geometry. The findings revealed that instruction remains largely dominated by a one-way expository approach, in which the teacher serves as the primary source of information while students play a passive role as recipients of content. This method overlooks the principles of constructivist learning, which emphasize active student engagement in constructing meaning, especially critical in understanding abstract spatial concepts. Additionally, the instruction lacked integration with students' local cultural contexts. Geometry was primarily presented through two-dimensional illustrations in textbooks and standard worksheets, offering limited visual experiences necessary to foster spatial imagination and three-dimensional conceptualization. Digital technologies such as VR, which could provide immersive visualization and culturally contextualized simulations, had not yet been utilized. Needs assessment surveys completed by both teachers and students indicated that the topic of polyhedral geometry remains challenging, particularly in understanding the relationships between components (faces, edges, and vertices) and applying these concepts to real-life situations. Students also reported difficulties connecting geometric content to local cultural phenomena in their environment.

Field study findings revealed that within the Baduy cultural tradition, there are numerous artifacts with high mathematical value, such as symmetrical patterns in woven textiles (*sompé*), the spatial structure of traditional *leuit lenggang* granaries, and indigenous measurement systems used in agriculture and trade. Unfortunately, this ethnomathematical potential has not been integrated into formal instructional materials. As such, there is a clear need to develop a digital learning medium based on Virtual Reality that not only visualizes geometric objects in three dimensions but also incorporates local cultural values in a contextualized manner. This approach would enable students not only to comprehend geometric concepts visually and spatially but also to cultivate creative and reflective thinking skills by linking mathematics with their cultural identity. The ultimate goal is to foster deep learning, characterized by students'

ability to generalize, make interdisciplinary connections, and apply concepts within authentic contexts.

Table 1. Diagnostic Findings for Developing ETNO-VR Learning Materials

Diagnostic Aspect	Empirical Findings	Implications for ETNO-VR Learning Material Design
Problem-Solving and Creative Mathematical Thinking Skills	Diagnostic tests involving 30 students revealed that only 30% were able to correctly solve mathematical problem-solving tasks. Moreover, just 10% demonstrated the ability to reflect on their solutions. The creative thinking assessment based on TTCT indicators (fluency, flexibility, originality, elaboration) indicated a tendency among students to provide a single standard solution, with minimal exploration of alternative strategies or idea development.	Instructional materials should be designed to promote multi-strategy exploration (flexibility), allow space for open-ended ideas (originality), and incorporate scaffolding features that guide reflective thinking. VR simulations can be leveraged to present open-ended, culturally grounded challenges that stimulate idea fluency and solution elaboration.
Learning Resources Accessed by Students	90% of students relied on conventional textbooks. Only 25% perceived the content as relevant to their daily lives or cultural backgrounds.	There is a need to develop locally grounded cultural media (e.g., based on Baduy traditions) in the form of visual narratives, authentic contexts, and 3D objects. This can foster contextualized learning, increase engagement, and enhance knowledge transfer.
Cultural Potential of the Baduy Leuit in Geometry	The Leuit, a traditional Baduy rice barn, incorporates spatial geometry concepts (e.g., rectangular prisms, beams) and proportional reasoning related to structural height-to-width ratios. The roof architecture and interior design reflect practical applications of volume, symmetry, and spatial efficiency.	VR technology can be used to explore the Leuit in 3D, enabling students to measure dimensions, analyze stability, and redesign geometric structures within a cultural context. This supports problem-based learning models focused on cultural design challenges.

The diagnostic findings confirm that students' primary deficiencies lie in the areas of flexibility and originality in creative mathematical thinking. Local cultural contexts, such as the structure of the *Leuit,* offer rich cognitive and affective foundations for developing innovative, VR-based instructional materials centered on cultural redesign. This approach holds significant potential for bridging the gap in contextual mathematics learning while meaningfully enhancing students' creative thinking abilities in both applied and culturally relevant ways.

2. Design Phase

During the design phase, a prototype of a VR-based digital learning material was developed, integrating ethnomathematics content from the Baduy ethnic group. This development aimed to bridge the gap between the abstraction of geometric concepts, particularly three-dimensional solid shapes, and a contextual, visual, and culturally grounded learning experience. Cultural

artifacts such as the *leuit lenggang* (traditional rice barn), woven fabric motifs, and the proportional structures of Baduy traditional houses were contextualized within problem-based learning scenarios situated in immersive virtual environments. The product design encompassed the development of curriculum-aligned mathematical content, culturally aesthetic 3D visual designs, and VR navigation scenarios that support spatial exploration and reflective thinking. This approach is grounded in the principles of constructivist learning design and TPACK integration, aiming to foster students' mental representation and mathematical creativity.

