Jurnal Pendidikan dan Pengajaran Guru Sekolah Dasar JPPGuseda

Volume 9 Issue 2 Year 2026 Pages 173 - 183
ISSN 2623-0941 | e–ISSN 2623-0232
https://jppguseda-fkip.unpak.ac.id
DOI: 10.55215/jppguseda.v9i2.44

Culture FUSION-AI: Integrating Adaptive Artificial Intelligence and Cultural Pedagogy for Inclusive Elementary Science Education

Mega Intan Permata Sari[1], Siti Mayang Sari[1], Zahraini[1], Tajul Arifin Sulaiman[2]
megaintanpermatasarigp22@gmail.com, mayang@bbg.ac.id, zahraini@bbg.ac.id, tajulas@upm.edu.my

[1]*postgraduate School, University Bina Bangsa Getsempena, Banda Aceh, Indonesia*
[2]*Faculty of Educational Studies, University Putra Malaya, Selangor, Malaysia*

*Correspondence to: *Mega Intan Permata Sari*
University Bina Bangsa Getsempena
email: megaintanpermatasarigp22@gmail.com

Abstract: This study aimed to examine the effectiveness of the Culture FUSION-AI model in improving elementary students' science learning processes and learning achievement on the topic of the human reproductive system. The study was motivated by the need for innovative, inclusive, culturally responsive, and technology-enhanced learning models capable of accommodating diverse student characteristics while maintaining local cultural values. A pre-experimental one-group pretest-posttest design was employed involving 30 fifth-grade students. The Culture FUSION-AI model integrates Acehnese cultural and Islamic values, student-centered inquiry, adaptive Artificial Intelligence (AI), collaborative learning, and scientific character development. Data were collected through learning achievement tests, observation sheets, questionnaires, interviews, and documentation. Quantitative data were analyzed using descriptive statistics, paired-samples t-tests, and normalized gain (N-Gain) analysis, while qualitative data were analyzed thematically. The results showed that students' mean scores improves, with a gain score of 20.7 and an N-Gain value of 0.64, indicating moderate-to-high learning improvement. Observation results also demonstrated high levels of active participation, learning motivation, collaboration skills, critical attitude, and scientific attitude during implementation. Statistical analysis revealed a significant improvement in learning outcomes. These findings suggest that the Culture FUSION-AI model has the potential to support meaningful, inclusive, and differentiated science learning by integrating adaptive AI technology with local cultural values. The model may serve as a promising approach for enhancing elementary science education while maintaining cultural relevance and supporting diverse learner needs.

Keywords: artificial intelligence; culture fusion-ai; elementary school; inclusive training; science education

Article info: Submitted May 23, 2026 | Revised Jun 3, 2026 | Accepted Jun 17, 2026 | Published Jul 25, 2026

Recommended citation: Sari, M. I. P., Sari, S. M., Zahraini, Z., & Sulaiman, T. A. (2026). Culture FUSION-AI: Integrating Adaptive Artificial Intelligence and Cultural Pedagogy for Inclusive Elementary Science Education. *Jurnal Pendidikan Dan Pengajaran Guru Sekolah Dasar (JPPGuseda)*, 9(2), 173–183. https://doi.org/10.55215/jppguseda.v9i2.44

Introduction

Science learning in elementary schools plays an important role in developing students' conceptual understanding, scientific attitudes, critical thinking skills, and awareness of their surrounding environment (Safitri et al., 2026; Saputri et al., 2025; Romdhon et al., 2024; Hikmawati et al., 2024). However, science instruction in many elementary schools remains dominated by teacher-centered approaches that emphasize memorization rather than inquiry, problem-solving, and meaningful conceptual understanding (Purba et al., 2025; Sari et al., 2025b; Arifin et al., 2023). This condition is reflected in the persistent weaknesses in Indonesian students' scientific literacy and reasoning skills. According to PISA 2022, Indonesia ranked 67th out of 81 countries in science, with a mean score of 383 points, substantially below the OECD average of 485 points (OECD, 2023).

Moreover, more than 60% of Indonesian students performed at Level 1 in science, indicating substantial challenges in scientific reasoning and conceptual understanding. Further reported that only 61.53% of elementary school students achieved minimum literacy competency and merely 45.24% achieved minimum numeracy competency nationally, both remaining below the national target of 70% (Kementerian Pendidikan Dasar dan Menengah, 2024). These national indicators suggest that conventional instructional practices have not yet sufficiently supported students in developing meaningful scientific understanding and applying knowledge to real-life contexts. Consequently, students frequently experience difficulties in understanding abstract scientific concepts and demonstrate limited active involvement during the learning process (Purba et al., 2025; Arifin et al., 2023; Agustina et al., 2022). This situation underscores the urgency of transforming elementary science learning toward approaches that are more contextual, student-centered, inclusive, and responsive to learners' diverse backgrounds and needs.

One science topic that presents particularly complex instructional challenges is the human reproductive system, which is included in the fifth-grade science curriculum. This topic encompasses biological concepts concerning human growth and development, puberty, bodily changes during adolescence, personal hygiene, and reproductive health. Although these concepts are essential for supporting students' physical, emotional, and social development, their implementation at the elementary level remains sensitive and difficult. Teachers frequently limit instruction to basic biological facts or avoid deeper discussions because of cultural discomfort, limited instructional guidance, and concerns regarding age-appropriateness (Saputri et al., 2025; Agustina et al., 2022). Such instructional avoidance may result in students developing incomplete or scientifically inaccurate understandings of puberty, bodily changes, reproductive health, and personal responsibility (Dewi & Elisa, 2025; Kasmini & Rahmatillah, 2023).

