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ARSUKA: An Augmented Reality–Based Learning Application for Introducing Kaili Tribal Culture in Early Childhood Education

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Abstract

This study examines the development, feasibility, and initial effectiveness of ARSUKA, an augmented reality (AR)-based learning application designed to introduce selected elements of Kaili tribal culture in early childhood education. Although AR has been widely used in early childhood settings, much of the literature has focused on cognitive or STEM-related outcomes, with more limited attention to locally grounded cultural content, particularly in Global South contexts. To address this gap, the study employed a Research and Development approach using the Hannafin and Peck model, involving needs assessment, design, and development-implementation. The application integrated Kaili cultural elements, including local language, traditional clothing, and folk songs, into an interactive AR environment supported by flashcards and puzzle-based markers. Feasibility was examined through validation by three information technology experts, three material experts, and 12 early childhood education teachers. Initial effectiveness was evaluated through a one-group pretest-posttest field trial involving 19 children aged 5-6 years in a public kindergarten in Donggala Regency, Central Sulawesi. The results showed high feasibility ratings and improvement in children's observed acquisition of selected Kaili cultural knowledge, with mean scores increasing from 28.2 to 78.9 and an N-Gain score of 0.71. These findings suggest that AR can be designed as a culturally situated pedagogical medium rather than merely a technological add-on. The study offers a grounded example of how digital media may mediate indigenous cultural content in developmentally appropriate ways while remaining attentive to local classroom conditions. The findings should nevertheless be interpreted as evidence of initial feasibility and early effectiveness, given the small sample, single-site implementation, and short evaluation period.

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Introduction

Culture is far more than a set of inherited traditions or symbolic objects. It is a living, dynamic system through which people learn to make sense of the world and understand their place within it (Hu & Ødemotland, 2021; Rigoli & Lennon, 2025). For young children, this encounter with culture is not abstract. It happens through the texture of daily life: in conversation, in routines, in the symbols children see around them, and in the social worlds they gradually learn to navigate. Understood this way, early cultural education shapes far more than cognitive development. It lays the groundwork for identity, social awareness, and moral understanding (Asrifan et al., 2025; Faas & Wasmuth, 2019; Syaikhu et al., 2022). This aligns with Bronfenbrenner's ecological framework, which situates children's growth within the layered sociocultural environments that continuously shape how and what they learn (Bronfenbrenner, 1979).

In Indonesia, cultural education is broadly understood as a national responsibility, both to preserve cultural heritage and to protect locally distinct expressions of it, a commitment grounded in Article 32 of the 1945 Constitution (Nirmala, 2025). In practice, however, this policy intent rarely translates into meaningful classroom experience, particularly in early childhood education (ECE). Local cultural content is often sidelined in daily learning, while teachers continue to rely on generic materials that bear little connection to children's actual cultural surroundings. The result is a kind of cultural learning that feels thin, occasional, or performative, something observed rather than lived. This problem is compounded by the scarcity of learning materials that are at once culturally grounded, developmentally suited, and genuinely appealing to young children.

These tensions become even more pressing in light of digital innovation in education. Young children today are growing up with digital media as a natural part of their learning environment. Yet digital tools do not automatically bring cultural depth with them. Much of what passes for technology-enhanced learning in ECE tends to focus on generic content, decontextualized skill-building, or commercially packaged resources, with little regard for indigenous or locally rooted knowledge. The real question, then, is not simply whether technology can enhance learning, but whether it can do so without quietly eroding the cultural worlds from which children draw their sense of meaning, belonging, and identity.

Augmented Reality (AR) has drawn considerable attention in ECE precisely because it bridges physical and digital space, allowing children to interact with virtual elements layered onto their real environment in ways that support exploration, engagement, and deeper understanding (Aydoğdu, 2022; Garzón et al., 2019; Pan et al., 2021). For young learners especially, the ability to handle and explore three-dimensional representations within a familiar physical setting makes AR particularly well-suited to concrete, experiential learning (Ajao et al., 2024; Garg et al., 2025; Sahin & Ozcan, 2019; Yilmaz, 2016). Research consistently shows that AR can strengthen children's motivation, engagement, and conceptual understanding, and that AR-based environments tend to be warmly received by children, teachers, and parents alike (Albayrak & Yilmaz, 2022; Chen et al., 2017; Mirza et al., 2022; Nirmala et al., 2024a; Oranç & Küntay, 2019; Pan et al., 2021; Redondo et al., 2020).

What remains underdeveloped, however, is serious attention to the cultural dimensions of AR in early childhood learning. The literature is still largely preoccupied with cognitive outcomes, usability metrics, and STEM-related applications, leaving the pedagogical and cultural implications of AR for locally grounded learning largely unexamined (Ajit, 2021; Garg et al., 2025; Hidayat et al., 2026; Li et al., 2025). This is a meaningful gap. Cultural learning is not simply a variant of general content delivery. It is bound up with processes of meaning-making tied to language, identity, representation, and a community's relationship with its own inheritance. When AR is reduced to a tool for boosting attention or comprehension, its potential as a medium for culturally responsive education goes largely unrealized. This limitation is especially visible in Indonesia and across much of the Global South, where indigenous cultural knowledge is routinely absent from the design of digital learning applications, despite its formative importance for children's early socialization.

This study takes that gap seriously. It presents ARSUKA, an AR-based application developed to introduce Kaili tribal culture to young children in Central Sulawesi, Indonesia. Rather than treating AR as a technological supplement to existing content, this study reconceptualizes AR as a mediational environment through which children can encounter local cultural knowledge in ways that are concrete, multimodal, and appropriate to their developmental stage. Through ARSUKA, children can interact with elements of Kaili culture including local language, traditional dress, musical instruments, and dance, brought to life through AR experiences that transform what might otherwise be distant or abstract references into tangible, manipulable learning objects. The study's contribution, in this sense, extends beyond the application itself. It offers a repositioning of AR within ECE as a culturally responsive pedagogical medium for early engagement with indigenous heritage.

Three theoretical perspectives inform the design of ARSUKA. Constructivist theory frames children as active meaning-makers who build understanding through direct, purposeful engagement with their learning environment (Samat & Chaijaroen, 2019; Wibowo et al., 2025). Bronfenbrenner's ecological theory provides the basis for treating local culture not as supplementary material but as a constitutive developmental context, one that fundamentally shapes how children come to understand themselves and others (Burakgazi, 2025; Iruka et al., 2020). Vygotskian scaffolding, meanwhile, illuminates how AR can function as a mediating tool that supports learning by working within and gently extending the child's zone of proximal development (Crespo Torres et al., 2019; Han et al., 2020; Liu et al., 2020). Together, these frameworks position ARSUKA as something more than a digital product. They root it in a pedagogical logic that brings together interaction, cultural context, and mediated support as constitutive features of early childhood learning.

