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Integrating Contextual Learning, STEAM, and Virtual Reality in Geometry: An Investigation of Implementation and Challenges in South Sumatera

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Geometry is a fundamental branch of mathematics that supports the development of logical thinking, spatial reasoning, and problem-solving skills. Yet, many students still struggle to understand geometric concepts because learning remains abstract and lacks meaningful real-world connections. In Indonesia, geometry instruction often emphasizes procedural mastery over deep conceptual understanding, underscoring the need for innovative approaches that make learning more concrete and engaging. Integrating real-world contexts, the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach, and Virtual Reality (VR) technology offers a promising way to bridge the gap between abstract ideas and practical applications. This study investigates the extent of implementation and the challenges in applying contextual, STEAM-based, and VR-supported geometry learning in Indonesia. Participants included 100 junior high school students and 10 mathematics teachers, randomly selected from South Sumatera, a region whose Gambo Muba textile tradition provides a culturally relevant context for geometry learning. Using a mixed-methods design, data were collected through questionnaires, interviews, and classroom observations. Findings show that STEAM-based and VR-supported learning positively influences students' conceptual understanding, motivation, and engagement, particularly in geometric transformations. However, implementation remains at an early stage, with teachers displaying positive attitudes but limited experience, and with constraints on VR availability and training. The study underscores the need for capacity building and improved infrastructure to optimize this innovative approach.

Keywords: context; geometry; STEAM; virtual reality

INTRODUCTION

Geometry is a fundamental area of mathematics that plays an essential role in developing students' logical thinking, spatial reasoning, visual representation, and problem-solving skills (Akar, Geometric, & Quantitative, 2023). Within the junior high school curriculum, geometry serves as a core component of mathematical literacy, especially under the Merdeka Curriculum, which emphasizes contextual, inquiry-based, and competency-oriented learning (Sembiring & Hadi, 2008) and (Mulbasari et al., 2024). However, despite its importance, numerous studies have shown that students consistently struggle to understand abstract geometric concepts—particularly geometric transformations such as reflections, rotations, and translations. These concepts are often presented in symbolic or procedural forms that lack real-world relevance, making it difficult for students to internalize and apply them meaningfully (Charitas, Prahmana, & Ambrosio, 2020). As a result, students' motivation, engagement, and learning outcomes in geometry remain low. This persistent challenge highlights the need for instructional innovations that can bridge the gap between abstract mathematical concepts and meaningful, relatable learning experiences.

In response to these challenges, the integration of interdisciplinary and technology-enhanced learning approaches has emerged as a promising direction in mathematics education. One approach that has gained widespread attention is STEAM (Science, Technology, Engineering, Arts, and Mathematics), which encourages students to explore mathematical ideas through project-based learning, design activities, experimentation, and creative expression. Studies conducted by (Henriksen et al., 2019) and (Kartikaningtyas et al., 2025) show that STEAM strengthens numeracy literacy by promoting inquiry, design thinking, and cross-disciplinary reasoning. Furthermore, (Laksmiwati et al., 2024) demonstrate that STEAM-based instruction increases student engagement, creativity, and collaboration, while (Okeke & Ramaila, 2025) emphasize that STEAM fosters critical and innovative thinking skills. Although STEAM shows considerable potential for enhancing mathematics learning, its implementation in Indonesian classrooms often remains limited to small-scale projects and lacks integration with contextual or cultural elements that could further enhance relevance and meaning for learners. This creates an opportunity to explore STEAM not merely as a pedagogical trend, but as a culturally responsive and technologically supported instructional framework.

Parallel to STEAM, rapid advances in educational technology—particularly Virtual Reality (VR)—offer new opportunities to address the cognitive challenges associated with abstract mathematical topics. VR environments allow students to explore geometric objects and transformations in an immersive way, enabling them to visualize mathematical relationships from multiple perspectives in real time. Research by (Thomsen, 2023) and (Hidajat, 2024) demonstrates that VR increases student motivation and deepens understanding by providing dynamic visualizations that traditional textbooks cannot offer. (Lara-Alvarez et al., 2023) further confirm that VR supports spatial reasoning and enhances students' grasp of three-dimensional geometry. Despite these benefits, VR adoption remains very limited in schools, primarily due to constraints in infrastructure, lack of teacher training, and students' unfamiliarity with immersive technologies (Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). These challenges suggest that VR integration must be accompanied by pedagogically structured learning designs and adequate teacher support to ensure effective implementation.