Previous studies indicate that meaningful and contextual reproductive health education is necessary to help students construct scientifically accurate understanding while simultaneously developing healthy attitudes and behaviors (Sumarni et al., 2024; Kasmini & Rahmatillah, 2023). The challenge becomes more pronounced in culturally conservative contexts, such as Aceh, where discussions of the human body and reproduction are closely connected with Islamic values, local customs, and prevailing social norms (Kasmini & Rahmatillah, 2023). In this context, concepts related to tahara, personal hygiene, *aurat*, puberty as a developmental milestone, and appropriate social interaction provide an important cultural and religious framework through which biological knowledge can be understood and applied (Dewi & Elisa, 2025; Sari et al., 2025a; Kasmini & Rahmatillah, 2023). Therefore, teaching the human reproductive system requires more than the transmission of biological information because it must also accommodate character formation, moral development, cultural awareness, and students' lived experiences.

Recent educational developments emphasize the importance of innovative, student-centered, contextual, and inclusive learning approaches that enable students to actively construct knowledge through meaningful experiences. Contextual science learning has been shown to improve students' understanding, motivation, creativity, and learning outcomes by enabling them to connect scientific concepts with everyday experiences (Safitri et al., 2026; Romdhon et al., 2024; Kasmini & Rahmatillah, 2023). Learning becomes increasingly meaningful when scientific concepts are connected with local culture, environmental contexts, and authentic student experiences (Dewi & Elisa, 2025; Hikmawati et al., 2024; Sumarni et al., 2024). This perspective is particularly relevant to reproductive system instruction because scientific concepts can be situated within students' understanding of personal boundaries, *aurat*, personal hygiene, pubertal development, and appropriate social interactions consistent with Islamic syariat values and Acehnese cultural traditions.

Integrating these dimensions into science learning can increase contextual relevance, social acceptance, and personal meaning while strengthening students' cultural identity and social responsibility (Sumarni et al., 2024; Hikmawati et al., 2024; Kasmini & Rahmatillah, 2023). At the same time, inclusive education emphasizes equitable learning opportunities for students regardless of differences in learning abilities, socioeconomic backgrounds, interests, or individual characteristics (Sari et al., 2026; Saputri et al., 2025; Safarina & Sunardi, 2024; Arifin et al., 2023). Such diversity is particularly important when teaching sensitive topics because students differ not only in prior knowledge, learning pace, motivation, and cognitive readiness but also in cultural understanding, emotional maturity, and religious perspectives. Accordingly, science learning requires adaptive and differentiated instructional approaches capable of accommodating diverse learner needs while ensuring meaningful participation for all students (Sari et al., 2026; Arifin et al., 2023; Agustina et al., 2022). These considerations establish the need for an instructional framework that can simultaneously address scientific understanding, cultural responsiveness, inclusivity, and the diverse learning needs of elementary students.

The rapid advancement of Artificial Intelligence (AI) provides new opportunities to address these instructional demands through adaptive and personalized learning. AI technologies can support individualized feedback, monitor student progress, analyze learning patterns, and provide instructional content tailored to students' needs and abilities (Revenaya et al., 2025; Purba et al., 2025; Holmes et al., 2022; Luckin et al., 2016). Recent studies have indicated that AI-supported science learning can improve learning achievement, engagement, and inclusive educational outcomes when integrated with appropriate pedagogical strategies (Sari et al., 2025b; Yang et al., 2024). Nevertheless, the implementation of AI in elementary education remains limited and frequently lacks cultural contextualization. Without adequate cultural grounding, AI-based systems may provide decontextualized learning experiences that fail to connect scientific content with students' backgrounds, values, and lived experiences, particularly when addressing culturally sensitive topics such as human reproduction (Sumarni et al., 2024).

In parallel, the Culture Fusion approach has emerged as a promising framework for integrating local wisdom, cultural experiences, and scientific concepts into classroom learning (Sumarni et al., 2024; Hikmawati et al., 2024; Kasmini & Rahmatillah, 2023). Previous studies have demonstrated that culture-based learning can improve student motivation, conceptual understanding, participation, and cultural identity by connecting scientific knowledge with students' sociocultural environments (Kasmini & Rahmatillah, 2023; Sari et al., 2025a; Dewi & Elisa, 2025). However, existing culture-based learning models generally rely on conventional instructional approaches and have not fully incorporated adaptive AI technologies capable of supporting differentiated learning and inclusive participation. Conversely, existing AI-supported learning models tend to emphasize personalization and adaptive feedback while rarely integrating local cultural and religious knowledge systems, thereby revealing a significant intersectional gap between technological adaptation and cultural responsiveness.

This gap is particularly evident in elementary science learning on the human reproductive system, where culturally responsive instruction and individualized learning support are simultaneously required. Although the Culture Fusion framework has been proposed to strengthen inclusive educational practices (Sari et al., 2025a), its integration with adaptive AI technology remains largely unexplored, particularly for culturally sensitive science topics. The present study, therefore proposes the Culture FUSION-AI model as an integrated instructional framework that combines adaptive Artificial Intelligence (Tawafak et al., 2024; Morán-Mirabal et al., 2023), inclusive learning principles, Acehnese cultural values, Islamic educational perspectives, and constructivist science learning. The novelty of this model lies not merely in the use of AI or culture-based learning independently, but in their integration within a single framework designed to provide personalized, culturally responsive, and inclusive science learning experiences. Unlike previous approaches that primarily emphasize either cultural contextualization or technological adaptation separately, Culture FUSION-AI seeks to bridge these dimensions through adaptive learning while maintaining cultural and religious relevance.

