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The Integration of the Visual–Auditory–Kinesthetic (VAK) Learning Model with Augmented Reality (AR) Technology

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Abstract

This study aims to design and evaluate a Visual–Auditory–Kinesthetic (VAK)–based Augmented Reality (AR) learning medium to enhance elementary students' understanding of the Lontara script, an important element of South Sulawesi's cultural heritage. Using the ADDIE development model—Analysis, Design, Development, Implementation, and Evaluation—the research followed a systematic process involving expert validation, classroom trials, and learning outcome assessment. The participants were teachers and students from SD Negeri Samata, Gowa Regency, Indonesia. Data were collected through questionnaires, expert validation sheets, and pre- and post-tests, and analyzed using descriptive statistics. The validation results showed an average score of 87.5%, categorized as very valid, indicating that the content, design, and language were suitable for elementary learners. The practicality test obtained an average of 89.6%, categorized as very practical, reflecting the medium's usability and appeal to both teachers and students. Effectiveness testing revealed a mean increase from 48.5 to 80.0, with a gain score of 0.68 (high improvement), demonstrating a significant enhancement in students' understanding of the Lontara script. The integration of the VAK learning model with AR technology created an engaging, multisensory learning environment that improved comprehension and fostered cultural awareness. The developed medium not only supports meaningful learning but also contributes to preserving local identity through technology-based education. This study provides a framework for integrating technology, pedagogy, and culture into an innovative and culturally responsive digital learning design.

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Introduction

The rapid growth of educational technology has brought many changes to teaching and learning. Today, teachers are encouraged to use more interactive and student-centered approaches that make learning more meaningful. Among the new innovations, Augmented Reality (AR) has become one of the most attractive technologies because it can combine digital elements—such as 3D models, animation, and sound—with real environments. This combination helps students to connect abstract ideas with concrete experiences and makes learning more enjoyable and memorable (Akçayır & Akçayır, 2017; Bacca et al., 2022). Previous studies have also found that AR can improve students' motivation, understanding, and memory in many learning subjects (Saidin et al., 2015; Yoon et al., 2021).

In Indonesia, the use of AR in education has started to increase. Many teachers and schools are experimenting with AR-based materials, especially in primary education, because AR can support visualization and active learning (Rosyid et al., 2020; Purwanto et al., 2022). It was even reported that more than ten thousand Indonesian teachers have tried to use AR to make their classes more interactive (Anisa, 2023). However, most of the AR materials still come from foreign sources and are not closely related to the Indonesian culture or curriculum. Therefore, it is important to develop AR learning media that are both pedagogically strong and culturally relevant (Azuma et al., 2019).

One of the cultural aspects that can benefit from this development is the Lontara script, a traditional writing system from the Bugis-Makassar culture in South Sulawesi. The Lontara script is more than just a writing tool; it also represents the history, identity, and values of the local people (Rahman, 2020; Nur, 2021). Historically, it was used for writing genealogies, daily records, and literary works such as I La Galigo, one of the longest epics in the world (Mattulada, 1985). Unfortunately, younger generations today are less familiar with this script, and their ability to read or write it has declined (Rahim, 2022). New and engaging learning methods are therefore needed to help preserve this cultural heritage and to make the learning of Lontara more relevant for modern students.

Some elementary students have a low level of understanding of the Lontara script. They often find it difficult to recognize the characters and to remember how to read or pronounce them. One of the main causes is the use of conventional teaching methods, which depend on memorization and textbook activities. Such methods are less effective for today's children, who are used to interactive and digital forms of learning (Rahim, 2022; Nur, 2021). As a result, students often lose interest quickly and do not develop a deep understanding of the script. In addition, the teaching materials that exist today are not yet supported by modern learning media. Teachers usually rely on printed charts or blackboard writing, which do not provide visual, auditory, or kinesthetic stimulation. Therefore, it is necessary to create learning media that are interactive, culturally contextual, and able to attract students' attention while improving their learning outcomes.