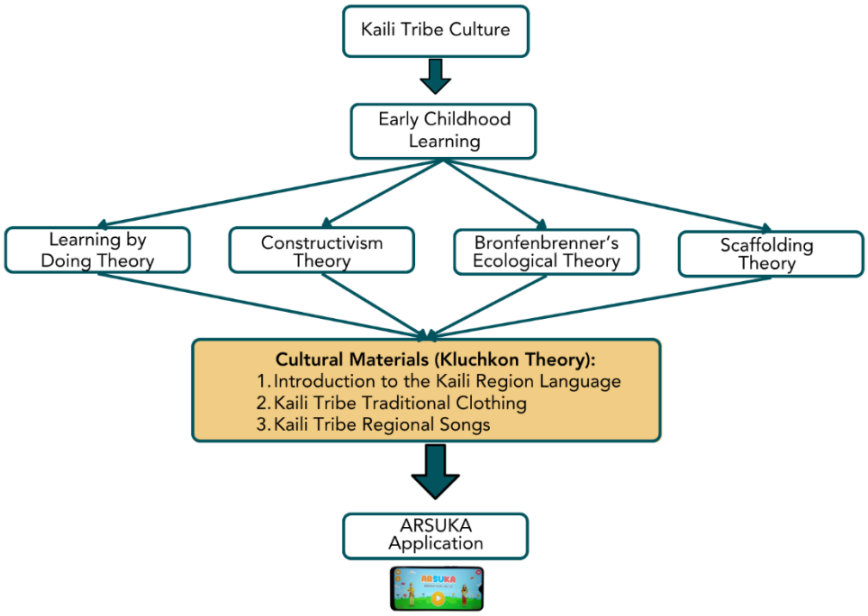

Figure 1. Theoretical Framework for ARSUKA Development

This study is thus directed toward the development and evaluation of ARSUKA as a culturally responsive AR learning medium for introducing Kaili tribal culture in ECE settings, with attention to both its technical feasibility and its initial effectiveness in supporting children's acquisition of Kaili cultural knowledge. Beyond its immediate local context, this work speaks to wider conversations in global educational research, offering a case for how AR can be designed not merely to engage or inform, but to preserve, mediate, and transmit indigenous cultural knowledge in the earliest years of a child's education.

Methods

Research Design

This study employed a Research and Development (R&D) approach guided by the Hannafin and Peck development model, which unfolds across three iterative phases: needs assessment, design, and development-implementation, each followed by systematic evaluation and revision. What sets this model apart from other widely used frameworks such as ADDIE or Borg and Gall is its sustained emphasis on continuous formative evaluation and recursive refinement, qualities that make it particularly well-suited to the development of interactive multimedia and AR-based learning applications (Simamora et al., 2024; Sudarma et al., 2022). While ADDIE tends to follow a more linear sequence and Borg and Gall is oriented toward broader large-scale field testing, the Hannafin and Peck model permits flexible movement between stages. This flexibility matters especially when AR features must be carefully aligned with young children's

developmental characteristics and with the demands of culturally specific learning content. The model's practical usefulness in multimedia and application-based development has also been demonstrated in prior studies (Alfis & Sasmita, 2021; Kurniawan et al., 2019; Sudarma et al., 2022).

In methodological terms, the study combined product development with an embedded preliminary field evaluation of initial effectiveness. The R&D component was used to generate and iteratively refine the ARSUKA application, while the evaluation component examined whether the revised product was pedagogically feasible and showed early evidence of supporting children's acquisition of Kaili cultural knowledge. This positioning reflects the study's objectives, which center on product development, feasibility assessment, and initial effectiveness rather than on causal impact testing.

The development process unfolded across three stages. During the needs assessment stage, classroom observations, review of existing learning documentation, and teacher interviews were used to identify the relevance of Kaili cultural content, existing classroom conditions, and teachers' readiness to work with AR-based tools. The design stage focused on interface layout, AR interaction flow, content visualization, and storyboard preparation. The development-implementation stage involved prototype production, expert validation, revision, limited trial use, and full classroom implementation. Formative evaluation results gathered at the close of each stage informed product revisions before the process moved forward. This iterative logic ensured that the final application reflected both developmental appropriateness and contextual cultural relevance, as illustrated in Figure 2.

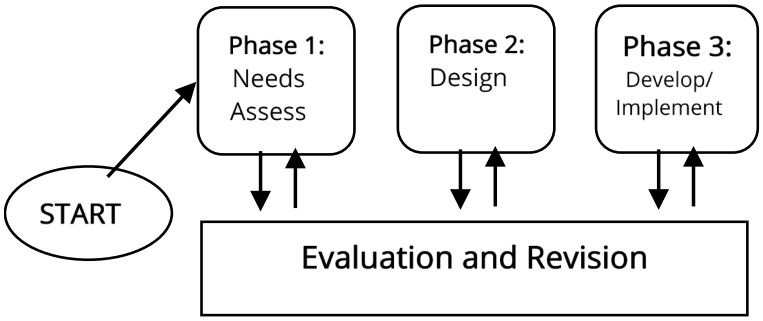

Figure 2. CAI Design Model (Source: Hannafin and Peck, 1988)

Participants

The study was conducted at a public kindergarten in Banawa, Donggala Regency, Central Sulawesi, Indonesia. Child participants were aged 5 to 6 years, corresponding to the target age group for the ARSUKA application. Two sequential trials were undertaken during the development process. A preliminary limited trial involving 8 children was used to surface practical issues related to usability, classroom implementation, and children's initial interaction with the application. Findings from this trial informed product refinement. Following revision, a field trial involving 19 children served as the basis for the analysis of initial effectiveness.

Of the 32 children enrolled at the kindergarten, 19 met all inclusion criteria for the field trial. Participants were selected through purposive sampling based on four predefined criteria: age suitability (5 to 6 years), regular school attendance, parental or guardian consent, and active participation in classroom activities. Because the study involved young children, data collection proceeded only after school permission and parental or guardian consent had been secured. No personally identifying information is reported in the study.

Beyond the child participants, the validation stages involved three information technology experts, three material experts, and 12 early childhood education teachers who assessed the application from technical, pedagogical, and user perspectives respectively. The small sample size and single-site setting were considered appropriate for developmental research aimed at establishing initial feasibility and early indications of effectiveness. These features do, however, limit the generalizability of the findings, and the study is therefore best understood as an initial developmental evaluation rather than a large-scale effectiveness study.

Data Collection Techniques and Instruments

Data were collected through classroom observations, document review, teacher interviews, and questionnaires. Different instruments were applied at different stages of the study to maintain alignment between the development process, the feasibility assessment, and the outcome evaluation.

During the needs assessment stage, classroom observations were used to examine how local cultural content was represented in ongoing learning activities, and review of learning documents was used to determine whether Kaili cultural elements had been systematically embedded in classroom planning. Teacher interviews were conducted to explore perceived needs, available learning media, classroom constraints, and the technological readiness of the setting for AR-based learning.