Each instructional unit begins with a culturally contextual problem, followed by virtual exploration, conceptual explanation, and reinforcement activities through exploratory student worksheets (LKPD). Evaluation instruments were developed to assess content and visual validity (via expert validation forms), implementation practicality (through limited trials), and students' creative mathematical thinking skills based on modified Torrance indicators. The distinctiveness of this design lies in the use of VR not merely as a visual aid but as a fully integrated ethnopedagogical learning ecosystem, enabling students to experience, explore, and reconstruct mathematical concepts through meaningful and creative engagement with cultural artifacts. In the design phase, an initial prototype of a VR-based digital learning material was developed, integrating Baduy cultural ethnomathematics into the topic of three-dimensional geometry. The rationale for using VR stemmed from the need to enhance students' spatial visualization and contextualize abstract concepts through culturally grounded representations. The Baduy culture was deliberately selected due to the rich geometric structures embedded in its traditional architecture, such as the *Leuit* (rice granary) and the inherent educational values reflected in its motifs and construction systems. The design process consisted of: (1) developing geometry content (cuboids, cubes, and prisms) linked to the *Leuit* structure, including estimations of dimensions, volume, and geometric proportions; (2) constructing a three-dimensional *Leuit Baduy* model using Blender and integrating it into a VR platform for interactive exploration of faces, edges, and vertices; and (3) designing learning interactivity through cultural narratives, usage instructions, and problem-solving exercises rooted in local contexts.

Initial validation of the prototype was conducted by two media experts and two subject matter experts using a five-point Likert-scale validation instrument, with consistency measured using Aiken's V. The results indicated a high level of validity across content ($V = 0.82$), media design ($V = 0.80$), and cultural relevance ($V = 0.78$), meeting the criteria for advancement to the development stage. These findings suggest that the initial prototype effectively integrates an ethnomathematical approach with immersive technology, resulting in a valid and contextually grounded instructional design.

3. Development Phase

The digital instructional material based on ETNO-VR was validated by three experts, consisting of two lecturers from La Tansa Mashiro University and one from Sultan Ageng Tirtayasa University. The validation process began with a Focus Group Discussion (FGD) to establish consensus on evaluation indicators, followed by a document review of the product and a scoring process using a structured evaluation rubric. The validation covered several key aspects: content relevance, material accuracy, presentation techniques and flow, language readability, and the contextual alignment of ethnomathematical content with Baduy cultural elements. The validation results are summarized in Table 2.

Table 2. Expert Validation Results of the ETNO-VR Product Based on Aiken's V Index

Aspect	Aiken's V Index	Category
Content Relevance	0.58	Valid
Content Accuracy	0.65	Valid
Presentation Technique	0.78	Valid
Presentation Flow	0.56	Valid
Language Readability	0.76	Valid
Ethnomathematical Context Relevance	0.80	Valid
VR Engagement and Interactivity	0.72	Valid
Ease of Navigation and User Experience (UX)	0.70	Valid

Based on the validity test results, all assessed aspects were deemed valid, with Aiken's V values exceeding 0.50 (Susanta et al., 2023), indicating that the media met the standards of content appropriateness, presentation quality, language clarity, and integration of local cultural elements. The ETNO-VR learning media developed in this study demonstrated strong content validity, practical implement ability, and pedagogical effectiveness. Expert validation by scholars in ethnomathematics and educational technology yielded Aiken's V scores ranging from 0.56 to 0.80, categorized as valid to highly valid. These results are presented in Table 2 and confirm that ETNO-VR is a robust learning tool in terms of content, usability, and educational impact. These findings indicate that, conceptually, the product has satisfied the criteria for content relevance, visual design, and contextual alignment with local cultural values elements that are essential for meaningful mathematics learning rooted in students' lived realities. Although all components met the minimum validity threshold ($V > 0.50$; Retnawati, 2014), some indicators, such as "presentation flow" ($V = 0.56$) and "content suitability" ($V = 0.58$), were near the lower bound, suggesting the need for structural revisions to narrative sequencing and adjustments to content depth following students' cognitive levels. In contrast, components such as ethnomathematical integration ($V = 0.80$) and VR interactivity ($V = 0.72$) were identified as key strengths, effectively bridging mathematics learning with local cultural values. Expert feedback is summarized in Table 4, highlighting suggestions for improvements ranging from consistent material structuring and enhanced visual illustration to stronger problem-based learning activities. All three validators emphasized the importance of authentic contextual representation and consistent use of mathematical language.

Table 3. Recommendations for Improvement from Expert Validators

Validator	Suggested Revisions
Expert 1	a. The material should be presented more consistently, including contextual problem examples and their systematic solutions.
	b. Realistic problems should be based on concepts and phenomena that are familiar to students' daily experiences.
Expert 2	a. Add realistic visual illustrations to enhance students' understanding of contextual problems.
	b. Reinforcement exercises must align with indicators of mathematical problem-solving skills.

Validator	Suggested Revisions
Expert 3	a. Each contextual question should be accompanied by culturally relevant illustrations, particularly those related to Baduy traditions. b. Review the consistency of mathematical notation and language usage throughout the material.