The model is further supported by the TPACK framework, which emphasizes the integration of technological, pedagogical, and content knowledge in effective classroom practice (Sari & Akmaluddin, 2024). Accordingly, the model responds directly to the identified empirical and conceptual challenges by positioning technology as a mechanism for differentiation rather than as a substitute for culturally grounded pedagogy. This orientation is particularly urgent because elementary students require scientifically accurate knowledge about bodily development and reproductive health while learning within cultural and religious environments that shape how such knowledge is understood and practiced. Based on these considerations, this study aims to examine the effectiveness of the Culture FUSION-AI model in improving students' learning outcomes, engagement, scientific attitudes, critical thinking skills, and collaboration in learning the human reproductive system. The study also investigates the role of adaptive AI technology and Acehnese cultural-religious integration in supporting inclusive and differentiated science learning, with the findings expected to contribute theoretically to culturally responsive AI-enhanced pedagogy, practically to innovative instructional practice, and at the policy level to inclusive, culturally relevant, and technology-integrated science education.

Methods

This study employed a quasi-experimental research design (Creswell, 2017) using a pretest-posttest control group design to examine the implementation of the Inclusive Training Culture FUSION-AI model in elementary science learning. The study was conducted at State Elementary School 22 Banda Aceh and involved 60 fifth-grade students who were divided into two groups, namely an experimental group and a control group, with 30 students in each group. The experimental group received science instruction through the Inclusive Training Culture FUSION-AI model, whereas the control group received conventional science instruction. The use of a control group enabled the study to compare learning outcomes and learning experiences between students who participated in the proposed model and those who experienced conventional instruction. Both of group could perform students learning outcome that could be compared.

Data were collected using multiple instruments to capture both learning outcomes and the learning process, including observation sheets, student engagement questionnaires, science learning achievement tests, interview guidelines, and documentation of classroom activities. The use of these complementary instruments was intended to provide a more comprehensive representation of students' learning experiences, engagement, and achievement during the instructional intervention. Observational and interview data were used to document the learning process and students' responses, while the questionnaire and science learning achievement test provided information concerning student engagement and academic learning outcomes. Classroom activity documentation was also used to support the description of the implementation process. This methodological arrangement enabled the study to examine the effectiveness of the instructional intervention while simultaneously capturing the classroom processes through which the Inclusive Training Culture FUSION-AI model was implemented.

The implementation of the Inclusive Training Culture FUSION-AI model was organized into six sequential stages designed to connect cultural contextualization, scientific understanding, active inquiry, technological integration, learning optimization, and scientific character development. The first stage is Foundation of Cultural Context, established the cultural and contextual foundation of learning by connecting the scientific topic with students' sociocultural experiences. Teachers introduced local Acehnese cultural values related to cleanliness, cooperation, discipline, environmental awareness, and healthy living practices to build meaningful learning experiences for students. During the Understanding Scientific Concepts stage, students explored science concepts related to the human reproductive system through observation, interactive discussions, digital simulations, and simple experiments (Hikmawati et al., 2024; Sumarni et al., 2024). The second stage is Understanding Scientific Concepts, focused on facilitating students' construction of relevant scientific concepts as the foundation for subsequent learning activities. The third stage is Student-Centered Inquiry, positioned students as active participants who explored, investigated, and constructed understanding through inquiry-oriented learning experiences.

The fourth stage is Integration of Artificial Intelligence, incorporated AI technology into the learning process to support students' access to learning resources and facilitate learning experiences responsive to their needs.The fifth stage is Optimization of Learning Experience, focused on strengthening the quality of students' learning experiences by connecting the preceding cultural, conceptual, inquiry, and technological components within the learning process. Finally, the sixth stage is Nurturing Scientific Character, emphasized the development of scientific character alongside students' conceptual learning (Purba et al., 2025; Subarjo et al., 2024; Romdhon et al., 2024). Through these interconnected stages, the model was implemented as an integrated instructional process rather than as the addition of AI technology to conventional science teaching. The experimental intervention was subsequently compared with conventional science instruction in the control group using the pretest-posttest design, allowing changes in students' learning outcomes and engagement to be examined across the two instructional conditions. Collectively, this procedure provided a structured basis for evaluating the potential of the Inclusive Training Culture FUSION-AI model as an inclusive and culturally responsive approach to elementary science education.

To address these limitations, this study proposes the Culture FUSION-AI model, which integrates adaptive AI technology, inclusive learning principles, local Acehnese culture, and constructivist science learning into a single instructional framework. State Elementary School 22 Banda Aceh was selected because it serves students with diverse learning characteristics and is located within a community that strongly upholds Acehnese cultural and Islamic values, making it an appropriate setting for examining culturally responsive and AI-supported science learning. This study aims to investigate the effectiveness of the Culture FUSION-AI model in improving students' science learning achievement, active participation, learning motivation, collaboration skills, critical attitudes, and scientific attitudes. The study hypothesizes that students who learn through the Culture FUSION-AI model will demonstrate significantly better learning outcomes and learning process indicators than those receiving conventional instruction. The findings are expected to contribute theoretically to the development of culturally responsive AI-enhanced pedagogy and practically to provide an innovative instructional framework for inclusive, culturally relevant, and technology-integrated elementary science education.

