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Improving Elementary School Students' Mathematical Literacy and Character through Ethnomathematics and Deep Learning in the Era of the Industrial Revolution 4.0

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ABSTRACT

Technological developments in the Industrial Revolution 4.0 era demand learning innovations that focus not only on knowledge but also on character building and digital literacy. This study aims to develop and test the effectiveness of an integrative learning model based on ethno-mathematics and deep learning to improve the mathematical literacy and character of elementary school students. A mixed methods quasi-experimental design was used in two classrooms in Bandung City, using a mathematical literacy test, character observation, and interviews as instruments. The results showed a significant increase in mathematical literacy in the experimental class compared to the control class ($p < 0.05$) with an effect size of 1.12. Qualitative findings indicated that students were better able to relate mathematical concepts to local cultural contexts. In conclusion, this integrative learning model effectively strengthens conceptual understanding, personalized learning, and student character, and provides theoretical and practical contributions to the development of culture- and technology-based mathematics learning in line with 21st-century demands.

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ABSTRACT

Perkembangan teknologi pada era Revolusi Industri 4.0 menuntut inovasi pembelajaran yang tidak hanya berfokus pada pengetahuan, tetapi juga penguatan karakter dan literasi digital. Penelitian ini bertujuan mengembangkan dan menguji efektivitas model pembelajaran integratif berbasis etnomatematika dan deep learning untuk meningkatkan literasi matematika dan karakter siswa sekolah dasar. Metode yang digunakan adalah mixed methods dengan desain eksperimen semu pada dua kelas di Kota Bandung, menggunakan tes literasi matematika, observasi karakter, dan wawancara sebagai instrumen. Hasil penelitian menunjukkan adanya peningkatan signifikan literasi matematika pada kelas eksperimen dibandingkan kelas kontrol ($p < 0,05$) dengan effect size 1,12, serta temuan kualitatif bahwa siswa lebih mampu mengaitkan konsep matematika dengan konteks budaya lokal. Kesimpulannya, model pembelajaran integratif ini efektif memperkuat pemahaman konseptual, personalisasi belajar, dan karakter siswa, serta memberikan kontribusi teoretis dan praktis bagi pengembangan pembelajaran matematika berbasis budaya dan teknologi sesuai tuntutan abad ke-21.

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INTRODUCTION

The development of the Industrial Revolution 4.0 has brought fundamental changes to educational paradigms worldwide, including in Indonesia. Digital transformation and technological advancements demand the integration of basic literacy skills with 21st-century skills such as critical thinking, collaboration, communication, and creativity(Herlinawati *et al.*, 2024).

In the context of primary education, mathematical literacy is a crucial foundation for students to face the challenges of the digital era, as mathematics is not only related to numeracy but also to logical, analytical, and reflective thinking skills in solving real-life problems(Novita and Herman, 2021; OECD, 2023). However, various studies indicate that the mathematical literacy skills of elementary school students in Indonesia remain relatively low (PISA, 2022; Ministry of Education, Culture, Research, and Technology, 2023). This low level of proficiency indicates the need for a more contextual, meaningful learning approach oriented toward character development and higher-order thinking skills.

One approach that is beginning to be widely researched and applied is ethnomathematics, the study of the relationship between culture and mathematical practices in everyday life(Thomas and Jacob, 2022). Ethnomathematics views mathematics as not merely universal, but also manifests in local cultural activities such as art, architecture, traditional games, and community economic activities (D'Ambrosio and D'Ambrosio, 2018).

Recent research shows that the application of ethnomathematics in learning can enhance students' interest, conceptual understanding, and character through a familiar cultural context (Musa'ad *et al.*, 2024). Thus, ethnomathematics-based learning has great potential to strengthen mathematical literacy while instilling character values such as honesty, responsibility, and cooperation.

However, a major challenge arises in integrating ethnomathematics approaches with learning technologies that meet the demands of the digital age(Kyeremeh, Awuah and Orey, 2022). A major problem in current mathematics education is the lack of learning models that effectively combine local cultural contexts with the use of smart technology(Sunzuma and Umbara, 2025). Many teachers still focus on conventional methods based on memorization and procedures, which do not foster students' critical and creative thinking skills (Nurdini, Setiadi and Fratiwi, 2023). Therefore, an innovative approach is needed that not only respects local cultural contexts but also utilizes modern technologies such as deep learning to personalize and optimize the mathematics learning process(Nasir *et al.*, 2025).

