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Analysis of Student and Teacher Needs for AR Geometry Media based on Kraton Culture

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Abstract

Purpose: This study aims to conduct a systematic needs analysis of elementary school students and teachers as a basis for designing augmented reality (AR)-based geometry learning media integrated with Kraton culture.
Methodology: This descriptive qualitative study involved 22 fourth- and fifth-grade students and two teachers at SD Negeri 2 Pandean. Data were collected through a questionnaire, semi-structured teacher interviews, classroom observations, and document analysis. Thematic analysis was used, and descriptive statistics were applied to closed items.
Results: Students have trouble visualizing how nets relate to solid figures with static images. They need AR features such as manipulable 3D models that can be rotated and explored. Animations that unfold and refold solid figures, along with clear highlights of faces, edges, and vertices, aid comprehension. Step-by-step guidance, interactive short quizzes with instant feedback, and examples connecting geometry to Kraton architecture are also needed. Teachers see potential in AR media if it offers a dedicated teacher mode, explicit usage guidelines, concise lesson segments, compatibility with mid-range devices, offline access, and a curriculum-aligned balance between cultural and standard content.
Applications/Originality/Value: This study provides context-sensitive and practical design guidelines for developing AR geometry learning media that address students' spatial visualization difficulties, align with curriculum demands, and are feasible for elementary school contexts with limited technological infrastructure.

Introduction

Geometry learning in elementary schools still faces fundamental challenges in spatial visualization. Students often struggle to understand spatial figures and their relationships to nets when given only two-dimensional representations. Many have difficulty connecting flat images with full three-dimensional shapes (Tarng et al., 2024). Studies show that augmented reality (AR) can enhance mathematics learning by providing manipulable 3D objects and improving geometric understanding (Bulut & Borromeo Ferri, 2023; Nadzeri et al., 2024; Rohendi et al., 2025; Wu et al., 2024). At the same time, transforming mathematics learning in the digital era requires alignment among learning objectives, strategies, assessment, and technology. Only then can classroom changes become truly meaningful (Weigand et al., 2024). For example, a quasi-experimental study of the Think-Pair-Share (TPS) strategy with portfolio assessment found that combining cooperative strategies, authentic assessment, and high learning interest improved mathematics outcomes more than expository instruction (Kholid et al., 2019). In other contexts and at other levels, an integrated STEAM Flip Flop model has helped students understand material on function composition during online learning. Pre-class, in-class, and post-class activities, when structured, play an important role when technology is integrated into mathematics learning (Ishartono et al., 2023). In line with this, teachers' understanding of Technological Pedagogical Content Knowledge (TPACK) is key to ensuring that the integration of technology, including AR, extends beyond cosmetic aspects and truly improves the quality of learning (Kholid et al., 2023).

AR lets students interact with 3D objects, helping build spatial skills (Nadzeri et al., 2024). AR-based picture books improve geometry comprehension by managing cognitive load and learning flow (Wu et al., 2024). At higher grades, AR increases interactivity and student interest in geometry (Rohendi et al., 2025). To be effective, AR must be simple, align with the curriculum, and be easy to use during class time (Perifanou et al., 2023). Teachers' digital skills and school resources affect AR use, so first analyze needs before making AR media (Nikou et al., 2024).

The ethnomathematics approach emphasizes that mathematical concepts do not stand alone but exist within cultural practices and artifacts, thus providing an authentic context for understanding geometry material (Prahmana et al., 2021). Research shows that cultural ornaments and artifacts, including religious and traditional architecture, contain flat and spatial geometric patterns that can serve as sources for contextual learning (Kurniawan et al., 2024; Purniati et al., 2022).

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Other studies add that linking mathematical concepts to cultural practices and artifacts can increase relevance, a sense of connection, and a more equitable learning experience for students (Chatsiopoulou & Michailidis, 2025). In this study, the local cultural context referred to is the Kraton environment. The term "Kraton" refers to a traditional Javanese royal palace complex and its surrounding neighbourhood, which functions as a political, cultural, and spiritual centre. Kraton buildings, gates, and ornaments display a variety of geometric forms, including prisms, pyramids, and symmetrical motifs, as well as tessellation-like motifs, which are familiar to students in their daily lives because the school is located in the Kraton area. This context creates opportunities to develop AR geometry media that not only help students understand abstract concepts but also strengthen their connection with local culture. In the context of the Kraton, the richness of architecture, ornaments, and cultural objects provides opportunities to develop contextually sensitive AR geometry media, so that students are not only confronted with abstract spatial structures but also connect them to the cultural environment in which they live. Figure 1 illustrates the Kraton Mangkunegaran palace and highlights several solid figures (rectangular prism-shaped hall, prism-shaped roof, cylinder-shaped pillar, and cuboid-shaped pillar) that become the cultural and geometric context for the AR-based geometry learning media in this study.