The product was thoroughly revised based on the above feedback. Improvements included the addition of visual illustrations representative of Baduy culture, the development of problems grounded in students' authentic experiences and exploration, and a comprehensive review of language consistency and mathematical symbols. This revision process aligns with the principles of educational design research, which emphasizes iterative refinement, critical reflection, and contextual responsiveness as key elements in designing humanistic and transformative mathematics learning experiences. Examples of the pre- and post-revision design can be seen in Figures 5 to 8, which illustrate the contextualized problem scenarios used in the instructional materials.

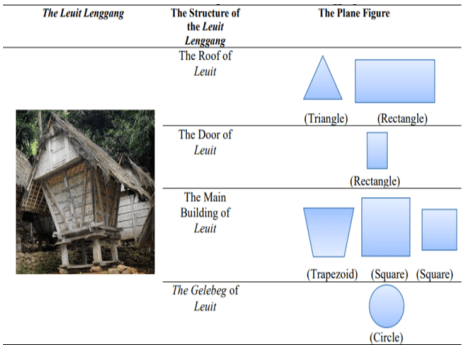

Figure 5. Before revision: Concept of Flat-Sided Leuit Lenggang Geometry

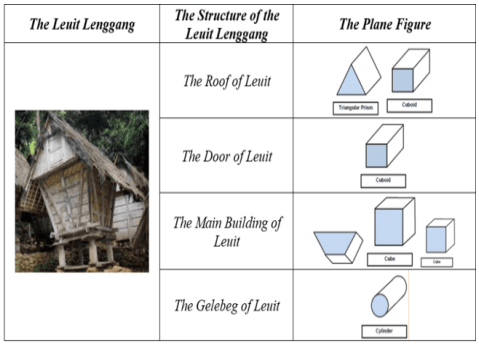

Figure 6. After revision: Concept of Flat-Sided Leuit Lenggang Geometry

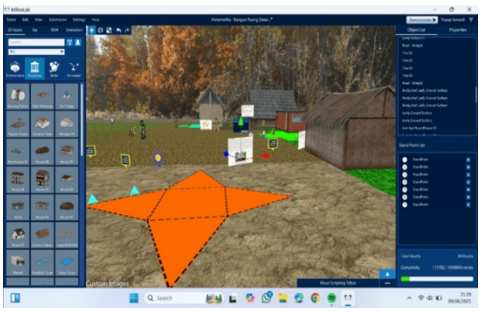

Figure 7. After revision: Culture-based ETNO-VR teaching materials

Figure 8. Finish Culture-Based ETNO-VR Teaching Materials

4. Practicality Test Results (Small Group Trial)

The ETNO-VR-based digital learning material, having undergone expert validation and conceptual revisions, was subjected to a limited-scale practicality test involving 30 eighth-grade students representing three academic ability levels (high, medium, and low). This practicality test followed Tessmer's formative evaluation model (1998), focusing on key aspects such as visual design, cognitive accessibility, language clarity, and the contextual relevance of culturally grounded problem items. The evaluation results revealed high appreciation for the visual elements, particularly the use of color and culturally inspired illustrations, with an average score of 3.50, categorized as "very good." This indicates that the design effectively captured students' attention and enhanced their engagement. Readability of font and layout also received positive feedback (average >3.40). However, the clarity of realistic problem items and their connection to students' real-life environments scored lower (average 3.00–3.04), suggesting a need for improvement in contextualizing problem design based on local student experiences. Teacher and student responses regarding the practicality of the media yielded an average score of 3.48 (categorized as "practical") on a 4-point scale, indicating ease of use and alignment with learners' needs (Nieveen, 1999). These findings recommend the optimization of cultural illustrations and locally relevant narratives to ensure that the ETNO-VR product is not only visually engaging but also pedagogically and culturally meaningful. Table 4 presents a summary of the practicality assessment results for the ETNO-VR product.

Table 4. Practicality Assessment of the ETNO-VR Product

Aspect	Average Score	Category
Visual Design Quality (images, color, VR resolution)	3.50	Very Good
Font Type and Size	3.45	Very Good
Layout and VR Navigation Flow	3.56	Very Good
Language Clarity	3.39	Good
Integration of Realistic Contextual Problems (Baduy Culture)	3.23	Good
Presentation of Materials and Exercises (in VR environment)	3.39	Good
Comprehensibility of Math Problems in VR	3.00	Good
Alignment of VR Content with Students' Local Environment	3.04	Good
Ease of Navigation and VR Interactivity	3.48	Very Good
Relevance of Virtual Cultural Artifacts (weaving, leuit, traditional measurement)	3.42	Very Good