During the validation stage, questionnaires were administered to information technology experts, material experts, and teacher users. Expert validation instruments were designed to assess the technical and pedagogical feasibility of the ARSUKA application. Information technology experts evaluated aspects including application eligibility, interface design, application quality, reliability, efficiency, and connectivity performance. Material experts assessed the clarity of content, its anticipated impact on learners, and the feasibility of the cultural material for early childhood learners. The teacher user questionnaire examined content clarity, perceived impact on learners, and the practical feasibility of using AR-based media in classroom settings. Structured rating scales were used across these instruments to generate summary scores for feasibility interpretation.

To assess children's learning outcomes, a structured observation instrument was developed to measure children's cultural understanding of Kaili culture, conceptualized in this study as the ability to recognize, name, and verbally express basic elements of local cultural heritage. The instrument was grounded in early childhood cultural learning frameworks and culturally responsive pedagogy, which identify language, symbolic representation, and music as foundational components of cultural identity formation in young children. The selected indicators also reflect core elements of Kaili cultural transmission commonly introduced in early childhood contexts.

The observation instrument consisted of three indicators: recognition and use of local language expressions, representing linguistic and identity awareness; identification of traditional clothing, reflecting visual-symbolic understanding of cultural heritage; and recognition of local songs introduced during learning activities, representing cultural expression through music and oral tradition. These indicators were designed to capture observable behaviors appropriate for early childhood learners and to remain consistent with the study's focus on initial cultural knowledge acquisition rather than broader or long-term cultural internalization.

Each indicator was rated using a four-point scale (1 = not demonstrated, 2 = emerging, 3 = developing, 4 = well developed), based on children's observable responses before and after ARSUKA-assisted learning activities. Observations were conducted during regular classroom sessions using a standardized observation sheet and shared scoring guidelines to improve consistency. The classroom teacher and the researcher conducted observations jointly to reduce individual bias and to align scoring decisions with classroom realities. Inter-rater reliability was not formally tested, however, and this remains a methodological limitation of the study.

Questionnaires were also used to collect user responses to the ARSUKA application. Instrument validity for questionnaire items was examined using product-moment correlation (r-count = 0.826 > r-table = 0.754, $\alpha = 0.05$), confirming that all items were valid. Reliability analysis using Cronbach's alpha produced a coefficient of 0.871, indicating high internal consistency. These results support the adequacy of the questionnaire for feasibility assessment, although the observational outcome measure should still be interpreted within the bounds of an initial developmental evaluation.

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Data Analysis Technique

Data analysis relied on descriptive statistical methods to examine expert validation results, user responses, and children's learning outcomes, including mean scores and percentage distributions. Descriptive summaries were appropriate here given the developmental and exploratory orientation of the study and the field trial's purpose of generating initial evidence of feasibility and learning improvement rather than establishing causal impact.

To assess children's learning improvement following the use of ARSUKA, normalized gain (N-Gain) analysis was applied (Meltzer, 2002), calculated using the following formula:

$$\text{N-Gain (g)} = \frac{\text{Posttest score} - \text{pretest score}}{\text{Ideal score} - \text{pretest score}}$$

The resulting N-Gain values were interpreted using Hake's classification criteria (Hake, 1998), as presented in Table 1.

Table 1. Criteria of N-Gain Score

N-Gain (g)	Category
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

To deepen the interpretation of effectiveness, descriptive comparisons between pretest and posttest scores were also conducted at the indicator level to identify patterns of improvement across different aspects of cultural understanding. Qualitative insights drawn from classroom observations during implementation were used to support and contextualize the quantitative findings, providing a basic layer of triangulation across data sources.

Given the developmental nature of the study, its exploratory focus, the limited sample size, and the reliance on observational ratings as the primary child outcome measure, inferential statistical analyses were not conducted. The findings are therefore interpreted as evidence of initial effectiveness rather than causal impact. Future studies are encouraged to draw on larger samples, stronger comparison designs, formal inter-rater reliability testing, inferential statistical analysis, and multi-source data triangulation to strengthen methodological rigor and support broader generalizability.

Result

The implementation of the Hannafin and Peck development model resulted in three interrelated sets of findings corresponding to the needs assessment, design, and development-implementation phases (Hannafin, M. J. & Peck, 1988). The three phases clarify how the ARSUKA application emerged from identified instructional needs, was translated into a structured AR-based design, and was subsequently evaluated for technical feasibility, material appropriateness, user acceptance, and initial learning effectiveness. This structure makes the findings readable in relation to the developmental logic of the study rather than as isolated outputs. The sequence also makes visible that the product was shaped through linked pedagogical, technical, and evaluative considerations.

Needs Assess Phase

The needs assessment phase identified three key conditions that justified the development of ARSUKA. First, Kaili cultural content was only minimally integrated into everyday early childhood learning activities. Classroom observations showed that Kaili culture was rarely represented in daily learning experiences and was not supported by dedicated instructional media (CO-03). Consistent with this, review of learning documentation indicated that cultural content had not been systematically planned or embedded in existing curricula (CD-02).

Second, teachers reported a clear need for learning media that could introduce Kaili

cultural elements in forms accessible to young children. Interview data pointed specifically to the absence of classroom resources designed to support early exposure to local language vocabulary, traditional clothing, and folk songs. These findings indicate that the problem was not only limited cultural content, but also the lack of developmentally appropriate media through which such content could be meaningfully introduced. The need for ARSUKA therefore emerged from both curricular insufficiency and media limitations at the classroom level.

Third, the setting showed sufficient readiness for digital adaptation. Kaili cultural materials were already available in visual and audio forms suitable for further development into digital learning content (CD-04; CW-03). Teachers also reported routine use of digital devices such as tablets in classroom activities (CO-04). These findings established both the pedagogical need and the contextual feasibility for developing an AR-based cultural learning application.

Design Phase

The design phase translated these needs into a structured learning media plan for the ARSUKA application. The principal outputs of this phase were a storyboard document and an initial prototype of the augmented reality learning media. The storyboard organized learning objectives, content sequencing, user interactions, and media components for each activity, thereby providing the pedagogical and technical framework for the application. The design phase therefore did not merely generate visual assets, but also established the internal logic through which cultural content would be delivered to children.

The resulting design was organized around four cultural themes: (1) animal names in the Kaili language, (2) fruit names in the Kaili language, (3) traditional clothing of the Kaili tribe, and (4) Kaili folk songs. Each theme combined operational instructions with learning activities supported by 3D objects, audio narration, and text. The 3D objects were designed to be resized and manipulated during use, allowing children to engage with cultural content through direct interaction. This thematic structure indicates that the application was designed to integrate linguistic, visual, and musical dimensions of Kaili culture within a single learning environment.