Figure 1. Identifying solid figures in the Kraton Mangkunegaran palace complex: rectangular prism-shaped hall (red), prism-shaped roof (black), cylinder-shaped pillar (yellow), and cuboid-shaped pillar (blue).

From a cognitive perspective, linking math problems to culture strengthens geometric problem-solving (Murtafiah et al., 2022). To ensure AR learning does more than attract attention, reflection is needed. Reflective thinking helps students deepen their understanding of AR experiences (Asmawati et al., 2023). Research shows that reflective thinking in math problem-solving can be fragmented. Targeted learning can restore reflective skills and improve problem-solving (Kholid, Santosa, et al., 2024). Creative thinking during math problems guides designers to make activities that use varied representations, such as AR images (Kholid, Mahmudah, et al., 2024). For teachers, reflection and structured self-study help them review and refine innovations, including AR and cultural learning, to meet classroom needs (Wei, 2024).

Based on this research landscape, there is still a gap in research on the design of AR geometry media that explicitly analyzes the needs of students and teachers in elementary schools while also integrating local cultural contexts, such as the Kraton, in a proportional manner. Many AR and ethnomathematics studies focus on testing the effectiveness of existing media, while the needs analysis stage, as a basis for formulating design principles, is rarely discussed in depth. Therefore, this study focuses on the needs analysis phase as the starting point for formulating the design principles of Kraton culture-based geometric AR media in elementary schools. Specifically, this study aims to: (1) map students' learning needs, conceptual difficulties, and preferences regarding the features and flow of activities in AR geometry media; and (2) explore pedagogical needs, the forms of support needed, and the implementation constraints experienced by teachers when integrating AR media with Kraton cultural nuances into geometry learning.

Method

Research Design

This study used a descriptive qualitative approach. This approach was chosen to gain an in-depth understanding of students' and teachers' needs, the conceptual difficulties they face, and the context for implementing Kraton culture-based AR geometry media in the classroom (Creswell, 2015). The main data were collected in narrative form through open-ended questionnaire responses, semi-structured interviews, and observation notes. This enabled the researcher to capture how students and teachers interpreted learning solid figures and nets, and their expectations for the AR media to be developed.

Research Subjects

The research subjects were 22 fourth- and fifth-grade students at SD Negeri 2 Pandean and two teachers: the fourth- and fifth-grade classroom teachers. The students provided data on learning experiences, difficulties, and preferences for AR media features. Teachers served as key informants, sharing their views on student difficulties, teaching strategies, media used, and their readiness and needs for integrating AR media based on Kraton culture into geometry learning.

Instruments

The instruments used in this study included the Teacher Interview Guidelines, the Student Learning Needs Analysis Questionnaire, and the Classroom Observation Sheet. The first instrument, Teacher Interview Guidelines, was designed to guide semi-structured interviews with the two classroom teachers. The questions in the Teacher Interview Guidelines covered how teachers explained spatial concepts and nets; the types of difficulties often experienced by students; the strategies and media that had been used; teachers' views on the use of technology, particularly AR, in geometry learning; and teachers' perceptions of the potential use of AR based on the cultural context of the Kraton. The second instrument, the Student Learning Needs Analysis Questionnaire, was used to map students' needs, difficulties, and preferences related to geometry learning and AR media. This questionnaire included a combination of closed-ended items (Likert and multiple-choice) and open-ended items. Closed items provide an overview of the frequency and trends in student responses, while open items invite students to describe their learning experiences, the parts of the material they find difficult, the ways they find helpful in understanding spatial figures, and the features and activities they expect from AR media. The third instrument, the Classroom Observation Sheet, is used to document geometry learning practices that take place without AR media intervention. This sheet records how teachers explain the material, the form of teacher-student interaction, the types of media used (e.g., books, pictures, or concrete models), student responses during activities, and the conditions of infrastructure relevant to AR implementation, including the availability of devices, projectors, and internet connections in the classroom. The items in the Student Learning Needs Analysis Questionnaire, Teacher Interview Guidelines, and Classroom Observation Sheet were reviewed by experts to assess their suitability for the research objectives and the developmental level of elementary school students. Input from this review was used to clarify wording and reduce the potential for multiple interpretations of some questions.