In addition to technological and interdisciplinary innovations, mathematics education in Indonesia is increasingly encouraged to incorporate local cultural contexts to promote meaningful learning. Ethnomathematics provides a framework for connecting mathematical concepts with cultural practices, traditional crafts, and everyday community activities. Research by (Kartikaningtyas et al., 2025) reveals that incorporating batik motifs into geometry lessons helps students understand geometric transformations more easily and strengthens cultural awareness. (Kurniawan et al., 2024) similarly argue that traditional textiles provide rich sources for exploring symmetry, patterns, and geometric structures. These culturally grounded approaches align with the principles of the Merdeka Curriculum, which emphasizes contextualization, character development, and the preservation of local wisdom (Novrika, Putri, & Hartono, 2016). However, although ethnomathematics has been used to enrich

geometry learning, most existing research focuses on cultural artifacts alone and does not integrate them with modern technologies or interdisciplinary learning frameworks such as STEAM.

A review of existing literature shows that research on STEAM, VR, and cultural contexts has progressed in separate pathways, each producing valuable insights. Yet, there is a significant gap in the state of the art: very few studies have attempted to integrate these three components into a single pedagogical design. Most research on STEAM excludes cultural relevance; studies on VR seldom incorporate interdisciplinary structures; and ethnomathematics research rarely explores its potential within immersive or technology-rich environments. This fragmentation indicates that the field has not yet explored how these complementary elements can work together to address students' persistent difficulties in understanding geometric transformations. The absence of integrative studies represents a significant opportunity for innovation—one that aligns with both global educational trends and national curriculum goals.

Therefore, the present study is urgently needed to address this gap by investigating how a learning design that integrates STEAM principles, Virtual Reality, and the local cultural context of Gambo Muba textiles can enhance the teaching and learning of geometric reflection. This integration is expected to offer a more holistic instructional approach: STEAM encourages interdisciplinary problem-solving; VR provides immersive visualization of abstract concepts; and the cultural context supports meaningful, identity-based learning. Together, these elements have the potential to create rich, engaging, and culturally responsive learning experiences that are aligned with the demands of twenty-first-century education. Moreover, this study contributes empirically to understanding teachers' and students' readiness, perceptions, and challenges in adopting an integrated STEAM–VR–ethnomathematics model—insights that are essential for developing innovative instructional designs suitable for Indonesian classrooms.

METHOD

This study uses quantitative and qualitative descriptive methods. The main purpose of this method is to provide an objective description or overview of a particular situation (Masfufah & Afriansyah, 2021). The research subjects comprised 100 ninth-grade students (48 male and 52 female) and 10 mathematics teachers, all from three junior high schools in Musi Banyuasin. The selection aimed to ensure representation from each school so that the research results could reflect a broader perspective.

Data collection techniques were carried out through questionnaires and interviews with a research focus on four aspects of student perception, namely: (1) aspects of understanding and interest in STEAM, (2) aspects of real-world contexts in mathematics learning, (3) aspects of perception of the use of Virtual Reality (VR) in mathematics learning, and (4) aspects of readiness and learning support. Questionnaires were administered to measure the extent to which these aspects influence the mathematics learning process. In addition, researchers conducted interviews with mathematics teachers to obtain further perspectives on learning design.

In this study, a descriptive approach was used to process the questionnaire data, which was analyzed through assessment and categorization methods based on value intervals to measure the extent to which the four aspects of perception were related to mathematics learning design. The interview data was then used to explore in greater depth the strategies for implementing learning design, the obstacles that arose in the field, and the effectiveness of the approaches used in the learning process.