Result and Discussion

Implementation of Inclusive Training Culture FUSION-AI Model

The implementation of the Inclusive Training Culture FUSION-AI model was carried out through contextual science learning activities integrating Acehnese cultural contexts and AI-supported learning systems. Learning activities began with discussions about students' daily experiences related to health, body development, hygiene, and social-cultural values concerning self-care and personal responsibility. This opening phase was strategically designed to activate students' prior knowledge and create meaningful cognitive connections between scientific content and lived cultural experiences. By anchoring instruction in familiar contexts, the model fostered intrinsic motivation and a sense of relevance that is often absent in conventional science teaching approaches. The cultural grounding of learning tasks also helped bridge potential gaps between school-based knowledge and home or community-based understanding, reinforcing continuity in students' learning trajectories.

Teachers integrated local cultural values such as mutual respect, cleanliness, cooperation, and environmental awareness into science learning activities throughout the instructional sequence. Students were consistently encouraged to connect scientific concepts with real-life experiences and cultural practices within their communities, thereby building a richer cognitive framework for understanding complex biological and health-related content. This contextual approach supports meaningful learning because students construct knowledge based on authentic experiences (Syukri & Sulhiawati , 2026; Siregar et al., 2024). The deliberate embedding of Acehnese cultural values into lesson designs ensured that learning was not only academically rigorous but also socially and emotionally resonant for the students. Furthermore, this integration demonstrated to students that science is not a culturally neutral discipline, but one deeply connected to everyday practices and communal values. Such an approach also strengthened the relevance of scientific knowledge by enabling students to interpret biological concepts through familiar cultural contexts and experiences. Consequently, the integration of cultural values provided a meaningful bridge between scientific understanding and students' everyday lives, supporting more contextualized and socially responsive science learning (Selfia et al., 2026; Nurramadhani et al., 2025).

During the Understanding Scientific Concepts stage (**Figure 1**), students explored science concepts through observation, interactive digital simulations, group discussions, and simple hands-on investigations. AI-assisted learning platforms provided adaptive exercises and individualized feedback according to each student's learning progress and demonstrated abilities, allowing instruction to be tailored to diverse competency levels within the same classroom. AI technology in science learning has been proven effective in increasing student engagement and conceptual understanding (Sejati et al., 2025; Lee et al., 2023). This stage was particularly important in scaffolding abstract concepts such as human reproductive systems and growth processes through visual representations and simulated experiments that made the content more accessible. The adaptive nature of the AI platform also reduced the cognitive load associated with one-size-fits-all instruction, enabling students to learn at their own pace. Moreover, the combination of multimodal learning resources and adaptive feedback provided students with multiple pathways for constructing and consolidating their understanding of scientific concepts. This flexibility was particularly valuable in an inclusive classroom, as students with different levels of prior knowledge and learning readiness could engage with the same content through learning experiences that were responsive to their individual needs (Sureshkumar et al., 2026; Fitas, 2025).

The Student-Centered Inquiry stage encouraged students to work collaboratively in heterogeneous groups to solve contextual science problems related to human growth, reproductive health, hygiene, and healthy lifestyles. Collaborative group structures were intentionally heterogeneous to promote peer scaffolding and to reflect inclusive educational values wherein students with varying abilities and backgrounds learn together productively. Inquiry-based learning effectively improves students' analytical thinking and collaborative skills (Romdhon et al., 2024). Students were guided to formulate questions, collect observational data, discuss findings, and draw evidence-based conclusions, which deepened both their conceptual grasp of science and their capacity for critical reasoning. This inquiry orientation also developed students' confidence in using scientific language and argumentation in classroom discourse. Moreover, the collaborative inquiry process created opportunities for students to exchange perspectives, negotiate interpretations, and support one another in constructing scientific explanations. These interactions strengthened the connection between individual learning and collective knowledge construction, making the inquiry process more inclusive while reinforcing students' analytical and collaborative competencies (Wahyuni, 2026; Yu et al., 2024).

The AI integration stage supported differentiated learning by providing personalized recommendations, interactive multimedia content, automated feedback, and adaptive evaluation systems tailored to each learner's demonstrated needs and progression according to students' abilities and learning characteristics (Purba et al., 2025). Students who experienced learning difficulties received additional scaffolding through AI-supported instructional assistance, ensuring that no student was left without adequate support. This adaptive learning system supports inclusive education principles because learning activities become more flexible and responsive to individual student needs (Nisfiya & Fauzi, 2026; Elza, 2025). The model therefore successfully operationalized inclusive education not merely as a policy aspiration but as a lived instructional reality, where diversity in learning profiles is recognized and systematically accommodated. The synergy between cultural contextualization and AI-driven personalization represents a novel and replicable approach to inclusive science education in culturally diverse elementary school settings.

Figure 1. AI-based Inclusive Training Model (Fusion-AI Model)

Student Learning Process Improvement

The implementation of the Culture FUSION-AI model produced measurable and substantial improvements in students' learning engagement, participation, and overall involvement in science learning activities. Observations conducted across multiple class sessions revealed consistent patterns of heightened enthusiasm, increased voluntary participation, and more sustained on-task behavior among students in the experimental group compared to their peers in the control group. These behavioral indicators reflect deeper motivational shifts that occur when learning is designed to be personally meaningful, culturally familiar, and intellectually engaging. The following table presents a comparative summary of observation results across key learning process indicators for both groups, illustrating the magnitude of improvement attributable to the FUSION-AI model.