To support AR activation in classroom use, the design also incorporated physical markers in the form of flashcards and puzzles, which functioned as triggers for displaying 3D cultural content. These markers linked children's physical manipulation of learning materials with the digital projection of cultural objects. This design maintained a concrete mode of engagement appropriate to early childhood learning. At the end of this phase, an initial prototype integrating these components had been completed and prepared for further refinement and implementation.

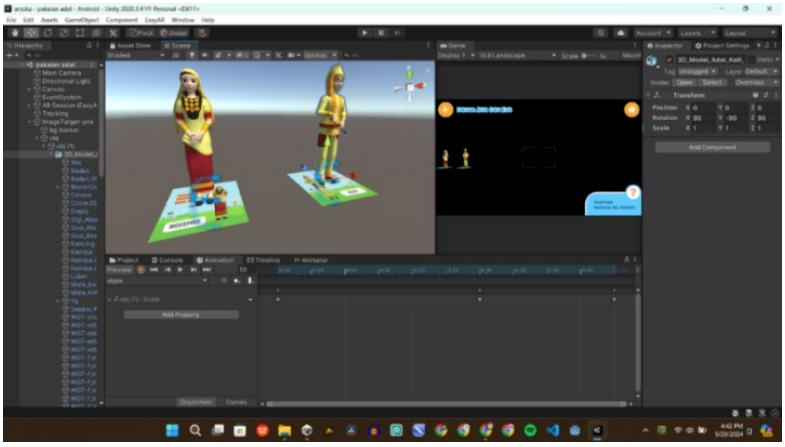

Figure 3. Creating 3D assets in the unity application

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Develop and Implement Phase

The development-implementation phase generated findings related to product feasibility and initial effectiveness. At this stage, the storyboard and design structure were translated into an operational ARSUKA application that could be used in classroom activities. The resulting product combined cultural content, AR interaction, and supporting visual components in a single learning medium. The application interface and its implementation are presented in Figure 4.

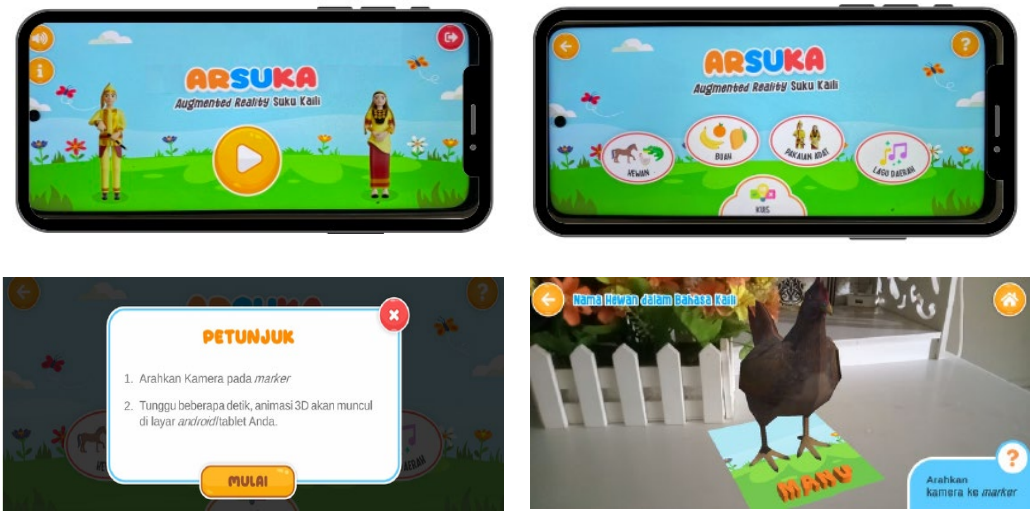

Figure 4. The ARSUKA Application (Nirmala, 2025)

After prototype completion, the ARSUKA application underwent formative evaluation by three information technology experts. After prototype completion, the ARSUKA application underwent formative evaluation by three information technology experts. Across the assessed aspects, the technical validation results were consistently high, indicating that the application met the expected standards for classroom use. The strongest ratings were obtained for interface design (4.9), application eligibility (4.8), application quality (4.8), and connectivity and download speed (4.8), while efficiency received the lowest, though still strong, score (4.3). Overall, the expert evaluation produced a mean score of 4.7 out of 5, corresponding to a validity percentage of 94%, which placed the application in the very valid category and indicated its suitability for further implementation.

Table 2. Results of validation by information technology experts

Aspects	**Average Score**
Application eligibility	4.8
Interface design	4.9
Application quality	4.8
Application reliability	4.6
Efficiency	4.3
Connectivity and download speed	4.8
Average	**4.7**
Criteria	**Very valid**

The cultural content of the ARSUKA application was then evaluated by three material experts. As shown in Table 3, all assessed aspects received high ratings, with feasibility of material obtaining the highest score (4.86), followed by clarity of material (4.78) and impact on learners (4.77). The overall mean score was 4.83, equivalent to 96.6%, indicating that the cultural content was judged to be highly appropriate for early childhood learners and sufficiently accurate in its representation of Kaili culture. These results reinforce the view that the application was not only technically workable, but also materially aligned with the

cultural and developmental aims of the study.

Table 3. Material Expert Validation Results

Aspect	Average Score
Clarity of material	4.78
Impact on learners	4.77
Feasibility of material	4.86
Overall mean score	4.83
Average	**4.83**
Criteria	**Very valid**

User-based validation further supported the feasibility of the application. Ratings from 12 early childhood education teachers in Donggala Regency, Central Sulawesi, remained consistently high across all assessed aspects. Clarity of material and feasibility of AR-based learning media each obtained a mean score of 4.73, while perceived impact on learners received a slightly lower score of 4.63. The overall mean score was 4.7 out of 5, corresponding to 94%, which again placed the application in the very valid category. These results suggest that, from the perspective of intended classroom users, ARSUKA was considered both usable and pedagogically feasible for implementation in early childhood education settings.

Table 4. User Validation (Teacher)

Aspect	Average Score
Clarity of material	4.73
Impact on learners	4.63
Feasibility of AR-based learning media	4.73
Average	**4.7**
Criteria	**Very valid**

The field trial also produced evidence of initial learning improvement. Changes in children's understanding of Kaili tribal culture between the initial and final observations are presented in Figure 5. The comparison indicates a mean increase of 32 points between the two measurements, suggesting improvement in children's cultural knowledge following the use of ARSUKA. This result extends the feasibility findings by showing that the application was associated not only with positive expert and user evaluations, but also with measurable gains in children's observed performance.