The assessment was carried out by giving scores to each statement based on the frequency of students' answers. Each statement in the questionnaire was presented with five options: Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD). The neutral option is important so that respondents do not feel compelled to choose extreme answers and are free to answer according to their actual conditions or opinions (Tijmstra & Bolsinova, 2023). The scores were assigned according to Table 1.

Table 1. Scoring Scale

Category	Score
Strongly agree	4
Agree	3

Category	Score
Neutral	2
Disagree	1
Strongly disagree	0

Source: (Tijmstra & Bolsinova, 2023)

The data from the questionnaire were analyzed quantitatively and descriptively based on the interval scale listed in Table 1. In addition, to determine the level of achievement for each aspect, grouping was carried out based on the guidelines from (Budiaji, 2013), which divided the scores into five categories, namely very low, low, moderate, high, and very high. The categorization results were then categorized into levels according to the criteria listed in Table 2.

Table 2. Score Categories Achieved by Students on a Scale of 0 - 4

Category	Average Interval Score
Strongly agree	0.00 – 0.79
Agree	0.80 – 1.79
Neutral	1.80 – 2.79
Disagree	2.80 – 3.79
Strongly disagree	3.80 – 4.00

Source: (Budiaji 2013)

The results of the questionnaires completed by students were analyzed to provide an overview of the application of STEAM-based learning aspects in the context of VR in mathematics. Next, calculations were performed for 100 students across four aspects of student perception using percentage analysis. The calculations were performed per point for each aspect, with each aspect comprising several indicators. From the data analysis of the questionnaires and teacher interviews, interrelated conclusions were drawn. The final results of this data analysis were used to examine five aspects of students' perceptions of STEAM-based learning design in a real-world context, assisted by VR, which has not yet been fully implemented in mathematics learning.

RESULTS

Based on data obtained from surveys administered to junior high school students and mathematics teachers regarding their perceptions of STEAM-based learning designs that integrate real-world contexts and are supported by Virtual Reality (VR) technology, several important findings emerged that provide a comprehensive picture of the readiness, experiences, and challenges involved in implementing this innovative instructional model. The learning design, which combines interdisciplinary STEAM elements with a local cultural context—specifically the traditional motifs of Gambo Muba fabric—and immersive VR-based visualization, is perceived as a promising approach to bridging the gap between the abstract nature of geometric transformation concepts and students' concrete and meaningful learning experiences. These findings not only reflect how students and teachers understand and respond to the integration of STEAM, culture, and VR but also reveal the extent to which this approach can be realistically implemented within the current Indonesian educational context.

Specifically, the data presented in Tables 3 and 4 illustrate students' and teachers' perceptions across four main dimensions: understanding of and interest in STEAM, use of real-world contexts in learning, application of VR in geometry instruction, and readiness of devices and supporting learning systems. These quantitative results provide an important foundation for analyzing how an interdisciplinary, technology-assisted, and culturally grounded learning model influences student engagement, motivation to learn, and conceptual understanding. In addition, teachers' perceptions offer valuable insights into pedagogical readiness, practical challenges in classroom implementation, and the potential sustainability and scalability of this learning design in educational practice.

Furthermore, the developed learning design explicitly demonstrates the integration of STEAM elements and VR technology at each stage of geometry transformation instruction. The Science (S) component is reflected in students' understanding of scientific principles related to visual perception, symmetry, and changes in the position of objects in space. The Technology (T) component is implemented using Virtual Reality devices as interactive learning media, allowing students to explore geometric objects and observe transformation results in an immersive, real-time manner. The Engineering (E) component is implemented through design-oriented activities, problem-solving, and decision-making, in which students systematically design and evaluate the outcomes of geometric transformations applied to fabric motifs. The Art (A) component is integrated through the exploration of the aesthetic and cultural values embedded in Gambo Muba fabric motifs, ensuring that learning emphasizes not only mathematical cognition but also appreciation of art and local wisdom. Meanwhile, the Mathematics (M) component serves as the core of instruction, particularly in understanding and applying geometric transformation concepts such as reflection, translation, rotation, and dilation within real-world contexts.