After a limited trial was conducted, improvements were made to the ETNO-VR media, focusing on enhancing the quality of realistic problem visualization and the immersive contextualization of Baduy culture. These refinements included the addition of a 360-degree rotatable 3D simulation of traditional Baduy houses and weaving patterns, as well as the integration of localized narratives within problem-solving scenarios. The field trial involved 30 students from SMPN 1 Banjarsari and was carried out over two sessions covering the topic of three-dimensional geometric solids. Before implementation, the teacher received training through a focus group discussion (FGD) to align understanding regarding the instructional procedures and the completion of the mathematical creative thinking assessment instruments. Effectiveness

testing using a paired t-test revealed a statistically significant difference between pre-test and post-test scores ($p < 0.05$), with an average score increase of 17.3 points. Students' mathematical creative thinking skills improved from a pre-test mean of 58.9 to a post-test mean of 76.2, indicating notable cognitive development. These findings align with Suherman & Vidákovich (2022), who emphasized the importance of interactive media in fostering fluency, flexibility, originality, and elaboration (Alabbasi et al., 2022). Test results showed that the average score for students' creative mathematical thinking ability was 70.05 (classified as high), with the highest score being 80.25 and the lowest being 25.04. The distribution of students' creative thinking ability levels is presented in Table 6.

Table 5. Levels of Students' Mathematical Creative Thinking Skills

Score Interval	Category	Number of Students	Percentage
0–33	Low	2	4.05%
34–66	Medium	10	31.08%
67–100	High	18	64.86%

These data indicate that the majority of students (64.86%) fell into the high category, suggesting that ETNO-VR holds significant potential in supporting culturally contextualized mathematical problem-solving skills. This finding reinforces the notion that ethnomathematical approaches within virtual environments can stimulate more flexible cognitive activity, particularly in conceptualizing spatial structures through local symbols and artifacts. Furthermore, this media supports D'Ambrosio's (1985) view that integrating cultural elements such as traditional weaving motifs and the *leuit* (granary) structures of the Baduy community can enrich the mathematical learning experience both cognitively and affectively. The use of VR technology is consistent with immersive learning theory (Ainsworth, 2006; Freina & Ott, 2015), enabling students to engage in meaningful and contextually grounded three-dimensional spatial learning.

Figure 9. Small Group Trial

5. Dissemination Phase

The dissemination phase of this study focused on evaluating the implementational feasibility and user perceptions of the ETNO-VR-based digital learning media. The product was distributed to mathematics teachers at partner schools, particularly those teaching solid geometry, through two channels: (1) direct distribution via digital storage devices (e.g., flash drives) to support access in areas with limited internet connectivity, and (2) online dissemination through a web-based learning platform, enabling multi-device and cross-location access. In addition to technical distribution, the dissemination activities included pedagogical training and intensive mentoring for participating teachers to enhance their understanding and

skills in integrating the ETNO-VR media into classroom instruction. Teachers were not only involved as end-users but also served as initial evaluators, providing critical feedback on interface design, content flow, clarity, and alignment with the goals of the *Kurikulum Merdeka*. This dissemination strategy was designed to assess the readiness for broader adoption of the product and to explore the potential for local culture-based media adaptation in thematic, contextual, and differentiated learning. It aligns with the spirit of *Kurikulum Merdeka*, which emphasizes meaningful learning rooted in cultural identity and promotes the *Profil Pelajar Pancasila* through immersive technological approaches to local identity exploration.

Discussions

This study demonstrates that integrating elements of Baduy ethnomathematics into a VR learning environment significantly enhances students' creative mathematical thinking. The observed improvements in flexibility and elaboration reflect contextually grounded knowledge construction, an outcome not typically fostered by traditional, non-immersive instruction. These findings underscore the potential of culturally responsive VR as an innovative approach in mathematics education, particularly within underrepresented indigenous contexts. To the best of our knowledge, this is the first study to incorporate Baduy cultural artifacts into a VR-based ethnomathematics learning platform designed to promote deep learning and 21st-century skills in secondary education settings. Content validity testing using Aiken's V yielded scores ranging from 0.56 to 0.80, indicating varying degrees of appropriateness from moderate to high depending on the assessed criteria. The eight evaluation indicators were grouped into three core domains: content substance, instructional design, and cultural-technological integration. Lower validity scores, especially those related to the presentation flow and the depth of cultural representation, highlight key areas for refinement. Validators recommended restructuring the content delivery for improved coherence and incorporating more authentic representations of Baduy culture to strengthen the connection between ethnomathematical context and spatial geometry concepts, in line with the ethno-constructivist approach (D'Ambrosio & Rosa, 2017; Mania & Alam, 2021).