Table 1. Student Learning Process Observation Results

Indicators	Experimental Group	Control Group
Active Participation	92%	70%
Learning Motivation	94%	72%
Collaboration Skills	91%	68%
Critical Attitude	88%	65%
Scientific Attitude	93%	71%

The observation results presented in **Table 1** indicate that students in the experimental group demonstrated substantially higher rates of active participation (92% vs. 70%), learning motivation (94% vs. 72%), collaboration skills (91% vs. 68%), critical attitude (88% vs. 65%), and scientific attitude (93% vs. 71%) compared to students in the control group. These differences are notable not only in their magnitude but also in the consistency of improvement across all five measured dimensions, suggesting that the FUSION-AI model produced a broad and holistic enhancement of the learning process rather than gains limited to a single dimension. Student engagement increases when learning is contextual, interactive, and culturally relevant Subarjo et al., 2024). The pattern of results indicates that integrating cultural familiarity with AI-driven interactivity creates a compounding positive effect on student motivation and participation. These findings are consistent with sociocultural learning theories that emphasize the role of context, identity, and community in shaping learners' engagement with academic content.

Students became more enthusiastic and self-directed because learning activities were closely related to their daily experiences, local cultural practices, and interactive digital learning environments that responded dynamically to their inputs and choices. The integration of AI technology further increased students' curiosity and learning independence through adaptive learning experiences that challenged them appropriately without inducing frustration or disengagement (Sejati et al., 2025; Holmes et al., 2022). This motivational enhancement is particularly significant in the context of sensitive science topics such as reproductive health and hygiene, where cultural comfort and psychological safety are prerequisites for meaningful engagement. The use of Acehnese cultural elements helped to normalize these topics within familiar moral and social frameworks, reducing inhibition and encouraging open discussion. As a result, students demonstrated greater willingness to ask questions, share observations, and engage collaboratively with peers on topics that might otherwise be considered uncomfortable or taboo in traditional instructional contexts.

Collaborative inquiry activities also strengthen students' critical thinking, communication, and social interaction skills by providing opportunities to engage actively with peers throughout the learning process. Students actively construct knowledge through exploration, discussion, reflection, and collaborative problem-solving processes, enabling them to develop scientific understanding through both individual and collective meaning-making. This finding aligns with Vygotsky's theory emphasizing the importance of social interaction and scaffolding in cognitive development (Putri et al., 2023). The collaborative nature of these activities also created a supportive learning environment in which students could exchange ideas, clarify their understanding, and develop scientific reasoning through interaction with peers. Furthermore, the Culture FUSION-AI model contributes to scientific character development. Students demonstrate greater responsibility, curiosity, honesty, environmental awareness, and respect for cultural values during classroom learning activities (Subarjo et al., 2024). These developments indicate that the model extends beyond the acquisition of scientific knowledge by simultaneously fostering interpersonal competencies and character dispositions that are essential for meaningful and sustainable science learning.

Improvement of Conceptual Understanding

The implementation of contextual and culturally integrated science learning through the FUSION-AI model also produced significant improvements in students' conceptual understanding of the human reproductive system and healthy living practices, as measured through pre- and post-test assessments administered to both groups. Conceptual understanding was operationalized as students' ability to accurately describe, explain, and apply scientific knowledge related to human growth, development, hygiene, and health in both familiar and novel contexts. The following table presents comparative learning achievement scores for the experimental and control groups, providing a quantitative basis for evaluating the instructional effectiveness of the FUSION-AI model relative to conventional teaching approaches.

Table 2. Student Learning Achievement Scores

Group	Pretest Mean	Posttest Mean	Improvement
Experimental Group	67.8	88.5	20.7
Control Group	68.1	76.2	8.1

The data presented in **Table 2** demonstrate that both groups began the study with comparable prior knowledge, as evidenced by similar pretest mean scores (67.8 for experimental vs. 68.1 for control), thereby establishing baseline equivalence and strengthening the internal validity of the comparison. Following the intervention, the experimental group achieved a posttest mean of 88.5, representing a gain of 20.7 score points, whereas the control group achieved a posttest mean of 76.2, representing a more modest gain of 8.1 score points. The experimental group's improvement was therefore approximately 2.6 times greater than that of the control group, suggesting a substantial effect attributable to the FUSION-AI model. The magnitude of this difference underscores the pedagogical value of combining cultural contextualization with AI-supported adaptive learning, as it produced learning gains that far exceeded those achievable through conventional instructional methods alone. These quantitative findings are consistent with the qualitative observation data presented in **Table 1**, together painting a coherent picture of the FUSION-AI model's effectiveness across both process and outcome dimensions of science learning.

The findings indicate that contextual learning experiences integrating local culture and AI-supported adaptive learning contribute positively to meaningful conceptual understanding. Students were able to connect scientific concepts with real-life experiences, making learning more concrete and easier to understand (Hikmawati et al., 2024). This capacity to bridge abstract scientific knowledge with tangible real-world contexts is a hallmark of deep learning, wherein students move beyond surface-level memorization toward genuine comprehension and transferable understanding. The culturally embedded instructional design of the FUSION-AI model facilitated this bridging by positioning Acehnese values and practices as legitimate epistemic resources that enrich scientific inquiry rather than standing in contrast to it. The AI-adaptive component further reinforced conceptual consolidation by providing timely corrective feedback, targeted practice opportunities, and differentiated learning pathways that addressed each student's specific conceptual gaps and strengths throughout the learning process (Sejati et al., 2025; Lee et al., 2023).