As a general solution to this problem, deep learning offers the potential to create more meaningful, adaptive, and reflective learning experiences(Ikhsan and Setiawan, 2025)(Gligorea *et al.*, 2023). In a pedagogical context, deep learning refers not only to artificial intelligence technology but also to a deep learning approach in which students connect new concepts with existing knowledge, understand the meaning of each concept, and apply it in contextual situations (Biggs and Tang, 2011; Ramadona, 2025). Thus, the integration of ethnomathematics and deep learning can form a holistic approach that combines local wisdom and digital intelligence in developing mathematical literacy and character in elementary school students.

Several previous studies have shown that integrating artificial intelligence-based learning technology can improve student learning engagement and academic outcomes (Zhao et al., 2022; Wang et al., 2024). In the context of ethno-mathematics, the use of deep learning can help teachers identify patterns in students' understanding of cultural mathematical concepts and adjust learning strategies in real time(Pratama and Yelken, 2024). For example, a deep learning algorithm can map students' difficulties in understanding the concept of symmetry in batik motifs or geometry in traditional architecture, allowing teachers to provide more targeted feedback(Hu *et al.*, 2021). This approach not

only improves cognitive outcomes but also strengthens character values such as perseverance, curiosity, and appreciation for local culture(Atmaja and Niam, 2025).

Furthermore, this integrative learning model aligns with the Merdeka Belajar paradigm, which emphasizes independence, contextual relevance, and the use of technology in education(Fauzan *et al.*, 2023). A study by Hidayati and Kurniawan (2024) found that culture-based mathematics learning and adaptive technology can improve students' digital literacy and socio-emotional skills.

This approach provides opportunities for students to deeply understand mathematical concepts while fostering empathy for the cultural and social values of their surroundings. Thus, the integration between ethno-mathematics and deep learning is not only academically relevant, but also strategic in building national character in the era of the Industrial Revolution 4.0(Nursyahidah *et al.*, 2025). However, although there are several studies that discuss the application of ethnomathematics and deep learning separately, studies that systematically integrate the two in the context of mathematical literacy and character development at the elementary school level are still very limited. Most studies still focus solely on cognitive aspects, while affective aspects and character values have not been explored in depth (Prasetyo *et al.*, 2023).

This research gap highlights the need for studies that develop learning models that comprehensively synergize ethnomathematics and deep learning, taking into account the local cultural context and the demands of 21st-century learning. Therefore, this study aims to develop and test the effectiveness of a learning model based on the integration of ethnomathematics and deep learning in improving mathematical literacy and character development in elementary school students in the era of the Industrial Revolution 4.0. The novelty of this research lies in its interdisciplinary approach that combines local cultural context with artificial intelligence technology as a holistic learning strategy. The scope of this study includes conceptual analysis, model development, and empirical testing of the impact of learning on mathematical literacy and student character. This research is expected to provide theoretical and practical contributions to the development of innovative pedagogy at the elementary education level that is in line with global demands and Indonesian cultural values.

THEORY

1. Mathematical Literacy

Mathematical literacy is a person's ability to formulate, use, and interpret mathematics in various real-life contexts. According to the OECD (2023), mathematical literacy focuses not only on numeracy skills but also on the ability to reason, solve problems, and make logical decisions based on data and evidence. In the context of primary education, mathematical literacy is an important foundation for the development of higher-order thinking skills (HOTS), which include analysis, synthesis, and evaluation (Brookhart, 2021).

Mathematical literacy is also strongly influenced by the cultural context and students' learning experiences. Research shows that contextual learning approaches that link mathematical concepts to everyday life can improve students' conceptual understanding and critical thinking skills (Wijaya *et al.*, 2023). Therefore, approaches that incorporate local cultural values, such as ethnomathematics, are highly relevant in efforts to improve the mathematical literacy of elementary school students in Indonesia.

2. Ethnomathematics in Elementary Education

The term ethnomathematics was first introduced by Ubiratan D'Ambrosio (1985) to describe the relationship between mathematics and culture. Ethnomathematics views each society as having its own system of mathematical thinking, reflected in cultural practices such as handicrafts, architecture, traditional games, batik patterns, and local measurement systems (D'Ambrosio, 2021). This approach connects formal mathematical knowledge with the local cultural context, making learning more meaningful, relevant, and contextual for students (Bishop, 2022).