The effectiveness of VR in mathematics instruction is further supported by prior studies emphasizing the role of spatial visualization and immersive engagement in enhancing conceptual understanding and cognitive involvement (Buchori & Osman, 2023; Hsu, 2021; Kurzaeva et al., 2020). Local cultural contexts, such as the *leuit lenggang* granary artifact, strategically represent mathematical ideas such as volume estimation and geometric transformation (Handoyo et al., 2022; Kusuma et al., 2024). By blending culturally embedded exploratory learning within an interactive VR environment, ETNO-VR has the potential to deepen students' reflective and contextual mathematical meaning-making (Lidinillah et al., 2022). Additionally, validators' emphasis on navigational ease aligns with the CAMIL design model (Makransky & Petersen, 2021), which highlights interface comfort as a prerequisite for optimal engagement and learning outcomes. In conclusion, while ETNO-VR exhibits a strong conceptual foundation, further enhancement of its cultural narrative and multimodal learning experiences is needed to ensure that the integration of culture and mathematics unfolds in a cohesive and meaningful way.

The practicality of the ETNO-VR media was evaluated through a small group trial involving 30 eighth-grade students at SMPN 1 Banjarsari, Lebak Regency. The results indicated an average score of 3.38 on a 4-point scale, which, based on the classification frameworks of Akker (1999) and Tessmer (1998), falls within the "practical" category. The assessment instrument covered four key dimensions: navigation, visualization, instructional clarity, and content appeal (Farida et al., 2019; Yerizon et al., 2024). Students expressed enthusiasm toward the immersive aspects of the media, aligning with findings by Makransky & Petersen (2021) and Marougkas

et al. (2023) that virtual reality enhances engagement and learning motivation through contextualized experiences. However, challenges emerged in students' comprehension of culturally embedded symbolic narratives, reinforcing the observations of Hamilton et al. (2021) and Akman & Çakır (2020) regarding the need for adaptive cross-cultural design. Therefore, simplifying visual elements and language becomes essential to ensure inclusivity (Kusuma et al., 2024; Montagud et al., 2020).

Empirical evidence of ETNO-VR's effectiveness was demonstrated through a significant increase in students' creative mathematical thinking scores from 58.9 to 76.2 ($\Delta \approx 17.3$; $p < 0.01$; $n = 30$). The most notable improvements were observed in the indicators of flexibility and elaboration, reflecting students' ability to construct diverse solutions and expand their representation of ideas using Baduy cultural artifacts (Hadar & Tirosh, 2019; Suherman & Vidákovich, 2022). These results support the principles of ethnomathematics (D'Ambrosio & Rosa, 2017), which emphasizes that integrating local cultural contexts can enrich mathematical learning and foster creativity. The use of VR has been shown to strengthen spatial imagination, idea elaboration, and conceptual understanding through interactive visualization (Asad et al., 2021; Buchori & Osman, 2023; Hsu, 2021). In conclusion, ETNO-VR demonstrates substantial potential in supporting culturally responsive education and enhancing 21st-century competencies contextually and adaptively.

The enhancement of students' creative mathematical thinking in this study was supported by the immersive learning experiences provided by the ETNO-VR media. This aligns with the Cognitive Affective Model of Immersive Learning (CAMIL) proposed by Makransky and Petersen (2021), which emphasizes that VR-based learning is most effective when it simultaneously activates both cognitive and affective engagement. Marougkas et al. (2023) found that emotional involvement and spatial perception in VR environments significantly reinforce the construction of mathematical concepts. Cultural relevance was further embedded through the integration of Baduy values and artifacts, which enabled students to elaborate and generate original ideas, an effect also supported by Iasha et al. (2023) and Faiziyah et al. (2020). Uteuliev and Madyarov (2022) added that embedding local cultural contexts within immersive media bridges the gap between concrete and abstract experiences, a critical factor in developing cognitive flexibility. The ETNO-VR product incorporates ethnomathematical geometry (D'Ambrosio & Rosa, 2017) into interactive simulations that have been validated in terms of content, construct, and practicality. Istikomah et al. (2024) confirmed that all four indicators of creative thinking fluency, flexibility, originality, and elaboration were actualized through this approach. By integrating immersive technology with local cultural contexts, ETNO-VR not only strengthens students' conceptual understanding but also serves as an innovative model for bridging local mathematical literacy with global competencies (Kim & Kwon, 2023; Paloș et al., 2025). These findings highlight important implications for the design of culturally responsive educational technologies that connect global technological advancements with indigenous and traditional knowledge systems, supporting UNESCO's Sustainable Development Goal (SDG) 4 on inclusive and equitable quality education.