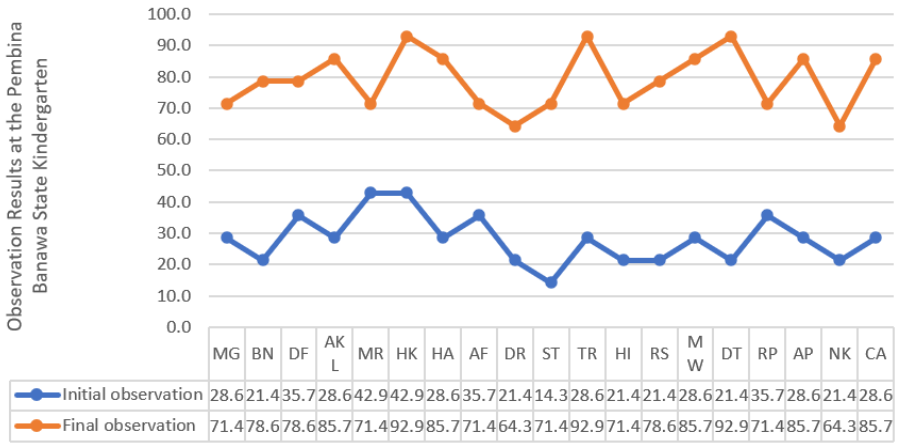

Figure 5. Initial and final results of children's cultural knowledge

This increase was further examined through N-Gain analysis, as presented in Figure 6. The mean observation score increased from 28.2 at the initial measurement to 78.9 at the final measurement, resulting in an N-Gain score of 0.71. According to the applied criteria,

this value falls into the high category, indicating that the use of ARSUKA was associated with substantial improvement in children's initial acquisition of Kaili cultural knowledge during the implementation period. The N-Gain result therefore supports the descriptive comparison shown in Figure 5 and strengthens the interpretation that meaningful learning improvement occurred during the trial.

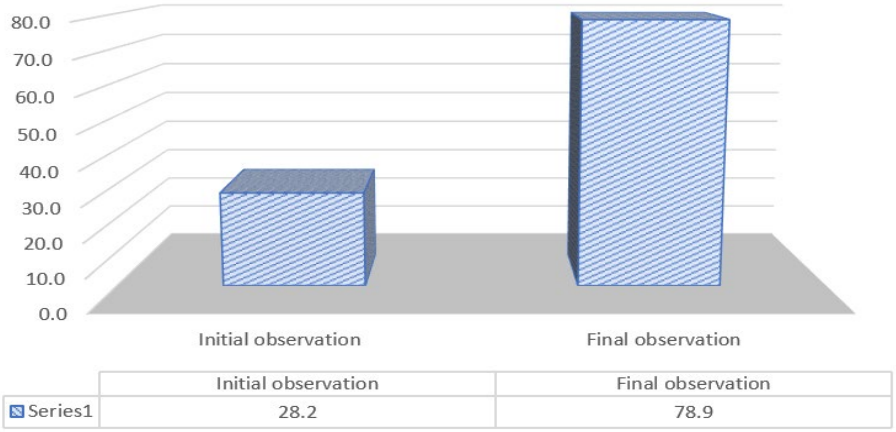

Figure 6. Findings from the analysis of pre- and post-observation data

The findings from the development-implementation phase show a consistent pattern across technical validation, material validation, teacher responses, and child outcome measures. The application was rated highly by different evaluator groups and was accompanied by substantial improvement in children's observed cultural knowledge during the trial period. These converging results strengthen the claim that ARSUKA functioned as a feasible and pedagogically relevant learning medium within the context in which it was developed. At the same time, because the evidence remains limited to an initial field implementation, the findings are best understood as support for early effectiveness rather than as definitive proof of broader impact.

Discussion

The findings invite a particular reading of ARSUKA: not as a universally transferable digital solution, but as a context-sensitive pedagogical response to a specific instructional problem. The needs assessment revealed that Kaili cultural content had only a limited presence in classroom routines, that dedicated learning media were largely absent, and that the setting nonetheless carried sufficient readiness for digital adaptation. Read alongside the validation results and the observed learning gains, these findings suggest that the relevance of ARSUKA lies not simply in its use of augmented reality, but in the way its design was anchored to a clearly identified local educational need. What matters here is therefore not AR in the abstract, but AR configured around culturally specific content, age-appropriate interaction, and the practical realities of early childhood classrooms.

Prior AR studies in early childhood education have largely concentrated on general cognitive development, engagement, usability, or STEM-related outcomes (Aslam et al., 2025; Gun & Atasoy, 2017; Majeed & ALRikabi, 2022; X. Wang et al., 2024). The present study does not overturn that body of work, but it does redirect attention toward a less examined question: how AR might support children's early encounter with local cultural knowledge. That redirection is modest but meaningful. It moves the conversation beyond whether AR can make learning more attractive and toward what kinds of knowledge AR can meaningfully mediate in early childhood settings. Within that narrower but significant frame, the findings suggest that culturally grounded AR design deserves far more serious attention, particularly in Global South contexts where digital learning resources frequently circulate without strong connection to the cultural worlds children actually inhabit.

The pattern of results also helps clarify how the application might be read through the

theoretical perspectives informing the study, though the findings do not support expansive theoretical claims. From a constructivist standpoint, ARSUKA gave children opportunities to engage directly with manipulable representations of cultural objects rather than encountering them only through verbal explanation or static illustration (Samat & Chaijaroen, 2019; Wibowo et al., 2025). From an ecological perspective, the application drew its learning content from the sociocultural environment already surrounding the children, which is consistent with the view that development is shaped through continuous interaction with culturally meaningful contexts (Bronfenbrenner, 1979; Burakgazi, 2025; Iruka et al., 2020). From a Vygotskian standpoint, the combination of visual animation, audio narration, and guided teacher support can be understood as a mediated learning arrangement that helped children move from initial exposure toward more recognizable forms of cultural knowledge (Crespo Torres et al., 2019; Han et al., 2020; Liu et al., 2020). These theoretical connections are useful insofar as they help explain why the application may have worked in this particular setting, but they should be read as interpretive support rather than as evidence that the study advances theory in any broad sense.

A related point concerns the design conditions under which AR appeared workable for early childhood learning. The technical and user validations suggest that simplicity, usability, and multimodal presentation were central to the application's acceptability. The use of flashcard and puzzle-based markers, together with offline accessibility, points to an educational value that was tied to a design remaining concrete, guided, and functional within a low-resource setting rather than dependent on sophisticated infrastructure. This reading sits comfortably alongside work emphasizing ease of use, enjoyment, guided support, timely feedback, and user safety in AR design for children (R. Wang, 2022), and resonates as well with literature on multimedia and AR learning that treats interaction as a condition for conceptual access (Bakri et al., 2025; D'souza et al., 2025; Nirmala et al., 2024a; Syawaludin et al., 2019). The implication is not that all low-connectivity contexts can readily adopt AR, but that thoughtful design may reduce some of the barriers commonly associated with digital innovation in underserved regions such as Central Sulawesi (Nirmala & Annuar, 2020).