Data Collection Techniques

Data collection was conducted through classroom observation, semi-structured interviews with the two classroom teachers, documentation, and the Student Learning Needs Analysis Questionnaire. First, observations were made on the teaching of solid geometry and nets without using AR media to capture natural learning practices, including how teachers explained, the examples used, student participation, and obstacles that arose. Second, semi-structured interviews with teachers were conducted using the Teacher Interview Guidelines following the observation. These interviews aimed to clarify classroom findings, further explore the difficulties students faced, as reported by teachers, and discuss teachers' opportunities and concerns regarding the use of AR media in Kraton culture. Third, documentation in the form of Lesson Plans (RPPs), material lists, and teaching materials was collected to assess the alignment between written planning and learning practices, and to identify entry points for integrating geometry AR media. Fourth, the Student Learning Needs Analysis Questionnaire was distributed to fourth- and fifth-grade students and completed in class with the assistance of researchers and teachers to ensure that each item was understood. Data from closed items were used to map students' levels of ease/difficulty and interest, while open-ended answers provided detailed information about students' experiences, needs, and expectations regarding AR media. The combination of these four techniques formed a triangulation of sources and techniques in data collection.

Data Analysis

Data analysis was conducted using the qualitative thematic analysis method (Miles et al., 2013). The main data sources were the open-ended answers on the Student Learning Needs Analysis Questionnaire, teacher interview transcripts, and classroom observation notes. The analysis was conducted in three main steps. First, data reduction, which involved repeatedly reading all the data and marking the parts relevant to learning needs, expected media features, media usage flow, and the cultural context of the Kraton. Second, coding and categorization, which involved grouping data fragments into initial categories such as the need for 3D visualization, step-by-step instructions, teacher mode, offline access, and integration of Kraton culture. Third, theme development and conclusion drawing, by organizing the initial categories into main themes that describe the needs of students and teachers for Kraton culture-based AR geometry media. Data from the Student Learning Needs Analysis Questionnaire closed-ended items were analyzed descriptively (frequency and percentage) to reinforce the interpretation of these themes. Data validity was maintained through triangulation of techniques (questionnaires, interviews, observation) and sources (students and teachers). This study obtained permission from the school, and all participants were informed that participation was voluntary and that their answers would be kept confidential. The questionnaire was completed without including students' full names, and the data cited in the article were anonymized to protect participants' identities.

Results

The needs analysis in this study collected data from the Student Learning Needs Analysis Questionnaire, semi-structured teacher interviews, and classroom observations of geometry instruction. The Student Learning Needs Analysis Questionnaire was compiled based on several main dimensions, namely: (1) student profiles and access to learning, (2) experiences and difficulties in learning geometry, especially spatial figures and nets, (3) preferences for representation and learning activities, (4) needs for AR media features, and (5) integration of the Kraton cultural context. A summary of the Student Learning Needs Analysis Questionnaire grid is presented in Table 1.

Table 1. Student Learning Needs Analysis Questionnaire Framework

Code	Indicators measured	Example of item wording
A1	Challenges with 2D representation	"I find it difficult to understand spatial structures based solely on 2D images."
A2	Visualization of nets	"I find it difficult to imagine nets becoming three-dimensional shapes."
A3	Benefits of 3D manipulation	"I understand better if objects can be rotated/zoomed in 3D."
A4	Attitude toward AR	"I am interested in learning geometry using AR."
A5	Environmental/cultural context	"Examples from the local environment/culture help my understanding."
A6	Need for step-by-step instructions	"I am comfortable with step-by-step instructions on the screen."
A7	Activity duration	"15–20 minutes is sufficient for learning activities with AR."
B1–B4	Profile & preferences	Device ownership; internet stability; ideal duration; AR features
C-Open	Detailed requirements	Main difficulties; activity ideas to make geometry easier

This questionnaire was then distributed to 22 fourth and fifth-grade students. Tables 2–5 present the results of the Student Learning Needs Analysis Questionnaire, including respondent profiles and learning access; a summary of Likert-scale items; feature and topic preferences; and results of open-ended response coding. The results of teacher interviews are summarized in Table 6, while learning observations were used to complement and confirm the questionnaire and interview findings.