Pedagogical Foundation: The VAK Model

The Visual–Auditory–Kinesthetic (VAK) learning model provides a good foundation for designing interactive

media. This model explains that students learn best when they can use multiple senses—seeing, hearing, and moving—during the learning process (Fleming & Mills, 1992). The VAK model is especially suitable for young learners who need active and hands-on learning experience (Pritchard, 2018). When applied to the Lontara script, the VAK model can be used in three ways: visual components help students see the shape and color of the characters, auditory components help them hear the pronunciation, and kinesthetic components allow them to trace or manipulate the characters through interactive activities. These three elements together make learning more engaging and effective. According to cognitive learning theory, information becomes easier to remember when it is presented through more than one sensory channel (Mayer, 2021). Therefore, combining VAK and AR can support deeper and more lasting learning.

Integration of AR and VAK for Lontara Learning

Integrating AR technology with the VAK model can make learning the Lontara script more exciting and meaningful. Through AR, students can see three-dimensional models of the characters, hear how each letter is pronounced, and touch or move the characters using simple gestures on their devices. These activities activate multiple senses and create a strong connection between visual symbols, sound, and movement. Moreover, AR allows students to learn the script within its cultural context, such as by displaying traditional objects, songs, or stories related to the Bugis-Makassar heritage. This kind of learning not only improves understanding and memory but also builds cultural awareness and pride. Thus, an AR-based VAK medium can integrate technology, pedagogy, and culture into one holistic learning experience.

This study aims to design a VAK-based Augmented Reality learning medium to improve elementary students' understanding of the Lontara script. The specific objectives are:

1. To develop an AR learning medium based on VAK principles that supports visual, auditory, and kinesthetics learning.
2. To improve students' ability to recognize, pronounce, and understand the Lontara script.
3. To create a model that integrates educational technology, effective pedagogy, and local cultural values.

Through this research, it is expected that the development of a VAK-based AR medium will contribute to both educational innovation and the preservation of Indonesia's cultural literacy. In this context, the study argues that integrating the Visual–Auditory–Kinesthetic (VAK) learning model with Augmented Reality (AR) technology can create an effective and culturally meaningful learning medium that helps elementary students understand the Lontara script more deeply by combining technology, pedagogy, and cultural heritage in one interactive experience. Based on this purpose and theoretical orientation, this study explores how a VAK-based Augmented Reality learning medium can be designed to improve elementary students' understanding of the Lontara script.

Method

This study applied Research and Development (R&D) design using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) as described by van den Akker (2020). This model provides a

systematic and iterative framework for developing instructional media that align pedagogy, technology, and learning needs.

Research Design

The research focused on designing a VAK-based Augmented Reality (AR) medium to improve elementary students' understanding of the Lontara script, the traditional writing system of South Sulawesi. The study adopted the following ADDIE stages:

1. *Analysis Phase:* A needs analysis was conducted with teachers and students at SD Negeri Samata, Gowa Regency. Questionnaires and classroom observations identified learners' challenges and interest in technology-based media. The findings revealed that 93% of students expressed enthusiasm for AR learning, and all respondents believed that multisensory (VAK) activities enhanced their understanding.
2. *Design Phase:* Learning goals, content flow, and interface components were mapped according to Visual-Auditory-Kinesthetic (VAK) learning principles. Visual engagement was realized through 3D models of the Lontara script, auditory support through sound-based pronunciation, and kinesthetic engagement through gesture-based interactions within the AR interface. The design prototypes were created using Unity 3D and Vuforia SDK software.
3. *Development Phase:* The AR medium was developed and validated through expert judgment by specialists in learning content, instructional media, and language education. The average validity score of 87.5% indicated the product was very valid for educational use.
4. *Implementation Phase:* The AR medium was piloted in actual classroom settings with fifth-grade students. Teachers guided learners in using the AR features during Lontara lessons. The practicality test obtained an average score of 89.6%, categorized as very practical.
5. *Evaluation Phase:* Effectiveness was assessed through pre-test and post-test comparisons of students' comprehension. The mean score increased from 48.5 (pre-test) to 80.0 (post-test), reflecting a significant improvement in understanding and retention.

Research Design

Participants consisted of elementary school students and teachers at SD Negeri Samata. Instruments included:

1. Questionnaires for needs and practicality analysis,
2. Expert validation sheets for assessing content, design, and language quality, and
3. Achievement tests for measuring comprehension improvement.