Conceptually, Gambo Muba textile motifs feature strong, authentic geometric transformations. An illustration of Gambo Muba fabric motifs demonstrating elements of geometric transformations is shown in the following Figure 1.

Figure 1. Gambo Muba fabric patterns showing elements of geometric transformation

Based on Figure 1, repetitive patterns in the motifs indicate the presence of translation, while symmetrical patterns reflect the concept of reflection across specific axes. Some motifs also exhibit rotational elements, as seen in the repetition of shapes around a central point, as well as dilation, evident in variations in motif size while maintaining similar shapes. The presence of these geometric transformation elements positions Gambo Muba fabric not only as an object of aesthetic and cultural value, but also as a relevant and meaningful context for mathematics learning. In the VR-based learning design, Gambo Muba fabric motifs are presented as the main learning context through interactive virtual visualization. Within this environment, students can observe geometric patterns embedded in the fabric motifs, identify basic shapes and symmetries, and directly explore various geometric transformations. The implementation of the STEAM approach within the context of Gambo Muba fabric motifs enables students to connect mathematical concepts with motif design processes (engineering), the use of digital technology (technology), aesthetic and cultural values (art), and scientific reasoning related to visual perception and spatial relationships (science).

Consequently, STEAM-based geometry learning supported by VR and grounded in local cultural contexts not only enhances students' engagement and motivation to learn but also has the potential to foster deeper conceptual understanding and strengthen students' mathematical literacy.

Overall, these findings provide a strong starting point for a more in-depth discussion of the effectiveness and implementation challenges of STEAM-based geometry learning models supported by VR technology and contextualized through Gambo Muba fabric motifs. By integrating quantitative survey data with qualitative findings from interviews with students and teachers, this study offers a comprehensive analysis of how a STEAM–VR–culture-based approach can contribute to developing innovative, contextual, culturally responsive, and technology-integrated learning models in the Indonesian educational context.

The findings presented in Tables 3 and 4 describe students' and teachers' perceptions of STEAM-based mathematics learning integrated with real-world contexts and supported by Virtual Reality (VR). The results are based on questionnaire data and supported by interview excerpts from students and mathematics teachers.

Table 3. Student perceptions of STEAM-based learning design assisted by VR

Aspects	Percentace	Avarage Category
Aspects of Understanding and Interest in STEAM	68%	Moderate x = 1.98
Aspects of real-world context in mathematics learning	72%	Moderate x = 2.65
Aspects of VR Use in Mathematics	82%	Low x = 1.79
Aspects of readiness and learning support	37%	Moderate x = 2.39

As shown in Table 3, students' perceptions of STEAM-based mathematics learning supported by Virtual Reality (VR) and real-world contexts varied across four aspects: readiness and learning support, understanding and interest in STEAM, integration of real-world contexts, and the use of VR in mathematics learning.

The aspect of readiness and learning support obtained a moderate average score (x = 2.39). Questionnaire data indicate that 72% of students reported having access to learning devices, while 91% expressed willingness to use new technologies in learning. However, only 37% indicated that device readiness and learning support systems were fully adequate. Interview data support these findings. One student stated, *"I don't mind using VR or new tools as long as the teacher shows us how to do it."* This response illustrates students' openness to technology use accompanied by the need for teacher guidance.

The integration of real-world contexts in mathematics learning also fell within the moderate category, with an average score of x = 2.65 and a percentage of 72%. Survey results show that 82% of students agreed that mathematics became easier when connected to daily life experiences such as shopping, buildings, handicrafts, or cultural elements, and 78% agreed that real-life story problems supported their understanding of mathematical concepts. Interview responses align with these findings. One student explained, *"When I drew the fabric pattern and looked for its reflection, I immediately understood. It's harder when it's only shown on paper."*

Students' understanding and interest in STEAM-based learning obtained a moderate average score (x = 1.98), with 68% of students expressing interest in STEAM-oriented activities. Questionnaire data also show that 87% of students enjoyed collaborative learning, while 30–40% selected neutral responses on several STEAM-related items. Interview data reflect this condition. One student commented, *"I like the activities with designing patterns and projects, but I didn't know it was called STEAM."*