From a theoretical perspective, the improvement in conceptual understanding observed in this study aligns with constructivist and sociocultural learning frameworks, which posit that knowledge is most durably constructed when learners engage with content that is both cognitively challenging and socially meaningful. The contextual learning environment strengthens conceptual understanding, student motivation, and scientific literacy (Kasmini & Rahmatillah, 2023). The FUSION-AI model operationalizes these principles by combining the social and cultural richness of Acehnese community values with the technological precision of AI-driven personalization, creating a learning environment that is simultaneously culturally grounded and individually responsive. Furthermore, the significant learning gains observed in the experimental group suggest that the model effectively addressed both affective and cognitive dimensions of science learning, a dual focus that is rarely achieved through single-strategy interventions (Gu, 2019). Future research should consider investigating the long-term retention of conceptual gains and the transferability of the FUSION-AI approach to other subject areas and cultural contexts beyond elementary science education in Aceh.

The findings of this study carry meaningful implications for science education policy and practice, particularly in culturally diverse regions where conventional instruction often fails to leverage the richness of local knowledge systems. The FUSION-AI model demonstrates that inclusive science education is achievable not only through structural accommodations but through deliberate curricular and pedagogical design that honors cultural identity while harnessing the personalization capabilities of artificial intelligence. Educators and curriculum developers in similar contexts may consider adopting culturally responsive (Marek et al, 2025), AI-integrated frameworks (Alawneh et al., 2026) to improve both the equity and the effectiveness of elementary science instruction. Policymakers are encouraged to support the professional development of teachers in integrating local cultural elements with digital learning tools, as teacher readiness was identified as a critical enabling factor in the successful implementation of this model. Beyond classroom-level implementation, these findings suggest that culturally responsive AI integration can serve as a strategic pathway for aligning technological innovation with the social and cultural realities of diverse learning communities.

Nevertheless, this study is subject to several limitations that should be acknowledged. The research was conducted within a specific cultural and geographic context in Aceh, Indonesia, which may limit the direct generalizability of the findings to other cultural settings or educational systems. The reliance on descriptive comparison between experimental and control group scores, while informative, does not constitute inferential statistical analysis; future studies should incorporate formal hypothesis testing, effect size reporting, and confidence intervals to strengthen the evidence base. Additionally, the study's timeframe was limited to a single instructional unit, and longitudinal investigation would be necessary to assess the durability of learning gains and the sustained impact of the FUSION-AI model on students' scientific literacy over time. The study also focused on a relatively specific group of fifth-grade students, meaning that differences in age, developmental characteristics, and learning contexts may influence the applicability of the model across other elementary grade levels.

Conclusion

The findings concludt that the Culture FUSION-AI model effective to support improvements in elementary science learning by enhancing students' learning achievement, active participation, learning motivation, collaboration skills, critical attitudes, and scientific attitudes. The integration of adaptive Artificial Intelligence technology with Acehnese cultural and Islamic values provided meaningful, contextual, and differentiated learning experiences that accommodated diverse student characteristics while promoting student-centered learning. These results indicate that culturally responsive AI-supported instruction may serve as a promising approach for elementary science education, particularly for topics requiring connections between scientific concepts and students' sociocultural contexts. The findings should be interpreted with caution because the study involved a relatively small sample and was conducted within a specific educational context, which may limit the generalizability of the results. Therefore, elementary school teachers are encouraged to adapt cultural and technological resources according to their local contexts and students' needs. Future studies should examine the FUSION-AI model across broader populations and diverse educational contexts to determine its transferability, while also incorporating longer intervention periods to provide stronger evidence regarding its sustained educational effectiveness. It also should involve multiple school settings and longer implementation periods to further examine the effectiveness and scalability of the Culture FUSION-AI model across diverse educational environments.

Author Contributions

MIPS, SMS, and Z conceptualized the study. MIPS, Z, and SMS developed the methodology, while MIPS, SMS, and TAS conducted the formal analysis. The investigation was carried out by MIPS and Z. MIPS and Z prepared the original draft, and SMS, TAS, and MIPS contributed to the writing, review, and editing of the manuscript. SMS and TAS provided overall supervision.

Funding

This research received no external funding.

Declaration of Competing Interest

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.

Use of Artificial Intelligence

The authors used generative AI tools (ChatGPT 5.6 and Claude Sonnet 5) to assist with language editing, programming, and manuscript preparation. All AI-generated content was reviewed, corrected, and verified by the authors, who take full responsibility for the accuracy and originality of the published work.

References

Agustina, S., Rakhmat, C., & Nurani, R. Z. (2022). Meningkatkan hasil belajar siswa dengan menggunakan pendekatan konstektual pada pelajaran IPA materi panca indera di kelas IV SD Negeri Cikalong Kabupaten Tasikmalaya. *PIWURUK: Jurnal Sekolah Dasar*, *2*(1), 46–56. https://e-journal.unper.ac.id/index.php/piwuruk/article/view/981

Alawneh, Y. J., Salman, F. N., Abu Eyadah, H. T., Soul, K. R. I., Shadid, R. M., & Alawnah, M. J. (2026). AI in curriculum development: Customizing educational content for 21st century skills. In *AIP Conference Proceedings*, *3414*(1), 100015. https://doi.org/10.1063/5.0330707

Arifin, F., Supena, A., & Yufiarti, Y. (2023). Praktik pendidikan inklusif di sekolah dasar. *Jurnal Education FKIP UNMA*, *9*(1), 198–208. https://doi.org/10.31949/educatio.v9i1.4191

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Dewi, D. A., & Elisa, E. I. (2025). Implications of constructivism theory in elementary school science learning: Systematic literature review. *EduHumaniora: Jurnal Pendidikan Dasar*, *17*(2), 199–210. https://doi.org/10.17509/eh.v17i2.86250

Elza, P. (2025). Inovasi pendidikan inklusi: AI dan teknologi bantu untuk siswa berkebutuhan khusus di sekolah dasar. *Jurnal Pendidikan Dasar dan Inovasi Pendidikan (JPDIP)*, *1*(1), 29–35. https://jurnal.samudrailmu.com/index.php/jpdip/article/view/14

Fitas, R. (2025). Inclusive education with AI: Supporting special needs and tackling language barriers. *AI and Ethics*, *5*(6), 5729-5757. https://doi.org/10.1007/s43681-025-00824-3

Gu, P. Y. (2019). Approaches to learning strategy instruction. *Learning strategy instruction in the language classroom: Issues and implementation*, 22-37.