CONCLUSION

This study demonstrates that the development of ETNO-VR effectively bridges the gap between mathematical abstraction and students' cultural realities through an immersive learning experience grounded in Baduy cultural artifacts. Empirical findings indicate that this medium enhances students' creative mathematical thinking, particularly in the domains of flexibility and elaboration dimensions that are often difficult to cultivate through traditional instruction. The study broadens the scope of ethnomathematics by integrating principles of

immersive learning, cultural scaffolding, and local spatial contexts into a unified digital learning ecosystem. Beyond its instructional effectiveness, the findings offer a conceptual contribution to the development of culturally responsive and reflective learning models within the context of disruptive technologies. Practically, ETNO-VR opens new possibilities for replicating culturally grounded instructional design in marginalized regions with limited infrastructure, aligning with the vision of the *Kurikulum Merdeka* and Sustainable Development Goal 4. Looking ahead, future research should involve cross-cultural and longitudinal investigations focused on AI-driven multimodal design, aiming to measure long-term impacts on spatial literacy, digital inclusion, and the transformative meaning-making of mathematics among Indonesian learners.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support from the Ministry of Research, Technology, and Higher Education (Kemenristekdikti), Republic of Indonesia, through the 2025 Beginner Lecturer Research Grant Scheme (*Penelitian Dosen Pemula*), under Contract Number: SK 125/C3/DT.05.00/PL/2025

REFERENCES

Akman, E., & Çakır, R. (2023). The effect of educational virtual reality game on primary school students' achievement and engagement in mathematics. *Interactive Learning Environments*, *31*(3), 1467–1484. https://doi.org/10.1080/10494820.2020.1841800

Alabbasi, A. M. A., Paek, S. H., Kim, D., & Cramond, B. (2022). What do educators need to know about the Torrance Tests of Creative Thinking: A comprehensive review. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.1000385

Ansari, B. I., Saleh, M., Nurhaidah, N., & Taufiq, T. (2021). Exploring Students' Learning Strategies and Self-Regulated Learning in Solving Mathematical Higher-Order Thinking Problems. *European Journal of Educational Research*, *volume-10*-(volume-10-issue-2-april-2021), 743–756. https://doi.org/10.12973/eu-jer.10.2.743

Asad, M. M., Naz, A., Churi, P., & Tahanzadeh, M. M. (2021). Virtual Reality as Pedagogical Tool to Enhance Experiential Learning: A Systematic Literature Review. *Education Research International*, *2021*, 1–17. https://doi.org/10.1155/2021/7061623

Biwer, F., Egbrink, M. G. A. oude, Aalten, P., & de Bruin, A. B. H. (2020). Fostering effective learning strategies in higher education—A mixed-methods study. *Journal of Applied Research in Memory and Cognition*, *9*(2), 186–203. https://doi.org/10.1016/j.jarmac.2020.03.004

Buchori, A., & Osman, S. (2023). Development of virtual reality math media in the junior high school Indonesia-Malaysia with group investigation model. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, 1–11. https://doi.org/10.23917/jramathedu.v8i1.1547

Bulut Ates, C., & Aktamis, H. (2024). Investigating the effects of creative educational modules blended with Cognitive Research Trust (CoRT) techniques and Problem Based Learning (PBL) on students' scientific creativity skills and perceptions in science education. *Thinking Skills and Creativity*, *51*, 101471. https://doi.org/10.1016/j.tsc.2024.101471

Cooper, G., Park, H., Nasr, Z., Thong, L. P., & Johnson, R. (2019). Using virtual reality in the classroom: preservice teachers' perceptions of its use as a teaching and learning tool. *Educational Media International*, *56*(1), 1–13. https://doi.org/10.1080/09523987.2019.1583461

D'Ambrosio, U., & Rosa, M. (2017). *Ethnomathematics and Its Pedagogical Action in Mathematics Education* (pp. 285–305). https://doi.org/10.1007/978-3-319-59220-6_12

Diamah, A., Rahmawati, Y., Paristiowati, M., Fitriani, E., Irwanto, I., Dobson, S., & Sevilla, D. (2022). Evaluating the effectiveness of technological pedagogical content knowledge-based training program in enhancing pre-service teachers' perceptions of technological pedagogical content knowledge. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.897447

Faiziyah, N., Sutama, S., Sholihah, I., Wulandari, S., & Yudha, D. A. (2020). Enhancing Creativity through Ethnomathematics. *Universal Journal of Educational Research*, *8*(8), 3704–3710. https://doi.org/10.13189/ujer.2020.080850

Farida, Supriadi, N., & Kurniawati, N. (2019). Developing Student Worksheet Assisted with Geogebra on Derivative Materials. *Journal of Physics: Conference Series*, *1155*(1). https://doi.org/https://doi.org/10.1088/1742-6596/1155/1/012096

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. *Sustainability*, *14*(3), 1493. https://doi.org/10.3390/su14031493

Hadar, L. L., & Tirosh, M. (2019). Creative thinking in mathematics curriculum: An analytic framework. *Thinking Skills and Creativity*, *33*, 100585. https://doi.org/10.1016/j.tsc.2019.100585

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1–32. https://doi.org/10.1007/s40692-020-00169-2

Hamzah, H., Hamzah, M. I., & Zulkifli, H. (2022). Systematic Literature Review on the Elements of Metacognition-Based Higher Order Thinking Skills (HOTS) Teaching and Learning Modules. *Sustainability*, *14*(2), 813. https://doi.org/10.3390/su14020813