The use of VR in mathematics learning received the lowest average score among all aspects (x = 1.79). Survey results indicate that 71% of students had never used VR before, and only 37% stated that VR directly helped them understand geometric transformations, despite 82% expressing interest or curiosity toward VR technology. Interview responses provide further insight. One student stated, *"In VR I could see where the reflection moved. In the textbook I only guess."* At the same time, some students reported difficulties such as discomfort or unfamiliarity when using VR devices.

Overall, the results presented in Table 3 indicate that students' perceptions of STEAM-based mathematics learning supported by VR and real-world contexts generally fall within the moderate category across all aspects. Questionnaire and interview data consistently show positive responses toward contextual learning and innovative technologies, alongside limitations related to technological readiness, prior experience with VR, and learning support facilities.

Table 4. Teachers' perceptions of STEAM-based learning design assisted by VR

Aspects	Percentace	Avarage Category
Aspects of Understanding and Attitudes Towards Science, Technology, Engineering, Art, and Mathematics (STEAM)	80-100%	High $x = 2{,}9$

Aspects	Percentace	Avarage Category
Aspect of Using Real-World Context in Mathematics Learning	90-100%	High $x = 3{,}06$
Aspects of VR Use in Mathematics	70-80 %	Moderate $x = 2{,}68$
Aspects of Readiness for Implementing Mathematics Learning Based on Science, Technology, Engineering, Art, and Mathematics (STEAM)	80-90 %	High $x = 3{,}64$

The results in Table 4 present teachers' perceptions of STEAM-based mathematics learning integrated with real-world contexts and supported by Virtual Reality (VR). Overall, the findings show that teachers demonstrate positive perceptions across all measured aspects, with varying levels of experience and readiness.

The aspect of understanding and attitudes toward STEAM was categorized as high, with an average score of x = 2.90. Questionnaire results indicate that 80–100% of teachers agreed that STEAM supports interdisciplinary learning and helps connect mathematical concepts with other disciplines. Interview data support this finding. One teacher stated, *"STEAM helps us see mathematics more broadly. It is not only about formulas but about how concepts relate to science, art, and engineering."* Another teacher added, *"Understanding STEAM is easy. The hard part is designing lessons that connect all five components."*

The aspect of using real-world contexts in mathematics learning also received a high category score, with an average of x = 3.06 and a percentage range of 90–100%. Survey results show that most teachers regularly integrate real-life situations and cultural contexts into mathematics instruction. Interview responses illustrate this practice. One teacher explained, *"Students become more enthusiastic when the material is connected to their daily activities."* Another teacher highlighted the use of local culture, stating, *"When students work with local fabric patterns, they understand reflection concepts more easily."*

Teachers' perceptions of VR use in mathematics learning were categorized as moderate, with an average score of x = 2.68. Questionnaire data indicate that 70–80% of teachers recognized VR's potential for visualizing abstract mathematical concepts, although many reported limited experience with VR in the classroom. Interview responses reflect this condition. One teacher stated, *"VR would be very effective for geometry, but we need training and access to devices."* Another teacher commented, *"When students see the reflection process in VR, they understand it faster."*

The highest score among all aspects was obtained for teacher readiness to implement STEAM-based mathematics learning, with an average score of x = 3.64 and a percentage range of 80–90%. Survey results indicate that most teachers felt ready to design and apply STEAM-oriented instruction and to integrate cultural contexts into mathematics learning. Interview data support this finding. One teacher stated, *"We are ready to apply STEAM and even VR if training and facilities are provided."* Another teacher added, *"Using local fabric motifs is not difficult and makes students more interested."*

Overall, the results in Table 4 indicate that mathematics teachers show generally positive perceptions of STEAM-based learning designs that integrate real-world contexts and are supported by VR. High levels of understanding, positive attitudes, and readiness are evident, while VR experience remains moderate based on questionnaire and interview data.