Research Design

Quantitative data were gathered from expert evaluations, questionnaires, and pre/post-tests. Data were analyzed using descriptive statistics to determine the media's validity, practicality, and effectiveness. Gain scores were computed to evaluate the extent of students' learning improvement after using the AR medium.

Results

The results of this study describe the outcomes of the validity, practicality, and effectiveness testing of the VAK-based Augmented Reality (AR) learning medium for teaching the Lontara script to elementary students. The findings are presented according to the three main evaluation stages of the ADDIE model: Development (Validity), Implementation (Practicality), and Evaluation (Effectiveness).

Validity of the AR Learning Medium

The validity testing aimed to determine the feasibility and appropriateness of the developed VAK-based Augmented Reality (AR) learning medium for teaching the Lontara script. Validation was carried out by three experts with different areas of specialization—namely, a content expert, a media expert, and a language expert. Each validator assessed the product using a structured rating sheet and also provided qualitative feedback to ensure that the final design met pedagogical, technological, and linguistic standards. The validation results are presented in Table 1.

Table 1. Expert Validation Results

Aspect Evaluated	Validator	Score (%)	Category
Content validity	Expert 1 (Learning Content)	88.0	Very Valid
Media design	Expert 2 (Educational Technology)	87.0	Very Valid
Language quality	Expert 3 (Linguistics)	87.5	Very Valid
Average Score	—	87.5	Very Valid

As shown in the table, the average validation score of 87.5% indicates that the AR learning medium achieved a very valid classification. Each expert emphasized that the learning content was well aligned with the characteristics of elementary school students, both in terms of language simplicity and conceptual clarity. The media design expert noted that the visual presentation, navigation system, and 3D object quality effectively supported the Visual-Auditory-Kinesthetic (VAK) learning principles. Meanwhile, the language expert found the instructions, pronunciation features, and verbal cues to be linguistically accurate and easy for young learners to understand.

The validators collectively agreed that the AR medium successfully integrated visual, auditory, and kinesthetic experiences into a cohesive instructional environment. Through 3D models, audio pronunciations, and interactive gestures, the product was able to present abstract linguistic symbols in a more concrete and enjoyable manner. This finding supports the idea that augmented reality can serve as a bridge between conceptual learning and practical application in language and literacy education.

Several minor revisions were recommended to further enhance the medium's usability. These included adjusting the clarity of voice output, refining gesture sensitivity for smoother interaction, and improving interface

readability to ensure accessibility for younger learners. All suggestions were incorporated into the final version of the product during the development stage.

Practicality of the AR Learning Medium

The practicality test was conducted to evaluate how easily and effectively the developed VAK-based Augmented Reality (AR) learning medium could be applied in real classroom settings. The goal was to measure its usability, attractiveness, and overall suitability for both teachers and students during the teaching and learning process of the Lontara script. The practicality test involved elementary school students and teachers from SD Negeri Samata, Gowa Regency, where the implementation phase of the ADDIE model took place. Data were collected through teacher and student questionnaires designed to assess key aspects such as user-friendliness, visual and auditory appeal, interactivity, and the ability of the medium to motivate learning. The results of the practicality test are presented in Table 2.

Table 2. Practicality of Test Results

Respondent Group	Mean Score (%)	Category
Teachers	91.2	Very Practical
Students	88.0	Very Practical
Average Score	89.6	Very Practical

As indicated in the table, the overall mean score of 89.6% places the developed AR medium in the very practical category. Both teachers and students reported positive experiences during the implementation, emphasizing that the AR medium was easy to operate, interactive, and highly engaging.

From the teachers' perspective, the medium effectively supported the instructional process without requiring complex technical assistance. Teachers noted that the interface layout and navigation system were intuitive and that the integration of visual, auditory, and kinesthetic elements made lesson delivery more efficient. The teachers also appreciated the realistic 3D presentation of Lontara characters, which helped students visualize and differentiate letter forms more accurately compared to traditional flat images in textbooks.