Table 2. Respondent profiles & learning access

Variable	Category	Number
Grade	IV	12
	V	10
Device Ownership	Yes	20
	No	2
Internet connection	Stable	9
	Unstable	11
	None	2

Table 2 shows that most students have access to devices, whether personal or family-owned, although internet connectivity is not yet uniform. At school, the use of devices as learning media remains limited and has not become a regular part of teaching and learning. This condition indicates that the AR media to be developed must run on low-specification devices and support offline use, so it is not overly dependent on an internet connection.

Table 3. Summary of Likert items 1–4

Code	Statement (summarized)	Agree/Strongly Agree
A1	Difficult to understand the spatial structure from 2D images	16/22 (72.7%)
A2	Difficult to imagine nets becoming three-dimensional shapes.	18/22 (81.8%)
A3	It is easier to understand if the object can be rotated/zoomed in 3D.	20/22 (90.9%)
A4	Interested in learning geometry with AR	19/22 (86.4%)
A5	Local environment/culture helps	17/22 (77.3%)
A6	Comfortable with on-screen step-by-step instructions	19/22 (86.4%)
A7	15–20 minutes is sufficient for AR activities	15/22 (68.2%)

A summary of student responses to the Likert scale items in Table 3 shows that the majority of students still experience difficulties understanding spatial figures only from 2D images and imagining folded nets that unfold into spatial figures. Conversely, a large proportion of students stated that it was easier to understand the material if they could see the spatial figures as 3D objects that could be rotated and zoomed, accompanied by step-by-step explanations. Responses to statements regarding AR also showed a generally positive attitude; most students were interested in learning geometry with AR media and considered 15–20 minutes sufficient for a single session.

Table 4. Feature & Topic Preferences

Indicator	Option	Respondents
Most difficult topic	Geometric nets	17
	Identifying sides, edges, and vertices	15
	Symmetry	8
	Angle measurement	6
Required AR features	Unfold–fold nets	19
	3D rotation & zoom	17
	Highlight sides, edges, points	19
	Quiz	13

Student preferences for media features and geometry topics are summarized in Table 4. Students consistently chose features that allowed them to rotate solid figures, zoom in and out, and highlight sides, edges, and vertices alternately. The unfold–fold animation feature, which displays the process of folding nets into solid figures, was considered very helpful in understanding how the parts of the figures are connected. In terms of topics, students showed a high level of interest in solid figures that they often encounter in their daily lives, as well as shapes similar to buildings or ornaments in their surroundings, including those related to the Kraton culture. This suggests that the AR media developed should ideally combine formal geometric concepts with contextual examples that are close to the students' experiences.

Table 5. Results of open-ended response coding

Themes from student responses	Description	Respondents
Difficult to imagine nets → shapes	Confused about connecting the sides/edges when folded	14
Need examples from everyday life/culture	Photos/real objects & ornamental patterns help	9
Need step-by-step instructions + quick checks	Requires structured guidance & brief exercises	8
Potential for distraction when using devices	Need rules for use & teacher supervision	6

The results of coding students' open-ended answers are presented in Table 5 and reveal several main themes. First, many students admitted that it was difficult to imagine nets becoming three-dimensional shapes, especially when they had to determine which parts would become the base, top, or sides. Second, there was a clear need for step-by-step explanations accompanied by visualizations of the folding process, not just looking at the final image. Third, students wanted examples that were close to their daily lives and mentioned that photos, real objects, and ornamental patterns helped them understand geometry. Fourth, some students recognized the potential for distraction when using devices and suggested rules for use and the role of teachers in directing activities. Overall, these themes emphasize the need for AR media that is not only visually compelling but also features a clear activity flow and meaningful context, including the cultural context of the Kraton.

Table 6. Teacher interview results

Teachers	Main Challenges	Feature/media needs	Class flow & assessment	Implementation Notes
Grade IV	Students confuse sides–edges–points; confused about nets	Manipulative 3D model + highlights; unfold–fold animation	15–20 minutes: perception, guided exploration, quick quiz with 2–3 questions	Offline-based, large icons, Indonesian language
Grade 5	Relevance & motivation	Examples from local environment/culture + geometric annotations	Mini tasks based on surrounding objects/local artifacts	Compatible with mid-range devices; no login required