DISCUSSION

This study aims to examine students' and teachers' perceptions of a STEAM-based geometry transformation learning design that integrates real-world contexts and is supported by Virtual Reality (VR) technology, using Gambo Muba fabric motifs as a local cultural context. Overall, the findings indicate generally positive responses from both students and teachers, although several challenges remain, particularly regarding technological readiness and instructional implementation. These findings are consistent with previous studies emphasizing the importance of systemic readiness, the role of cultural context, and the role of pedagogical support in technology-enhanced learning innovations.

The results reveal that the aspect of learning readiness and instructional support is categorized as moderate. Although most students have access to learning devices and demonstrate a strong

willingness to use new technologies, infrastructural support and learning systems have not yet been fully optimized. This finding aligns with the study by Ranak et al. (2023), which emphasizes that the availability of technological devices does not automatically guarantee the effectiveness of digital learning unless it is accompanied by well-structured instructional design, adequate teacher guidance, and comprehensive support systems.

Furthermore, this study reinforces the findings of (Saputra et al., 2023), who argue that technological readiness in educational contexts should be understood systemically, encompassing device availability, network infrastructure, teacher competence, and school policy support. In the context of STEAM learning supported by VR, such readiness becomes increasingly crucial, as VR technology requires more complex classroom management, greater technical proficiency, and more careful planning of instructional time than conventional learning approaches. Therefore, the implication of this finding is the need for an integrated approach that balances technological and pedagogical readiness to ensure the sustainable implementation of instructional innovation. Students' perceptions of the integration of real-world and local cultural contexts fall within the moderate category with a positive tendency. This result is consistent with the studies of Yanto et al. (2024) and Diana & Saputri (2021), which suggests that culture-based mathematics learning can bridge the gap between abstract concepts and students' concrete experiences. The use of Gambo Muba fabric motifs in learning about geometric transformations provides an authentic learning experience, as students can directly observe the application of reflection, translation, rotation, and dilation in cultural artifacts familiar to their daily lives.

This finding is also aligned with the ethnomathematics perspective proposed by D'Ambrosio, which emphasizes that mathematics is inseparable from the social and cultural contexts in which learners are situated. Integrating local culture into mathematics instruction not only strengthens students' conceptual understanding but also fosters appreciation of cultural heritage and local identity. The implication of this finding is that local cultural contexts, such as Gambo Muba fabric, have strong potential to be further developed as contextual, meaningful, and relevant learning resources for Indonesian students.

The results also indicate that students' understanding of and interest in STEAM are categorized as moderate. Students tend to enjoy project-based, collaborative, and design-oriented activities; however, they are not fully aware that these activities represent a STEAM learning approach. This finding is consistent with (A. A. Kurniawan et al., 2025) who found that STEAM implementation in schools is often implicit, where STEAM elements are embedded in learning activities but not explicitly introduced as an integrated instructional framework. This condition suggests that students respond more strongly to learning activities than to the conceptual framework underlying them. Consequently, teachers need to introduce the STEAM concept more explicitly so that students can understand the interconnections among science, technology, engineering, art, and mathematics within a unified learning experience. Such understanding is essential for fostering interdisciplinary thinking and 21st-century skills, as emphasized in the STEAM framework proposed by (Al-Ansi et al., 2023), which positions disciplinary integration as the core of meaningful learning.

Regarding VR use, this aspect received the lowest score in students' perceptions, despite their relatively high interest in the technology. This finding aligns with the studies of (Henderson et al., 2024) and (Al-Ansi et al., 2023) which states that the effectiveness of VR in learning is highly dependent on users' initial experiences, duration of use, and students' physical and cognitive readiness. Issues such as discomfort, dizziness, or confusion in operating VR devices may hinder optimal utilization.

Nevertheless, this finding also supports the results of (Dewi, 2020) and (Mouali et al., 2024), who demonstrated that VR has significant potential to enhance visualization and spatial understanding, particularly in topics on geometric transformations. Therefore, the implication is that VR should be integrated gradually and systematically, accompanied by orientation sessions, habituation, and teacher guidance to help students adapt to virtual environments and maximize the technology's educational benefits.