From the students' perspective, the AR medium provided a new and exciting learning experience. Many students expressed enjoyment when viewing and manipulating the 3D Lontara letters, listening to their pronunciations, and interacting with the movement-based features. The multisensory nature of the medium encouraged students to participate actively, ask questions, and repeat exercises voluntarily. This behavior indicates a strong motivational impact, as learning was transformed from a passive memorization process into an interactive exploration.

The practicality test also revealed that the medium was compatible with classroom facilities and did not require sophisticated technological infrastructure. The AR content could be accessed using standard mobile devices, making it adaptable for schools with limited resources. In this regard, the medium demonstrated not only practical

feasibility but also scalability for broader educational application.

Qualitative feedback from teachers further confirmed that the AR medium aligned well with the VAK learning approach, as it combined three sensory modalities—visual (seeing), auditory (hearing), and kinesthetic (moving)—to create a holistic learning environment. The ease of use and the level of student engagement supported the conclusion that the medium could be effectively integrated into the Lontara literacy curriculum.

Effectiveness of the AR Learning Medium

The effectiveness analysis aimed to determine the impact of the developed VAK-based Augmented Reality (AR) learning medium on improving students' understanding of the Lontara script. Effectiveness was measured by comparing students' performance before and after using the AR medium through a pre-test and post-test design. This evaluation focused on cognitive outcomes, particularly students' ability to recognize, read, and interpret Lontara characters correctly after the intervention.

The data were collected from students at SD Negeri Samata, Gowa Regency, who participated in the classroom implementation phase. Before using the AR medium, students completed a pre-test to measure their initial understanding of the Lontara script. After the series of learning sessions using the developed medium, the same group of students took a post-test. The improvement in scores between the two tests served as an indicator of the learning medium's effectiveness. The results are summarized in Table 3.

Table 3. Students' Learning Achievement

Assessment Type	Mean Score	Category
Pre-test	48.5	Fair
Post-test	80.0	Good
Gain Score	0.68	High Improvement

As shown in Table 3, the students' mean score increased from 48.5 on the pre-test to 80.0 on the post-test, resulting in a gain score of 0.68, which falls into the high improvement category. This significant rise in performance demonstrates that the VAK-based AR medium had a strong positive effect on students' comprehension and retention of Lontara characters.

The improvement can be attributed to the multi-sensory learning experience provided by the AR medium. The visual elements, such as animated 3D models of Lontara letters, helped students clearly observe the form and structure of each character. The auditory components, which included native sound pronunciations and verbal cues, supported students' phonetic awareness and memory reinforcement. Meanwhile, the kinesthetic interaction, achieved through movement and gesture-based activities, allowed students to engage physically with the script, strengthening their psychomotor involvement in the learning process.

Teachers also observed that the combination of visual, auditory, and kinesthetic features made students more motivated and confident during class activities. Learners who previously showed little interest in traditional rote-based methods became more active in recognizing and reproducing the characters. This finding aligns with the pedagogical foundation of the VAK learning model, which emphasizes that learning becomes more effective when multiple sensory modalities are stimulated simultaneously.

Qualitative observations further supported the quantitative data. Students displayed enthusiasm during learning sessions, frequently interacting with the AR content and showing curiosity about the cultural meanings behind the Lontara letters. Teachers noted that the technology not only improved recognition accuracy but also fostered a deeper appreciation for local language and heritage. This indicates that the AR medium functioned as both a cognitive enhancer and a cultural bridge, connecting digital learning experiences with traditional knowledge.

Summary of Findings

Overall, the research findings confirmed that the developed VAK-based Augmented Reality (AR) learning medium fulfilled all the required criteria of validity, practicality, and effectiveness. Each stage of the product development produced consistent evidence that the integration of visual, auditory, and kinesthetic elements within an AR environment can effectively enhance students' understanding of the Lontara script at the elementary level.

From the validity aspect, expert evaluations indicated that the AR medium was categorized as very valid with an average score of 87.5%. The learning content was judged as appropriate to the characteristics of elementary students, and the integration of 3D visualization, pronunciation sounds, and motion-based interactions was found to be aligned with the Visual-Auditory-Kinesthetic (VAK) learning framework. Experts agreed that the medium provided a balanced combination of cultural authenticity and interactive technological design. The minor revisions suggested by validators—such as adjusting sound clarity, improving interface readability, and optimizing gesture sensitivity—were subsequently addressed during the development stage to ensure smooth user interaction.