Findings regarding teachers' needs and views are summarized in Table 6. Teachers confirmed that students still often confuse flat shapes and solid shapes and have difficulty imagining nets becoming complete shapes when learning relies solely on pictures in books or on the blackboard. Teachers have been using verbal explanations, pictures, and some concrete objects, but realize that it is not easy to provide physical models for all solid figures. Teachers see AR as an opportunity to present solid figures and nets in a more concrete and interactive way, but emphasize the need for a teacher mode and step-by-step guidance to ensure the media's use aligns with the lesson plan and learning time allocation. Teachers also noted the limitations of devices and internet networks as important factors. Therefore, teachers hoped for AR media that could be used on mid-range devices in Indonesian, with large icons, and that could run without a login and offline. Teachers expressed interest in integrating examples from the local environment and culture, including the Kraton, because this context was considered helpful for students to understand concepts such as symmetry and patterns. However, teachers emphasized that cultural integration must remain proportional to mathematical objectives so that the focus of learning on geometric concepts is not shifted. Observations of geometry learning in the classroom reinforced the findings of the questionnaire and interviews. When teaching material on solid figures and nets, teachers combined verbal explanations with pictures and concrete objects, but some students remained hesitant when asked to explain the relationship between solid figures and nets or to identify which parts were sides, edges, and vertices. In terms of resources, the class did not routinely use gadgets for learning, and technology was limited to simple presentation media. Observations also showed that teachers actively maintained student engagement through questions and answers and brief discussions. This suggests that the AR media to be developed needs to be designed to support this pattern of interaction, not replace it. Overall, the results of observations, questionnaires, and interviews show that students and teachers need geometry AR media that: (1) clarifies the relationship between nets and solid figures through 3D visualization, unfold–fold animations, and step-by-step explanations; (2) provides short learning activities with quizzes and feedback; (3) is compatible with school infrastructure conditions, including device availability and network limitations; and (4) meaningfully integrates the cultural context of the Kraton while remaining aligned with the geometry learning objectives in elementary school.

Discussion

The results of the needs analysis confirm that students still experience significant difficulties in understanding the relationship between nets and solid figures, even though teachers have utilized images and several concrete models. This condition reinforces previous findings regarding spatial visualization problems in elementary school geometry (Tarng et al., 2024). Students' strong preference for rotatable 3D objects, unfold–fold animations, and highlighting of sides, edges, and vertices indicates the need for more dynamic and interactive representations. These findings align with research showing that AR can bridge the gap between two- and three-dimensional representations, manage cognitive load, and enhance geometry learning experiences (Bulut & Borromeo Ferri, 2023; Nadzeri et al., 2024; Rohendi et al., 2025; Wu et al., 2024).

Students' preferences for step-by-step explanations, opportunities for exploration, and short quizzes with feedback indicate a need for support at the cognitive process level, not just visual display. Media designs that present information gradually and incorporate short exercises help organize students' thinking schemas (Wu et al., 2024). Students' need for structured activity flows accompanied by brief evaluations is in line with findings in STEAM-integrated Flip Flop model-based online learning, where the pre-class, in-class, and post-class syntax designed to activate and guide students proved to be more effective in improving understanding of function composition than conventional learning (Ishartono et al., 2023). This pattern aligns with the principles of cooperative learning and authentic assessment. The Think-Pair-Share (TPS) strategy, combined with portfolio assessment and high learning interest, has been shown to improve learning outcomes compared to expository instruction (Kholid et al., 2019). Thus, the developed AR media should be integrated with classroom activities that provide space for discussion, brief reflection, and formative assessment, in line with the idea of alignment between objectives, strategies, assessment, and technology in mathematics learning in the digital era (Weigand et al., 2024).

From the teacher's perspective, the need for a teacher mode, step-by-step guidance, concise media usage duration, and compatibility with mid-range devices and offline mode indicates that the success of AR implementation is highly dependent on the teacher's work context. This is consistent with the TPACK framework, which emphasizes that effective technology integration depends on teachers' ability to harmonize content, pedagogy, and technology in real classroom situations (Kholid et al., 2023). Other studies also confirm that teachers are more prepared to adopt AR when the AR application is relevant to the curriculum, easy to operate within time constraints, and does not add excessive technical burdens (Koparan et al., 2023; Nikou et al., 2024; Perifanou et al., 2023). These research findings clarify that the technical design of the media, including the ease of the interface, the language used, and offline options, is not merely an additional aspect but an integral part of AR-based learning design.