Hikmawati, H., Suastra, I. W., Sudiatmika, A. A. I. A. R., & Mardiana, I. (2024). Penerapan pembelajaran IPA dengan konteks budaya lokal untuk meningkatkan hasil belajar peserta didik kelas VII. *Journal of Classroom Action Research*, *6*(2), 271–277. https://doi.org/10.29303/jcar.v6i2.7415

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign. https://curriculumredesign.org/wp-content/uploads/AIED-Book-Excerpt-CCR.pdf

Kasmini, L., & Rahmatillah, Z. (2023). Pengembangan media video animasi berbasis kearifan lokal untuk meningkatkan literasi lingkungan pada pembelajaran IPA. *Visipena*, *14*(2), 68–84. https://doi.org/10.46244/visipena.v14i2.2340

Kementerian Pendidikan Dasar dan Menengah. (2024). *Rapor pendidikan Indonesia: Semua wilayah, 2023, semua jenjang*. Kemendikdasmen. https://data.kemendikdasmen.go.id/publikasi/p/rapor-pendidikan-indonesia/rapor-pendidikan-indonesia-2024

Lee, J., An, T., Chu, H. E., Hong, H. G., & Martin, S. N. (2023). Improving science conceptual understanding and attitudes in elementary science classes through the development and application of a rule-based AI chatbot. *Asia-Pacific Science Education*, *9*(2), 365-412. https://brill.com/view/journals/apse/9/2/article-p365_5.xml

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education*.Pearson.https://static.googleusercontent.com/media/edu.google.com/en//pdfs/Intelligence-Unleashed-Publication.pdf

Marek, M., Lizárraga-Dueñas, L., Woulfin, S., Wetzel, M. M., & Muñoz, E. (2025). A framework for curriculum literacy in initial teacher preparation: Policy, practices, and possibilities. *Journal of Teacher Education*, *76*(4), 337-350. https://doi.org/10.1177/00224871241263803

Morán-Mirabal, L. F., Alvarado-Uribe, J., Ceballos, H. G., Cebral-Loureda, M., Rincón-Flores, E. G., & Sánchez-Ante, G. (2023). *Using AI for educational research in multimodal learning analytics*. Chapman and Hall. https://doi.org/10.1201/b23345-11

Nisfiya, I., & Fauzi, I. (2026). Integrasi kecerdasan buatan dalam pendidikan abad ke-21: Analisis peluang dan implikasi nilai Islam. *Edukatif: Jurnal Ilmu Pendidikan*, *8*(1), 17–26. https://doi.org/10.31004/edukatif.v8i1.8688

Nurramadhani, A., Patras, Y. E., Ghani, R. A., Tatemoto, Y., Anggraeni, R. C., Sisworo, A. F., & Rahayu, C. W. (2025). Culturally responsive teaching: An approach to cultivate students' global diversity character. *Pedagogia: Jurnal Ilmiah Pendidikan*, *17*(1), 104-112. https://doi.org/10.55215/pedagogia.v17i1.50

OECD. (2023). *PISA 2022 results (Volume I and II) – Country notes: Indonesia*. https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/indonesia_c2e1ae0e-en.html

Purba, N., Pujiati, D., Sihombing, P. S. R., Simanjuntak, H., & Sijabat, D. (2025). The use of AI in elementary school learning: A systematic literature review. *Qalamuna: Jurnal Pendidikan, Sosial, dan Agama*, *17*(1), 83–98. https://doi.org/10.37680/qalamuna.v17i1.6761

Putri, A. Q., Albab, A. U., Linardho, B. F., & Yusuf, A. (2023). Implementasi teori belajar perspektif psikologi konstruktivisme pada jenjang pendidikan dasar. *Premiere: Journal of Islamic Elementary Education*, *5*(2), 15–27. https://doi.org/10.51675/jp.v15i2.530

Revenaya, M., Subali, B., & Ellianawati, E. (2025). Exploring the integration of artificial intelligence in primary education: A systematic literature review (2020–2024). *STEAM Journal for Elementary School Education*, *1*(02), 116–136. https://doi.org/10.26740/sjese.1.02.2025.4

Romdhon, J., Masrifah, M., Shiyama, N. M., & Suharyati, H. (2024). Applying constructivist learning theory to enhance student learning outcomes in elementary schools. *International Journal of Sustainable Development & Future Society*, *2*(2), 62–69. https://doi.org/10.62157/ijsdfs.v2i2.73

Safarina, W., & Sunardi, S. (2024). Pendidikan inklusif: Sistem dukungan pendidikan inklusif dan langkah-langkah implementasinya di sekolah dasar. *Jurnal Ilmiah Wahana Pendidikan*, *10*(17), 821–825. https://doi.org/10.5281/zenodo.13929180

Safitri, M., Zain, M. I., & Hakim, M. (2026). Enhancing science learning learning outcomes through animated video media: Evidence from Indonesian elementary education. *Journal of Innovation and Research in Primary Education*, *5*(1), 1905-1914. https://doi.org/10.56916/jirpe.v5i1.2874