The practicality test results showed that both teachers and students perceived the AR medium as highly usable and engaging, with an overall average of 89.6%, which is categorized as very practical. Teachers observed that the medium was easy to operate and required minimal technical guidance, making it suitable for classroom integration even in schools with limited technological facilities. Students expressed high levels of enthusiasm and motivation while using the AR medium, as it allowed them to see and hear the correct forms and sounds of the Lontara characters. The kinesthetic features, such as moving and rotating 3D letters, gave students a sense of direct interaction with the script, which encouraged active participation and improved memorization. This finding implies that the developed medium not only supported instructional goals but also created a more dynamic and enjoyable learning atmosphere.

The effectiveness analysis demonstrated a significant improvement in students' learning outcomes. The mean pre-test score of 48.5 increased to 80.0 in the post-test after using the AR medium, showing a gain score of 0.68, categorized as high improvement. This increase reflects the positive influence of multi-sensory learning principles

embedded in the VAK approach. The combination of visual representation, auditory reinforcement, and kinesthetic engagement helped students better recognize, pronounce, and recall the shapes and meanings of the Lontara letters. In addition, the AR-based interactivity allowed learners to connect traditional knowledge with modern technology, thereby strengthening both cognitive understanding and cultural appreciation. These results are consistent with the earlier validation and practicality findings, proving that the designed medium met the criteria for an effective educational innovation.

In summary, the developed VAK-based AR medium can be considered pedagogically valid, practically feasible, and empirically effective. It not only improved students' comprehension of the Lontara script but also demonstrated how educational technology can serve as a cultural preservation tool when properly aligned with local learning contexts. Thus, the study provides a meaningful contribution to digital-based learning design, especially in integrating technology, pedagogy, and cultural heritage in elementary education.

Discussion

The results of this research clearly demonstrate that the developed VAK-based Augmented Reality (AR) learning medium is valid, practical, and effective for improving elementary students' understanding of the Lontara script. The integration of Augmented Reality technology with Visual-Auditory-Kinesthetic (VAK) learning principles successfully addressed the challenges identified in the initial needs analysis, particularly the limited student engagement and difficulty in recognizing Lontara characters using conventional methods. The findings are consistent with established theories of multimedia learning and educational media design, confirming that technology-supported instruction can significantly enhance comprehension when properly aligned with pedagogical models.

The Role of the VAK Learning Model

The findings of this study confirm that the Visual–Auditory–Kinesthetic (VAK) learning model plays an important role in helping students understand and remember learning materials more effectively. As mentioned by Yaumi (2022), the VAK model encourages students to learn through different senses, so that learning becomes more meaningful and easier to remember. In this study, the developed AR medium applied the VAK approach by allowing students to see, hear, and move when learning the Lontara script. They could observe 3D shapes of the characters, listen to their correct pronunciations, and interact with them through movement and touch. These activities made learning more active and enjoyable, and helped students connect abstract symbols with real experience.

This learning process also reflects what Dale (2020) describes in the Cone of Experience, which explains that students learn better when they are directly involved in the activity rather than only listening or reading. Through AR, students did not only see or hear the lesson but could also experience it. This helped them to retain information longer and to understand the meaning behind each character. The same idea is also supported by Moreno and Mayer (2007), who explain that learning becomes meaningful when students use more than one sense at the same

time — for example, by combining what they see and what they hear.

The effectiveness of the VAK-based AR medium can also be understood through Mayer's (2021) Cognitive Theory of Multimedia Learning. This theory states that learners understand better when they process information through both visual and verbal channels, and when the material encourages them to think actively. The developed AR medium met these conditions because it presented information visually through animation and verbally through sound, while also requiring students to interact and focus. This process reduced boredom and helped them build mental connections between the shape of a letter and its sound.

Another supporting explanation comes from Paivio's (1991) Dual Coding Theory, which suggests that memory improves when information is presented both in visual and verbal form. In this study, students learned the Lontara letters through their shape, sound, and motion at the same time. This combination activated both image and language systems in the brain, which made it easier for students to recall information later.