Cultural dimensions emerged strongly in students' and teachers' responses. Students were interested in shapes and patterns similar to real objects, including buildings and ornaments associated with the Kraton, while teachers assessed that examples from the local environment and culture facilitated understanding of concepts such as symmetry and patterns. This aligns with the ethnomathematics approach, which views mathematical concepts as embedded in cultural practices and artifacts and can serve as an authentic context for learning (Prahmana et al., 2021). Research shows that cultural ornaments and artifacts, including religious and traditional architecture, contain rich geometric patterns and can strengthen mathematical literacy when integrated into learning (Kurniawan et al., 2024; Purniati et al., 2022). On the other hand, linking mathematical concepts to cultural practices and artifacts contributes to the relevance, sense of connection, and fairness of the learning experience (Chatsiopoulou & Michailidis, 2025). In this context, Kraton-based cultural geometry AR media has the potential to present spatial structures and networks connected to Kraton architecture and ornamentation, while maintaining cultural integration proportional to mathematical objectives as emphasized by teachers.

From a cognitive process perspective, students' need for structured activity flows and space to try and reflect on what they have learned demonstrates the importance of support for problem solving and reflective thinking. Linking geometry problems to cultural contexts can enrich the problem-solving process (Murtafiah et al., 2022), while reflection spaces help process technology-based learning experiences into deeper conceptual understanding (Asmawati et al., 2023). Studies on the defragmentation of reflective thinking levels show that students' thinking structures can become fragmented, and that targeted learning interventions can restore their integrity, thereby making problem-solving more effective (Kholid, Santosa, et al., 2024). AR media that guides students through a cycle of exploration-triggering questions, brief reflection, and quizzes has the potential to serve as a structured intervention. On the other hand, the classification of creative thinking abilities in mathematical problem solving (Kholid, Mahmudah, et al., 2024) provides a reference for using 3D manipulation features and grid display variations to explore various representations. Thus, AR media is not only positioned to strengthen conceptual understanding but also to stimulate creative thinking. At the educator level, reflective practices and structured self-study, as suggested by Wei (2024), are important for teachers to continuously review and refine the integration of AR and local cultural contexts.

Based on integrating these findings and theoretical studies, several initial design principles for Kraton culture-based geometric AR media can be formulated. First, in terms of geometric content, the media needs to highlight features that explicitly address students' visualization difficulties, such as rotatable 3D visualizations, unfold–fold animations, and highlighting of structural elements. Second, from a pedagogical and assessment perspective, the flow of media use should align with learning strategies that provide space for interaction, reflection, and formative assessment, such as short discussions and quizzes with immediate feedback (Kholid et al., 2019; Weigand et al., 2024). Third, from a cultural context perspective, the objects and narratives of the Kraton are utilized to strengthen the relevance and meaning of learning without adding unnecessary cognitive load, in accordance with the principles of ethnomathematics (Chatsiopoulou & Michailidis, 2025; Kurniawan et al., 2024; Prahmana et al., 2021; Purniati et al., 2022). Fourth, from a technical implementation perspective, the media is designed to be compatible with mid-range devices, provides offline mode, and is accompanied by practical guidelines that make it easy for teachers to integrate it within the constraints of time and learning resources (Kholid et al., 2023; Koparan et al., 2023; Nikou et al., 2024; Perifanou et al., 2023).

Methodologically, the descriptive qualitative approach allows researchers to capture the nuances of student and teacher needs more richly through triangulation of questionnaires, interviews, and observations (Creswell, 2015; Miles et al., 2013). However, the limited number of subjects and the specific school context of elementary schools in the vicinity of the Kraton require caution in generalizing the findings. Further research is needed to develop and test AR media prototypes based on these design principles in various school types and to examine their impact on geometry concept understanding, student engagement, and teacher TPACK development.

Conclusion

This study mapped the needs of students and teachers for Kraton-themed augmented reality (AR) geometry learning media in elementary schools and developed initial design principles that integrate content, pedagogy, technology, and cultural context. The findings show that students still experience major difficulties in visualizing the relationships between nets and solid figures when learning is dominated by two-dimensional images, and require media that provide manipulative 3D visualizations, unfold–fold animations, highlighting of shape elements, structured activity flows (brief explanations, exploration, and quizzes with feedback), and contextual examples that are close to the life and culture of the Kraton. Teachers, on the other hand, view AR as potentially helpful but demand a teacher mode, step-by-step guidance, a concise usage duration, compatibility with mid-range devices, offline mode, and cultural integration aligned with the objectives of geometry. Based on these findings, the Kraton culture-based AR geometry media to be developed should be designed as a learning intervention that not only overcomes visualization barriers but also supports problem-solving, reflective thinking, and student creativity, while remaining realistic for use in school contexts. The limited number of subjects and specific school context indicate the need for further research to develop and test AR media prototypes based on these design principles in various types of schools and to examine their impact on geometry concept understanding, student engagement, and the development of teachers' TPACK and reflective practices.

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