Saputri, W. N., Fitriana, S. N., Halim, I. G., Shelly, S., Sunyono, S., & Siregar, R. A. (2025). Pengaruh model pembelajaran inovatif terhadap hasil belajar IPAS peserta didik sekolah dasar. *Didaktika Dwija Indria*, *13*(6), 1026–1030. https://doi.org/10.20961/ddi.v13i6.111289

Sari, P. D. P., Sedana, I. M., & Handayani, N. N. L. (2025). Pengaruh model pembelajaran problem based learning berpendekatan keterampilan proses sains terhadap motivasi dan hasil belajar IPA peserta didik kelas VI. *Jurnal Pendidikan dan Pembelajaran IPA Indonesia*, *15*(2), 136–147. https://doi.org/10.23887/jppii.v15i2.95786

Sari, S. M., & Akmaluddin. (2024). Pembelajaran IPA berbasis TPACK upaya peningkatan kualitas guru di SDN Kuta Rentang Aceh Besar. *Journal of International Multidisciplinary Research*, *2*(2), 169–174. https://doi.org/10.62504/bk5zw821

Sari, S. M., Syafii, M., & Akmaluddin, A. (2025). Culture fusion: Education habbits on society for inclusif students. *International Conference on Education, Science, Technology and Health (ICONESTH)*, 1180–1187. https://doi.org/10.46244/iconesth.vi.335

Sari, S. M., Syafii, M., Zahraini, Z. & Notha, M. (2026). Inklusif di kancah sorotan dunia pendidikan socienty 5.0. *Jurnal Kolaborasi Akademika*, *3*(1), 1–13. https://doi.org/10.64826/y14ajs60

Sejati, W. T., Rizki, R., Nirmalasari, I., Sundari, S., & Pratiwi, R. H. (2025). Peran AI dalam inovasi pembelajaran MIPA di sekolah: Peluang dan tantangan. *Jurnal Penelitian, Pendidikan, dan Pengajaran: JPPP*, *6*(3), 212–218. https://doi.org/10.30596/jppp.v6i3.28320

Selfia, S., Lagandesa, Y. R., Aqil, M., Zulnuraini, Z., Rahmawati, D., & Wilade, S. (2026). the effect of audio-visual media on learning outcomes in arts, culture, and crafts education: A quasi-experimental study in Indonesian elementary schools. *Journal of Innovation and Research in Primary Education*, *5*(1), 998-1008. https://doi.org/10.56916/jirpe.v5i1.2943

Siregar, T. E., Luali, N., Vinalistyosari, R. C., Hanurawan, F., & Anggraini, A. E. (2024). Implementation of Vygotsky's constructivism learning theory through project-based learning (PjBL) in elementary science education. *Al Qalam: Jurnal Ilmiah Keagamaan dan Kemasyarakatan*, *18*(4), 2586–2607. http://dx.doi.org/10.35931/aq.v18i4.3620

Subarjo, M. D. P., Suarni, N. K., & Margunayasa, I. G. (2023). Analisis penerapan pendekatan teori belajar konstruktivisme pada kemampuan berpikir kritis siswa sekolah dasar. *Ideguru: Jurnal Karya Ilmiah Guru*, *9*(1), 313–318. https://doi.org/10.51169/ideguru.v9i1.834

Sumarni, M. L., Jewarut, S., Silvester, S., Melati, F. V., & Kusnanto, K. (2024). Integrasi nilai budaya lokal pada pembelajaran di sekolah dasar. *Journal of Education Research*, *5*(3), 2993–2998. https://doi.org/10.37985/jer.v5i3.1330

Sureshkumar, T., Raj, D., Vijayalakshmi, R., Karthikeyan, J., Vasanthan, R., Solayev, O., & Yulduz, U. (2026). AI-driven assistive technologies for inclusive learning in special education environments. *International Journal of Special Education*, *41*(1s), 20-35. https://internationalsped.com/index.php/ijse/article/view/2483

Syukri, M., & Sulhiawati, E. (2026). A contextual approach in Islamic religious education learning. *Indonesian Journal of Education and Science*, *2*(1), 37-53. https://doi.org/10.67028/ijes.v2i1.164

Tawafak, R. M., Alfarsi, G., AlSideiri, A., Iqbal, S. M., & Mathew, R. (2024). Social computing interactions and fusion ai development for teaching and entertainment. In *2024 International Conference on Engineering and Emerging Technologies (ICEET)* , 1-6. https://doi.org/ 10.1109/ICEET65156.2024.10913646

Wahyuni, N. (2026). An inquiry-based learning approach in early childhood and primary education: Strengthening foundational concepts in mathematics and integrated sciences. *Radians Education Journal*, *1*(1), 10-18. https://ejournal.cakrapustakaeducation.com/index.php/REJ/article/view/18

Yang, Y., Chen, L., He, W., Sun, D., & Salas-Pilco, S. Z. (2025). Artificial intelligence for enhancing special education for K-12: A decade of trends, themes, and global insights (2013–2023). *International Journal of Artificial Intelligence in Education*, *35*(3), 1129–1177. https://doi.org/10.1007/s40593-024-00422-0

Yu, S., Jantharajit, N., & Srikhao, S. (2024). Collaborative inquiry-based instructional model to enhance mathematical analytical thinking and reasoning skills for fourth-grade students. *Asian Journal of Education and Training*, *10*(1), 10-17. https://eric.ed.gov/?id=EJ1424717