In addition, several studies in educational neuroscience support this finding. According to Shams and Seitz (2008) and Fischer (2019), learning through multiple senses — such as seeing, hearing, and moving — activates wider areas of the brain and helps students remember information for a longer time. Moreno and Mayer (2010) also explain that multimedia-based learning increases students' motivation and attention, which was clearly seen during the classroom implementation of this research.

Overall, the integration of the VAK model and AR technology created a multi-sensory learning environment that made the learning of the Lontara script more interactive and meaningful. Students could connect abstract knowledge with direct experience, while teachers could guide them more easily through digital tools. This study shows that when pedagogy and technology are combined well, the result is a richer and more effective learning process that fits the needs of 21st-century education.

Effectiveness of AR in Enhancing Cultural Literacy

The results of this study also show that Augmented Reality (AR) can be an effective tool for improving not only students' academic understanding but also their cultural literacy. In the context of Lontara script learning, AR helped students connect digital learning experiences with their local cultural identity. This finding supports previous studies showing that AR-based learning can bridge traditional knowledge with modern technology, thereby making local culture more relevant to younger generations (Billinghurst & Duenser, 2012; Chang et al., 2020).

In this study, AR technology allowed students to visualize the Lontara characters in three-dimensional form, listen to their correct pronunciation, and interact directly with the script through movement. These activities made the learning process more personal and immersive. Students were not only memorizing characters but also experiencing them through sight, sound, and movement. As a result, their curiosity and sense of cultural appreciation grew alongside their academic understanding. This aligns with Heinich et al. (2019), who argue that

learning media should not only deliver content but also create emotional engagement and connect learners to the context of what they are learning.

The integration of AR into Lontara learning also reflects Mayer's (2021) idea that technology-supported learning becomes more meaningful when it connects new information to students' prior knowledge. The Lontara script, being a cultural artifact familiar to the local community, became more accessible and engaging when presented through interactive technology. By visualizing the characters in motion and associating them with sound and touch, students were able to reconstruct the meaning of traditional symbols in a modern format. This process is consistent with the concept of constructivist learning, where students actively build knowledge through interaction and interpretation (Jonassen, 1999).

From a cultural perspective, this approach also supports the idea that language and script are key elements of identity (Crystal, 2000). By learning the Lontara script through AR, students were not only gaining literacy skills but also rediscovering their cultural roots. The experience of learning through technology helped them see that traditional scripts are not outdated or irrelevant, but rather part of a living heritage that can be reimagined in the digital age. Teachers observed that students expressed pride and excitement when recognizing the characters and understanding that the script belonged to their own ancestors.

This combination of cognitive and affective engagement is important for character and identity education. As emphasized by van den Akker (2020) and Yaumi (2022), meaningful learning should combine knowledge, skills, and values. In this study, the AR medium supported all three: students learned to recognize and write the Lontara characters (knowledge and skill) while also developing a sense of respect and connection to their local culture (value).

The result also confirms the function of educational technology as a semiotic bridge — a system of signs that connects learners to meaning through symbolic interaction. In this case, AR did not merely present information; it mediated cultural meaning. The students' interaction with the virtual Lontara script represented a symbolic process where digital forms became carriers of traditional identity. This reflects the broader concept of semiotic technology, where digital tools are seen as active participants in meaning-making processes (Bezemer & Kress, 2016). Through this interaction, the Lontara script was not just learned as a linguistic system but also experienced as a living cultural narrative. Therefore, the effectiveness of the AR medium was not only measured by the improvement in test scores but also by its ability to awaken cultural awareness. The students' enthusiasm, curiosity, and sense of pride during the learning process indicated that they developed both cognitive and emotional engagement. These outcomes suggest that when technology is used with cultural sensitivity and pedagogical intention, it can strengthen both learning outcomes and cultural identity simultaneously.

Media Validity, Practicality, and Educational Impact

The results of this research also show that the developed VAK-based Augmented Reality (AR) learning medium meets the main quality standards of instructional product development, namely validity, practicality, and

effectiveness. These three aspects are closely related and determine whether an educational medium can be used successfully in real classroom settings. The findings obtained from the expert validation, classroom implementation, and post-test results confirm that the AR medium developed in this study is not only technically functional but also pedagogically meaningful.