The learning gains observed during the field trial also call for careful interpretation. The increase in mean scores and the high N-Gain value indicate meaningful improvement in children's observed acquisition of selected Kaili cultural elements during the implementation period, and these results are consistent with prior studies showing that AR-based applications can strengthen motivation, learning interest, and conceptual engagement in early childhood settings (Angraini et al., 2023; Fauzi et al., 2021; Hassan et al., 2022; Yao et al., 2025). At the same time, the outcome measure in this study was focused on early recognition and expression of particular cultural elements, not on deeper cultural understanding, long-term retention, or broader developmental outcomes. For that reason, the findings should not be stretched into claims about sustained cultural awareness, social understanding, or character development, even though those domains may remain relevant in wider educational debates on cultural diversity, empathy, and respect for difference (Balikci et al., 2025; Bennett et al., 2022; Zamroni et al., 2021). What the evidence supports more securely is the conclusion that ARSUKA was associated with improved short-term acquisition of selected Kaili cultural knowledge under the conditions of this trial.

The broader significance of the study lies in what it suggests for global conversations on digital pedagogy in early childhood education. Much of the international discourse on educational technology continues to be shaped by generic models of innovation, platform expansion, and learning efficiency, often with limited attention to the cultural specificity of what is actually being taught. The present findings point toward a different possibility: that digital media in early childhood settings can be developed not only to deliver content more attractively, but also to mediate local knowledge in ways that remain pedagogically concrete and culturally situated. This does not establish a universally applicable model, yet it does offer a grounded example from Indonesia that may speak to wider efforts to rethink how indigenous

or locally rooted knowledge can enter digital learning environments without being reduced to decorative content. In that sense, the study's global contribution lies not in its scale, but in its invitation to place cultural context more centrally in conversations about early childhood educational technology.

Several limitations must remain central to how these findings are read. The study was conducted in a single kindergarten with a small number of participants, which restricts both generalizability and the range of contextual variation that can be observed. The evaluation also focused on short-term learning gains and relied primarily on observational measures, which means that claims about durability, transfer, or broader developmental impact cannot be sustained from the present evidence. Inter-rater reliability was not formally tested, and the study design did not include a comparison group, so the results are better understood as indications of initial effectiveness than as strong evidence of causal impact.

Future research would benefit from larger and more diverse samples, stronger comparison designs, and longitudinal follow-up capable of tracking whether early gains in cultural learning hold over time. Work across multiple cultural settings would also help determine whether the design principles embedded in ARSUKA can travel productively to other local knowledge traditions or whether they require substantial contextual reconfiguration. Educator perspectives and knowledge-transfer processes in technology adoption also deserve more systematic attention, particularly in relation to how teachers interpret, adapt, and sustain culturally grounded AR tools in everyday practice (Berglund, 2023; Kelpsiene & Monkeviciene, 2024; Perifanou et al., 2022; Wyss & Bäuerlein, 2024). Research along these lines would place future studies in a much stronger position to assess not only whether AR can support early cultural learning, but under what pedagogical, institutional, and cultural conditions such support becomes genuinely meaningful and durable.

Conclusion

The findings of this study suggest that ARSUKA functioned as a feasible and pedagogically relevant medium for introducing selected elements of Kaili tribal culture in an early childhood education setting. The study makes no claim about long-term cultural formation, but it does indicate that augmented reality can be designed to connect digital interaction with locally grounded learning content under ordinary classroom conditions. What stands out most is not the technology itself, but the coherence between technological design, cultural specificity, developmental appropriateness, and instructional need. Within that bounded but meaningful scope, ARSUKA was associated with children's initial acquisition of selected local cultural knowledge during the implementation period. The study therefore positions culturally situated AR not as a universal solution, but as a context-sensitive instructional possibility worth taking seriously in early childhood learning.

The study also speaks to wider conversations on digital pedagogy in early childhood education across diverse global contexts. At a time when educational technology is too often driven by generic content and decontextualized models of innovation, these findings make a case for designing digital media that remain genuinely attentive to local knowledge traditions and the sociocultural worlds in which children actually grow and learn. The contribution here is less about proposing a transferable model than about offering a grounded example of how indigenous cultural content can be meaningfully mediated through AR in a developmentally appropriate way. That said, the small sample size, single-site implementation, short evaluation period, and absence of a comparison group all require the findings to be read as evidence of initial feasibility and early effectiveness rather than confirmed broader impact. Future research would benefit from larger and more varied samples, longer follow-up periods, stronger comparison designs, and applications across different cultural settings to examine whether the gains observed here can be sustained or productively adapted under different pedagogical and institutional conditions.

Declarations

Author Contribution Statement

Besse Nirmala: Conceptualization, Methodology, Software, Investigation, Writing – original draft; Andi Agusniatih: Investigation, Validation, Data curation, Writing – review & editing; Syafnidar Abdul Halim: Investigation, Resources, Data curation, Writing – review & editing; Tri Sugiarti M. Bakri: Formal analysis, Visualization, Writing – review & editing; Marwany: Conceptualization, Theoretical framing, Writing – review & editing; Haerul Annuar: Supervision, Writing – review & editing; Muh Rizal: Project administration, Resources, Writing – review & editing. All authors approved the final version of the manuscript.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. To protect the confidentiality of young participants, publicly accessible raw data are not provided. Anonymized and aggregated data may be shared for academic purposes where appropriate.

Declaration of interests statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Additional information

No additional information is available for this paper.

References

Ajao, S. O., Aworinde, H. O., Falola, P. B., Adeniyi, A. E., & Sakpere, A. B. (2024). Augmented reality in experiential learning: An overview. In *2024 IEEE 5th International Conference on Electro-Computing Technologies for Humanity (NIGERCON)* (pp. 1–8). IEEE. https://doi.org/10.1109/NIGERCON62786.2024.10927359

Ajit, G. (2021). A systematic review of augmented reality in STEM education. *Studies of Applied Economics, 39*(1). https://doi.org/10.25115/eea.v39i1.4280

Albayrak, S., & Yilmaz, R. M. (2022). An investigation of pre-school children's interactions with augmented reality applications. *International Journal of Human-Computer Interaction, 38*(2), 165–184. https://doi.org/10.1080/10447318.2021.1926761

Alfis, A., & Sasmita, S. (2021). Implementasi Hannafin & Peck model pada aplikasi animasi pembelajaran teori graph berbasis Android. *Jurnal Teknologi Informasi Mura, 13*(1), 24–33. https://doi.org/10.32767/JTI.V13I1.1288

Angraini, L. M., Yolanda, F., & Muhammad, I. (2023). Augmented reality: The improvement of computational thinking based on students' initial mathematical ability. *International Journal of Instruction, 16*(3), 1033–1054. https://doi.org/10.29333/iji.2023.16355a

Aslam, F., Rahman, H., Wahid, S. A., Wahid, S. A., & Ali, N. (2025). Enhancing children's learning experience through alphabet AR-game: A usability and acceptability assessment of augmented reality game-based learning. *Multimedia Tools and Applications, 84*(25), 29183–29205. https://doi.org/10.1007/s11042-024-20346-0