Handoyo, F. W., Hidayatina, A., Nadjib, M., & Purwanto. (2022). Perspectives of indigenous communities on food security: understanding local values in agricultural practice. *IOP Conference Series: Earth and Environmental Science*, *1105*(1), 012007. https://doi.org/10.1088/1755-1315/1105/1/012007

Hasanah, S. I., Zayyadi, M., Tafrilyanto, C. F., & Ningtyas, Y. D. W. K. (2024). Ethnomathematics of Madurese Cultural Characteristics in the Emancipated Curriculum. *Journal of Innovation in Educational and Cultural Research*, *5*(3), 540–548. https://doi.org/10.46843/jiecr.v5i3.1147

Hidajat, F. A. (2024). Effectiveness of virtual reality application technology for mathematical creativity. *Computers in Human Behavior Reports*, *16*, 100528. https://doi.org/10.1016/j.chbr.2024.100528

Hsu, Y. C. (2021). Exploring the Effectiveness of Two Types of Virtual Reality Headsets for Teaching High School Mathematics. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(8), em1986. https://doi.org/10.29333/ejmste/10996

Kabuye Batiibwe, M. S. (2024). The role of ethnomathematics in mathematics education: A literature review. *Asian Journal for Mathematics Education*, *3*(4), 383–405. https://doi.org/10.1177/27527263241300400

Kallia, M., van Borkulo, S. P., Drijvers, P., Barendsen, E., & Tolboom, J. (2021). Characterising computational thinking in mathematics education: a literature-informed Delphi study. *Research in Mathematics Education*, *23*(2), 159–187. https://doi.org/10.1080/14794802.2020.1852104

Kim, K., & Kwon, K. (2023). Exploring the AI competencies of elementary school teachers in South Korea. *Computers and Education: Artificial Intelligence*, *4*, 100137. https://doi.org/10.1016/j.caeai.2023.100137

Kozlowski, A. C., Taddy, M., & Evans, J. A. (2019). The Geometry of Culture: Analyzing the Meanings of Class through Word Embeddings. *American Sociological Review*, *84*(5), 905–949. https://doi.org/10.1177/0003122419877135

Kurzaeva, L. V, Bondarenko, T. A., Kameneva, G. A., Maznina, Y. A., & Akmanova, S. V. (2020). The Use of AR Elements in the Teaching of Mathematics at a Technical University. In *Proceedings - 2020 Global Smart Industry Conference, GloSIC 2020* (pp. 328–334). https://doi.org/10.1109/GloSIC50886.2020.9267869

Kusuma, A. B., Hanum, F., Abadi, A. M., & Ahmad, A. (2024). Exploration of ethnomathematics research in Indonesia 2010-2023. *Infinity Journal*, *13*(2), 393–412. https://doi.org/10.22460/infinity.v13i2.p393-412

Lee, H., & Hwang, Y. (2022). Technology-Enhanced Education through VR-Making and Metaverse-Linking to Foster Teacher Readiness and Sustainable Learning. *Sustainability*, *14*(8), 4786. https://doi.org/10.3390/su14084786

Lidinillah, D. A. M., Rahman, R., Wahyudin, W., & Aryanto, S. (2022). Integrating Sundanese Ethnomathematics Into Mathematics Curriculum And Teaching: A Systematic Review From 2013 To 2020. *Infinity Journal*, *11*(1), 33. https://doi.org/10.22460/infinity.v11i1.p33-54

Lukovic, S., Marinkovic, B., & Zotovic-Kostic, M. (2022). The zone of actual and the zone of proximal development measured through preschool dynamic assessment as predictors of later school performance - a longitudinal study. *Psihologija*, *55*(1), 89–105. https://doi.org/10.2298/PSI200914004L

Makransky, G., & Petersen, G. B. (2021). The Cognitive Affective Model of Immersive Learning (CAMIL): a Theoretical Research-Based Model of Learning in Immersive Virtual Reality. *Educational Psychology Review*, *33*(3), 937–958. https://doi.org/10.1007/s10648-020-09586-2

Makri, A., Vlachopoulos, D., & Martina, R. A. (2021). Digital Escape Rooms as Innovative Pedagogical Tools in Education: A Systematic Literature Review. *Sustainability*, *13*(8), 4587. https://doi.org/10.3390/su13084587

Mania, S., & Alam, S. (2021). Teachers' Perception toward the Use of Ethnomathematics Approach in Teaching Math. *International Journal of Education in Mathematics, Science and Technology*, *9*(2), 282–298. https://doi.org/10.46328/ijemst.1551

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual Reality in Education: A Review of Learning Theories, Approaches and Methodologies for the Last Decade. *Electronics*, *12*(13), 2832. https://doi.org/10.3390/electronics12132832

Mokhtar, M. M., Jamil, M., Yaakub, R., & Amzah, F. (2020). Debate as a Tool for Learning and Facilitating Based on Higher Order Thinking Skills in The Process of Argumentative Essay Writing. *International Journal of Learning, Teaching and Educational Research*, *19*(6), 62–75. https://doi.org/10.26803/ijlter.19.6.4