From the validity aspect, the AR medium achieved an average score of 87.5%, which falls into the very valid category. This indicates that the content, design, and language of the medium were well-aligned with the learning objectives and the characteristics of elementary students. The validators noted that the 3D visualizations, audio pronunciation, and movement-based interactions were relevant to the VAK learning principles. These results are consistent with van den Akker's (2020) view that a valid instructional product must demonstrate alignment between pedagogy, content, and context. The development process in this study followed the systematic stages of the ADDIE model, ensuring that each component—analysis, design, development, implementation, and evaluation—was based on empirical data and expert input. This methodological rigor contributed to the high validation result.

The practicality aspect of the medium was also strongly supported by the implementation data. Teachers and students rated the AR medium as very practical, with an average score of 89.6%. Teachers reported that the application was easy to operate, visually appealing, and adaptable to classroom conditions. Importantly, the AR medium did not require high-end devices or complex setups, which means it can be used even in schools with limited technological access. These findings are supported by Heinich et al. (2019), who state that an effective instructional medium should be easy to use, efficient in supporting lesson delivery, and capable of engaging learners' attention. Students also expressed enthusiasm and enjoyment, showing that practicality in educational technology does not only mean ease of use but also includes motivational aspects that stimulate curiosity and active participation. This supports Keller's (2010) ARCS motivation model, which explains that attention, relevance, confidence, and satisfaction are crucial for sustaining learners' engagement.

The effectiveness of the AR medium was shown through the significant improvement in students' learning outcomes, with the average post-test score rising from 48.5 to 80.0 and a gain score of 0.68 categorized as high improvement. This demonstrates that the developed medium succeeded in enhancing students' understanding of the Lontara script. The improvement can be attributed to the multi-sensory learning process, which helped students connect visual form, auditory pronunciation, and kinesthetic movement into one coherent learning experience. The result supports Mayer's (2021) Cognitive Theory of Multimedia Learning, which states that effective instructional materials are those that integrate multiple representational modes and engage learners in active processing. The same finding is also consistent with Moreno and Mayer (2007), who found that interactive and multimodal learning environments lead to higher retention and deeper understanding compared to traditional learning approaches.

All things considered, the success of the AR medium in improving learning outcomes has an important educational impact. Beyond academic performance, the medium contributed to a more inclusive and student-centered learning environment. Teachers observed that even students with lower prior ability could follow the lessons more

confidently because the AR features provided immediate feedback and visualization that supported comprehension. The participatory nature of the medium encouraged collaboration and discussion among students, turning the classroom into a more interactive and communicative space. This supports the idea of social constructivism proposed by Vygotsky (1978), which emphasizes that learning takes place more effectively through interaction and shared experiences.

Implications for Digital Pedagogy and Future Research

The findings of this study offer several important implications for digital pedagogy, especially in the context of integrating technology, culture, and pedagogy within elementary education. The successful development of the VAK-based Augmented Reality (AR) medium provides evidence that educational technology can be designed not merely as a tool for delivering content but as a pedagogical bridge that connects learners' sensory experiences, cognitive processes, and cultural understanding. This integration supports the broader educational aim of preparing students to learn meaningfully in the 21st century, where digital literacy and cultural awareness are both essential competencies (Trilling & Fadel, 2009).

First, the study emphasizes that effective use of technology in education requires pedagogical intentionality. The success of the developed AR medium lies not only in its technological sophistication but also in its foundation on the VAK learning model, which ensures that technology serves learning goals rather than dominating them. This finding aligns with Mishra and Koehler's (2006) concept of Technological Pedagogical Content Knowledge (TPACK), which argues that meaningful integration of technology in education must balance three key elements: technology, pedagogy, and content. In this study, the AR medium embodied TPACK principles by harmonizing the VAK model (pedagogy), the Lontara script (content), and AR technology (tool), producing a holistic and learner-centered experience.