Asrifan, A., Ilyas, S. N., Asti, A. S. W., Afifah, F., Lismayani, A., & Saodi, S. (2025). Educational experience and expertise: Exploring terminological dimensions in shaping childhood. In *Shaping childhood through educational experiences* (pp. 1–28). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-9969-9.ch001

Aydoğdu, F. (2022). Augmented reality for preschool children: An experience with educational contents. *British Journal of Educational Technology, 53*(2), 326–348. https://doi.org/10.1111/bjet.13168

Bakri, T. S. M., Nirmala, B., & Annuar, H. (2025). Augmented reality-based digital collage for developing children's fine motor skills. In *Proceedings of the 1st International Conference on Educational Science and Teacher Education (ICESTE 2025)* (Vol. 206). https://doi.org/10.2991/978-2-38476-489-1_17

Balikci, S., Gulboy, E., & Rakap, S. (2025). Early childhood administrators' attitudes towards inclusive education: A systematic review. *Education Sciences, 15*(6), Article 734. https://doi.org/10.3390/educsci15060734

Bennett, S. V., Gunn, A. A., van Beynen, K., & Morton, M. L. (2022). Religiously diverse multicultural literature for early childhood. *Early Childhood Education Journal, 50*(4), 663–673. https://doi.org/10.1007/s10643-021-01180-7

Berglund, A. (2023). Overcoming integration thresholds for augmented reality. *International Journal of Emerging Technologies in Learning, 18*(14), 51–. https://doi.org/10.3991/ijet.v18i14.38385

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design.* Harvard University Press.

Burakgazi, S. G. (2025). The ecological model of human development. In *Exploring adult education through learning theory* (pp. 325–342). IGI Global. https://doi.org/10.4018/979-8-3693-5812-2.ch013

Chen, P., Liu, X., Cheng, W., & Huang, R. (2017). A review of using augmented reality in education from 2011 to 2016. In *Innovations in smart learning* (pp. 13–18). https://doi.org/10.1007/978-981-10-2419-1_2

Crespo Torres, N. M., Fernández Torres, A. del R., Gonzales Valero, M. I., Esparza Cruz, N. K., & León-Acurio, J. (2019). The augmented reality in the teaching-learning process of children from 3 to 5 years old. In *The International Conference on Advances in Emerging Trends and Technologies* (pp. 207–218). https://doi.org/10.1007/978-3-030-32022-5_20

D'souza, L., Sawant, S., Pujari, N., Shetgaonkar, N., & Naik, P. (2025). EDUFUSION: Augmented reality for education. In *2025 5th International Conference on Soft Computing for Security Applications (ICSCSA)* (pp. 1789–1796). https://doi.org/10.1109/ICSCSA66339.2025.11170769

Faas, S., Kasüschke, D., Nitecki, E., Urban, M., & Wasmuth, H. (Eds.). (2019). *Globalization, transformation, and cultures in early childhood education and care: Reconceptualization and comparison.* Springer. https://doi.org/10.1007/978-3-030-27119-0

Fauzi, W. J., Radzuan, N. R. M., Ngah, E., Rani, A. A., & Ali, F. (2021). Digitising English language learning for early childhood educators in Malaysian context: The rationale. *Asia-Pacific Journal of Research in Early Childhood Education, 15*(3). https://doi.org/10.17206/apjrece.2021.15.3.113

Garg, N., Kaur, A., Ahmad, F., & Dutta, R. (2025). Augmenting education: The transformative power of AR, AI, and emerging technologies. *Human Behavior and Emerging Technologies, 2025*(1), Article 5681184. https://doi.org/10.1155/hbe2/5681184

Garg, N., Kaur, A., & Dutta, R. (2025). Marker-based augmented reality in Unity: Enhancing education through interactive visualization. In *2025 3rd International Conference on Communication, Security, and Artificial Intelligence (ICCSAI)* (Vol. 3, pp. 374–378). https://doi.org/10.1109/ICCSAI64074.2025.11064199

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality, 23*(4), 447–459. https://doi.org/10.1007/s10055-019-00379-9

Gun, E., & Atasoy, B. (2017). The effects of augmented reality on elementary school students' spatial ability and academic achievement. *Egitim ve Bilim, 42*(191). https://doi.org/10.15390/eb.2017.7140

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student

survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74. https://doi.org/10.1119/1.18809

Han, X., Liu, Y., Li, H., Fan, Z., & Luo, H. (2020). Augmenting the makerspace: Designing collaborative inquiry through augmented reality. In *International Conference on Blended Learning* (pp. 148–159). https://doi.org/10.1007/978-3-030-51968-1_13

Hannafin, M. J., & Peck, K. L. (1988). *The design, development, and evaluation of instructional software.* Macmillan Publishing Company.

Hassan, S. A., Rahim, T., & Shin, S. Y. (2022). ChildAR: An augmented reality-based interactive game for assisting children in their education. *Universal Access in the Information Society, 21*(2), 545–556. https://doi.org/10.1007/s10209-020-00790-z

Hidayat, R., Samsudin, S., Wang, X., & Rahman, S. N. A. (2026). Augmented reality in science, technology, engineering and mathematics education: A meta-analysis. *Journal of Computer Assisted Learning, 42*(1), e70164. https://doi.org/10.1002/jcal.70164

Hu, A., & Ødemotland, S. (2021). Fostering cultural sustainability in early childhood education through a neighbourhood project. *Sustainability, 13*(9). https://doi.org/10.3390/su13095203

Iruka, I. U., DeKraai, M., Walther, J., Sheridan, S. M., & Abdel-Monem, T. (2020). Examining how rural ecological contexts influence children's early learning opportunities. *Early Childhood Research Quarterly, 52*, 15–29. https://doi.org/10.1016/j.ecresq.2019.09.005

Kelpsiene, M., & Monkeviciene, O. (2024). Predictors of deep learning and competence development in children aged 5–7 using augmented reality technology. *Education Sciences, 14*(9), Article 1024. https://doi.org/10.3390/educsci14091024

Kurniawan, A. P., Sartono, N. N., Zikra, F. A., & Ulwan, A. I. (2019). Multimedia augmented reality technology in daily basic knowledge learning media for early childhood and kindergarten. *IJAIT (International Journal of Applied Information Technology), 3*(1), 18–23. https://doi.org/10.25124/ijait.v3i01.2493

Li, X.-Z., Kang, X., Bai, X.-X., Han, C., & Yao, J. (2025). Augmented reality as a tool for cultural heritage education: Comparing interactive guides and traditional methods. *Education and Information Technologies*, 1–27. https://doi.org/10.1007/s10639-025-13827-8

Liu, C., Wu, S., Wu, S., & Cai, S. (2020). An AR-based case study of using textual and collaborative scaffolding for students with different self-efficacy to learn lever principles. In *2020 6th International Conference of the Immersive Learning Research Network (iLRN)* (pp. 9–15). https://doi.org/10.23919/iLRN47897.2020.9155197

Majeed, B. H., & ALRikabi, H. T. S. (2022). Effect of augmented reality technology on spatial intelligence among high school students. *International Journal of Emerging Technologies in Learning, 17*(24), 131–143. https://doi.org/10.3991/ijet.v17i24.35977

Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores. *American Journal of Physics, 70*(12), 1259–1268. https://doi.org/10.1119/1.1514215

Mirza, T., Tuli, N., & Mantri, A. (2022). Survey on use of augmented reality in early childhood education: Teachers perspective. In *2022 3rd International Conference on Computing, Analytics and Networks (ICAN)* (pp. 1–6). https://doi.org/10.1109/ICAN56228.2022.10007313

Nirmala, B. (2025). *Pengembangan model pembelajaran sentra budaya Kaili berbasis augmented reality untuk anak usia dini* [Doctoral dissertation, Universitas Negeri Jakarta].