Regarding teachers' perceptions, the findings indicate a high level of understanding and positive attitudes toward STEAM. This result is in line with (Safilda et al., 2021), who reported that teachers generally hold favorable views toward interdisciplinary and innovative learning approaches. Teachers perceive STEAM as an effective approach for connecting mathematics with other disciplines and real-life contexts.

However, interview results indicate that the primary challenge lies in the instructional design phase. This finding is consistent with (Aisyah et al., 2025), who emphasized that teachers' conceptual understanding of STEAM must be supported by practical training to enable meaningful and holistic integration of STEAM components rather than fragmented implementation. The implication is that continuous professional development is crucial to the successful implementation of VR-supported STEAM-based learning. Teachers also demonstrate highly positive perceptions of integrating real-world and local cultural contexts into mathematics learning. This finding strengthens the results of (Diana & Saputri, 2021), which indicates that contextual learning enhances students' motivation and conceptual understanding. Teachers perceive the use of Gambo Muba fabric motifs as an effective and relevant strategy for teaching concepts in reflection and geometric transformations.

On the other hand, teachers' perceptions of VR use are categorized as moderate, reflecting a gap between conceptual acceptance and practical implementation. This finding aligns with (Fofiqoh et al., 2023)highlight that the adoption of immersive technologies in schools is strongly influenced by the availability of facilities and teacher training. Despite this, teachers' readiness to implement STEAM-based learning is categorized as high, reinforcing the findings of (Mariana et al., 2023) that teacher readiness and attitudes are critical determinants of successful instructional innovation.

Theoretically, this study strengthens the literature suggesting that integrating STEAM, VR, and local cultural contexts can create more meaningful, contextual, and relevant mathematics learning experiences. Practically, the findings imply that the development of geometry transformation learning should carefully consider technological readiness, teacher training, and the planned integration of local cultural contexts.

In conclusion, this study not only aligns with previous research but also extends existing scholarship by presenting a STEAM–VR-based geometry transformation learning model grounded in the local cultural context of Gambo Muba fabric, a context that remains relatively underexplored in mathematics education research in Indonesia.

CONCLUSION

The results of this study indicate that the application of STEAM-based mathematics learning, integrating real-world contexts and Virtual Reality (VR) technology, can positively impact students' conceptual understanding, motivation, and engagement in the learning process. Both teachers and students agree that this approach makes mathematics feel more accessible, relevant, and easier to understand, especially in geometric transformations. However, teachers' limited experience in designing STEAM activities and the limited availability of VR devices remain obstacles that need to be overcome for this learning innovation to run optimally. Theoretically, this study confirms the importance of a constructivist approach to learning, in which students gain a stronger understanding through direct experience, cultural context, and interactive visual media. These findings are consistent with the PISA 2021 mathematical literacy framework, which emphasizes connecting mathematics to the real world, and with UNESCO's sustainable education (GCED/ESD) concept, which emphasizes the close relationship among cognitive, social, and cultural aspects. The practical implications of this study emphasize the importance of developing learning strategies that integrate local culture and use digital technology to support students' creativity, literacy, and critical thinking skills. Project-based learning (PBL or PJBL) models, supported by VR, can be an effective alternative for overcoming students' difficulties in understanding abstract concepts while fostering their appreciation of local wisdom. From a policy perspective, further support is needed in the form of teacher training, the provision of facilities, and curriculum policies that emphasize integrating cultural values and technology into mathematics learning. Teachers play an important role as facilitators who connect abstract knowledge with the

realities of students' lives. However, this study has limitations: it was conducted at a single school with a relatively narrow scope, so the results cannot be generalized. The limitations of VR devices also prevent maximum implementation. Therefore, further research is recommended to include more schools and a variety of learning media so that the picture of this model's effectiveness becomes more comprehensive.

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Additional Information	:	This study was conducted in accordance with ethical standards. Permission for data collection was obtained from the school authorities.

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