Second, the research highlights the importance of contextual and culturally relevant design in educational innovation. The learning of the Lontara script through AR shows that technology can be used to strengthen local identity while also advancing digital competence. This approach resonates with Banks et al. (2016), who argue that culturally responsive pedagogy empowers students to see their culture as valuable knowledge that can coexist with modern innovation. By combining cultural heritage and digital media, the AR medium made traditional learning more relatable, proving that technology can act as a mediator of cultural continuity. Such integration ensures that modernization in education does not lead to cultural erosion but rather to cultural renewal.

Third, the study demonstrates that AR-based learning can enhance learner engagement, motivation, and collaboration, which are key characteristics of effective digital pedagogy. The interactive and sensory-rich environment encouraged active participation and peer discussion, leading to higher involvement and confidence among students. This aligns with the constructivist approach that views learners as active participants in meaning-making rather than passive receivers of information (Jonassen, 1999; Vygotsky, 1978). The use of AR in this study created opportunities for students to explore, discuss, and reflect, transforming the classroom into a collaborative and inquiry-driven learning space.

Finally, this research provides valuable insights for future studies in educational media development. Future researchers may extend this work by applying the VAK-based AR model to other subjects or cultural learning contexts to test its generalizability. In addition, mixed-method research could further explore the affective and sociocultural impact of AR on students' identity formation and long-term motivation. It would also be valuable to examine how teacher training and institutional support affect the implementation of AR-based pedagogy in schools, as successful adoption requires not only effective design but also readiness and capacity within the educational ecosystem (Ertmer & Ottenbreit-Leftwich, 2010).

In the final analysis, the implications of this study go beyond the scope of Lontara script learning. They demonstrate how digital pedagogy can be culturally grounded, pedagogically sound, and technologically adaptive. The developed AR medium serves as a practical example of how educational innovation can respect local values while preparing students to thrive in a global, technology-driven learning environment. This balance between tradition and transformation represents the essence of sustainable educational development in the digital age.

Conclusion

This study aimed to design and evaluate a VAK-based Augmented Reality (AR) learning medium to improve elementary students' understanding of the Lontara script, which represents an important part of South Sulawesi's cultural heritage. Using the ADDIE development model, the research focused on three key aspects: validity, practicality, and effectiveness. The results from each stage consistently showed that the developed AR medium achieved high levels in all indicators, confirming its quality as both an instructional innovation and a cultural learning resource.

The findings indicate that the developed medium is very valid (87.5%), very practical (89.6%), and highly effective in improving students' understanding of the Lontara script, as shown by the increase in average scores from 48.5 to 80.0. The integration of the Visual–Auditory–Kinesthetic (VAK) model with AR technology successfully created a multisensory learning environment that encouraged students to visualize, hear, and manipulate the Lontara characters actively. This approach transformed abstract symbols into tangible, meaningful experiences, allowing students to learn through engagement rather than memorization.

The success of this model demonstrates that digital technology, when combined with an appropriate pedagogical foundation, can effectively enhance both learning outcomes and cultural appreciation. The developed AR medium not only improved cognitive understanding but also strengthened students' emotional connection to their cultural identity. In conclusion, this research proves that a VAK-based AR learning medium can serve as a powerful educational tool that harmonizes technology, pedagogy, and culture, and can be adapted for similar efforts in other regions and cultural contexts.

Recommendations

1. *For Teachers and Schools:* Teachers are encouraged to adopt AR-based media to make the learning of

local scripts and cultural content more engaging and accessible. Training and support should be provided to ensure teachers can integrate this technology effectively, even with limited resources.

2. *For Curriculum Developers:* Educational policymakers and curriculum designers should consider embedding local culture and digital literacy into classroom learning. Culturally relevant technologies can help balance innovation and heritage, ensuring that technological progress does not replace traditional values.
3. *For Media Designers and Developers:* Educational technologists should continue to refine AR-based learning tools by adding features that promote deeper interaction, such as storytelling, feedback, or gamification. Collaboration between developers, teachers, and cultural experts is crucial to ensure both educational and cultural accuracy.
4. *For Future Researchers:* Future studies could apply the VAK-based AR model to other subjects or regional scripts to test its generalizability. Researchers may also explore the long-term effects of AR-based learning on motivation, identity formation, and digital literacy, as well as institutional readiness for adopting such technologies.

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