Montagud, M., Orero, P., & Matamala, A. (2020). Culture 4 all: accessibility-enabled cultural experiences through immersive VR360 content. *Personal and Ubiquitous Computing*, *24*(6), 887–905. https://doi.org/10.1007/s00779-019-01357-3

Nusantara, D. S., Zulkardi, Z., & Putri, R. I. I. (2021). Designing Pisa-Like Mathematics Task Using A Covid-19 Context (Pisacomat). *Journal on Mathematics Education*, *12*(2), 349–364. https://doi.org/10.22342/jme.12.2.13181.349-364

Østerlie, O., Sargent, J., Killian, C., Garcia-Jaen, M., García-Martínez, S., & Ferriz-Valero, A. (2023). Flipped learning in physical education: A scoping review. *European Physical Education Review*, *29*(1), 125–144. https://doi.org/10.1177/1356336X221120939

Paloș, R., Vîrgă, D., & Dediu, R. (2025). Students' approach to learning and their intrinsic motivation to know – the moderating role of psychological needs. *Current Psychology*. https://doi.org/10.1007/s12144-025-07990-x

PISA 2022 Assessment and Analytical Framework. (2023). OECD. https://doi.org/10.1787/dfe0bf9c-en

PISA 2022 Results (Volume I). (2023). OECD. https://doi.org/10.1787/53f23881-en

Scurati, G. W., Bertoni, M., Graziosi, S., & Ferrise, F. (2021). Exploring the Use of Virtual Reality to Support Environmentally Sustainable Behavior: A Framework to Design Experiences. *Sustainability*, *13*(2), 943. https://doi.org/10.3390/su13020943

Suherman, S., & Vidákovich, T. (2022). Assessment of mathematical creative thinking: A systematic review. *Thinking Skills and Creativity*, *44*, 101019. https://doi.org/10.1016/j.tsc.2022.101019

Susanta, A., Sumardi, H., Susanto, E., & Retnawati, H. (2023). Mathematics literacy task on number pattern using Bengkulu context for junior high school students. *Journal on Mathematics Education*, *14*(1), 85–102. https://doi.org/10.22342/jme.v14i1.pp85-102

Tanujaya, B., Indra Prahmana, R. C., & Mumu, J. (2021). Mathematics Instruction to Promote Mathematics Higher-Order Thinking Skills of Students in Indonesia: Moving Forward. *TEM Journal*, 1945–1954. https://doi.org/10.18421/TEM104-60

Téllez-Acuña, F. R., Pineda-Ballesteros, E., Meneses-Cabrera, T., & Medina-Cruz, J. (2020). Expert systems and vocational guidance in ict mediated distance education. *Aibi, Revista de Investigacion Administracion e Ingenierias*, *8*, 186–195. https://doi.org/10.15649/2346030X.2424

Tene, T., Marcatoma Tixi, J. A., Palacios Robalino, M. de L., Mendoza Salazar, M. J., Vacacela Gomez, C., & Bellucci, S. (2024). Integrating immersive technologies with STEM education: a systematic review. *Frontiers in Education*, *9*. https://doi.org/10.3389/feduc.2024.1410163

Uteuliev, N. S., & Madyarov, N. K. (2022). The Possibilities of Using New Digital Technologies in Teaching Students the Course of Geometry. *Iasaýı Ýnıversıtetiniń Habarshysy*, *124*(2), 243–255. https://doi.org/10.47526/2022-2/2664-0686.20

Ye, H., Liang, B., Ng, O.-L., & Chai, C. S. (2023). Integration of computational thinking in K-12 mathematics education: a systematic review on CT-based mathematics instruction and student learning. *International Journal of STEM Education*, *10*(1), 3. https://doi.org/10.1186/s40594-023-00396-w

Yerizon, Sukestiyarn, Arnellis, & Suherman. (2024). Development Of Mathematics Learning Tools Based On The Mapos Approach To Improve The Reasoning Ability Of Class Vii Students. *Revista de GestÃ£o Social e Ambiental*, *18*(6), 1–29. https://doi.org/https://doi.org/10.24857/rgsa.vl8n6-029

Yulianto, D., Umami, M. R., Junaedi, Y., & Anwar, S. (2024). Analisis Literasi Matematis Siswa SMP di Kabupaten Lebak-Banten: Studi Kasus Soal Tipe PISA dengan Memperhatikan Faktor Akreditasi, Status Sekolah, Tingkat Kemampuan, dan Jenis Kelamin. *PAKAR Pendidikan*, *22*(1), 203–232. https://doi.org/10.24036/pakar.v22i1.509

Zaretsky, V. K. (2021). One More Time on the Zone of Proximal Development. *Cultural-Historical Psychology*, *17*(2), 37–49. https://doi.org/10.17759/chp.2021170204