Nirmala, B., & Annuar, H. (2020). Home visit: Strategi PAUD dari rumah bagi guru di daerah 3T pada masa pandemi Covid-19. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini, 5*(2), 1052–1062. https://doi.org/10.31004/obsesi.v5i2.716

Nirmala, B., Solihatin, E., & Sukardjo, M. (2024a). Augmented reality in early childhood education: Trends, practices, and insights from a literature review. *International*

Journal of Interactive Mobile Technologies, 18(22). https://doi.org/10.3991/ijim.v18i22.50337

Nirmala, B., Solihatin, E., & Sukardjo, M. (2024b). Augmented reality in education: A bibliometric analysis. *Proceedings of International Conference on Education, 2*(1), 325–340. https://doi.org/10.32672/pice.v2i1.1378

Oranç, C., & Küntay, A. C. (2019). Learning from the real and the virtual worlds: Educational use of augmented reality in early childhood. *International Journal of Child-Computer Interaction, 21*, 104–111. https://doi.org/10.1016/j.ijcci.2019.06.002

Pan, Z., López, M. F., Li, C., & Liu, M. (2021). Introducing augmented reality in early childhood literacy learning. *Research in Learning Technology, 29*, 1–21. https://doi.org/10.25304/rlt.v29.2539

Perifanou, M., Economides, A. A., & Nikou, S. A. (2023). Teachers' views on integrating augmented reality in education: Needs, opportunities, challenges and recommendations. *Future Internet, 15*(1), Article 20. https://doi.org/10.3390/fi15010020

Redondo, B., Cózar-Gutiérrez, R., González-Calero, J. A., & Sánchez Ruiz, R. (2020). Integration of augmented reality in the teaching of English as a foreign language in early childhood education. *Early Childhood Education Journal, 48*(2), 147–155. https://doi.org/10.1007/s10643-019-00999-5

Rigoli, F., & Lennon, J. (2025). Cultural incentive learning: How culture shapes acquisition of values. *Evolutionary Anthropology: Issues, News, and Reviews, 34*(3), e70005. https://doi.org/10.1002/evan.70005

Rohman, A. (2024). Integrating local cultural values into early childhood education to promote character building. *International Journal of Learning, Teaching and Educational Research, 23*(7), 84–101. https://doi.org/10.26803/ijlter.23.7.5

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355–385. https://doi.org/10.1162/pres.1997.6.4.355

Sahin, N., & Ozcan, M. F. (2019). Effects of augmented reality in teaching old Turkish language mementoes on student achievement and motivation. *Contemporary Educational Technology, 10*(2), 198–213. https://doi.org/10.30935/cet.5544501

Samat, C., & Chaijaroen, S. (2019). Design and development of constructivist augmented reality (AR) book enhancing analytical thinking in computer classroom. In *International Conference on Innovative Technologies and Learning* (pp. 175–183). https://doi.org/10.1007/978-3-030-35343-8_19

Seitz, H. J. (2021). Our place: Connecting young children to their communities. In *Handbook of research on empowering early childhood educators with technology* (pp. 247–263). IGI Global. https://doi.org/10.4018/978-1-7998-6888-0.ch013

Simamora, A. H., Agustini, K., Sudatha, I. G. W., & Suartama, I. K. (2024). Enhancing teaching materials development course with the ICARE learning model in e-learning. *Journal of Education and Learning (EduLearn), 18*(4), 1543–1552. https://doi.org/10.11591/edulearn.v18i4.21304

Sudarma, I. K., Prabawa, D., & Suartama, I. K. (2022). The application of information processing theory to design digital content in learning message design course. *International Journal of Information and Education Technology, 12*, 1043–1049. https://doi.org/10.18178/ijiet.2022.12.10.1718

Syaikhu, A., Muslim, S., Solihatin, E., & Hayati, M. (2022). Design early childhood learning program in early childhood outdoor learning. *Journal of Positive School Psychology, 6*(3), 2007–2013.

Syawaludin, A., Gunarhadi, & Rintayati, P. (2019). Development of augmented reality-based interactive multimedia to improve critical thinking skills in science learning. *International Journal of Instruction, 12*(4), 331–344. https://doi.org/10.29333/iji.2019.12421a

Wang, R. (2022). Application of augmented reality technology in children's picture books based on educational psychology. *Frontiers in Psychology, 13*, 1–14. https://doi.org/10.3389/fpsyg.2022.782958

Wang, X., Abdul Rahman, M. N. B., & Nizam Shaharom, M. S. (2024). The impacts of augmented reality technology integrated STEM preschooler module for teaching and learning activity on children in China. *Cogent Education, 11*(1), 2343527. https://doi.org/10.1080/2331186X.2024.2343527

Wibowo, S., Wangid, M. N., & Firdaus, F. M. (2025). The relevance of Vygotsky's constructivism learning theory with the differentiated learning primary schools. *Journal of Education and Learning (EduLearn), 19*(1), 431–440. https://doi.org/10.11591/edulearn.v19i1.21197

Wyss, C., & Bäuerlein, K. (2024). Augmented reality in the classroom: Mentor teachers' attitudes and technology use. *Virtual Worlds, 3*(4), 572–585. https://doi.org/10.3390/virtualworlds3040029

Yao, W., Wang, L., & Liu, D. (2025). Augmented reality-based language and math learning applications for preschool children education. *Universal Access in the Information Society, 24*(1), 759–770. https://doi.org/10.1007/s10209-024-01101-6

Yilmaz, R. M. (2016). Educational magic toys developed with augmented reality technology for early childhood education. *Computers in Human Behavior, 54*, 240–248. https://doi.org/10.1016/j.chb.2015.07.040

Zamroni, Dwiningrum, S. I. A., Hope, J., Kartowagiran, B., Sudartinah, T., Siteine, A., & Yao, Z. (2021). Cross-cultural competence in multicultural education in Indonesian and New Zealand high schools. *International Journal of Instruction, 14*(3), 597–612. https://doi.org/10.29333/iji.2021.14335a