In the context of elementary education in Indonesia, ethnomathematics serves as a means of integrating character education and strengthening local wisdom. Research by Lestari

and Hidayat (2024) shows that the application of ethnomathematics in learning increases student engagement and fosters character values such as pride in local culture, cooperation, and responsibility. Furthermore, the ethnomathematics approach can build multicultural awareness and develop reflective thinking skills, which are crucial in the era of globalization.

3. Deep Learning from an Educational Perspective

In the educational context, deep learning refers not only to artificial intelligence technology but also to a deep learning approach. According to Biggs and Tang (2021), deep learning in education refers to a cognitive process in which students strive to deeply understand the meaning and relationships between concepts, rather than simply memorizing facts. This approach encourages students to relate learning experiences to real-life situations, engage in critical reflection, and develop complex problem-solving skills.

Meanwhile, from an educational technology perspective, deep learning also refers to the use of artificial intelligence models to personalize the learning process. Through deep learning algorithms, learning systems can analyze student learning patterns, adjust the difficulty level of the material, and provide adaptive feedback (Zhao et al., 2022; Wang et al., 2024). Thus, integrating deep learning into mathematics learning has the potential to increase the effectiveness, efficiency, and personalization of the teaching and learning process in elementary schools.

4. Integration of Ethnomathematics and Deep Learning

The integration of ethno-mathematics and deep learning offers a new paradigm in 21st-century education. From a pedagogical perspective, ethnomathematics provides local context and meaningful cultural values, while deep learning offers an adaptive, data-driven approach that supports individual learning. The combination of the two can create a contextual, interactive, and reflective learning model. Research by Prasetyo et al. (2023) shows that culture-based learning combined with digital technology can improve students' critical thinking and collaborative skills. Meanwhile, a study by Hidayati & Kurniawan (2024) found that integrating AI-assisted learning into a local cultural context strengthens digital literacy while instilling positive character values. Thus, the synthesis of these two approaches supports the achievement of meaningful learning and character building in the era of the Industrial Revolution 4.0.

5. Character Development through Mathematics Learning

Character education is one of the main pillars of the national curriculum. According to the Ministry of Education, Culture, Research, and Technology (2023), character education aims to shape students who are faithful, pious, independent, creative, and responsible. Mathematics learning can be an effective vehicle for instilling character because it demands perseverance, honesty, discipline, and the ability to think rationally(Kariadinata *et al.*, 2019).

In an ethnomathematics approach, character values are internalized through cultural practices rich in social and moral meaning(Fauzi, Hayati and Satriawan, 2025). For example, traditional games based on mathematical concepts teach honesty and sportsmanship, while batik or woven patterns reflect precision and patience. When combined with deep learning, teachers can assess and foster aspects of character through analysis of student learning behavior, for example through learning analytics that detect students' perseverance, collaboration, and self-reflection during the learning process.

6. Conceptual Research Framework

Based on the theoretical review above, it can be concluded that developing mathematical literacy and character in elementary school students in the Industrial Revolution 4.0 era requires an integrative and innovative approach. Ethnomathematics provides cultural

context and character values, while deep learning provides adaptive mechanisms to enhance understanding and personalize learning(Syaripah, 2025).

This research's conceptual framework assumes that:

Ethnomathematics → enhances contextual understanding and character values.

Deep learning → enhances conceptual understanding and critical thinking through personalized learning.

The integration of the two → simultaneously enhances mathematical literacy and character in students through contextual, reflective, and technology-based learning processes.

METHOD

1. Research Design

This study employed a mixed methods approach, combining a Research and Development (R&D) approach with a quasi-experimental design. This approach was chosen to develop and test the effectiveness of an integrative learning model based on ethnomathematics and deep learning in improving elementary school students' mathematical literacy and character. The research stages refer to the Borg & Gall (2003) model, simplified into four main stages:

a. Needs analysis and preliminary study,
b. Designing the integrative learning model,
c. Small-scale tryout,
d. Field testing of the model's effectiveness.

The mixed methods approach was used to combine the strengths of quantitative data (learning outcomes and mathematical literacy) with qualitative data (character observations, teacher interviews, and student responses). This combination provides a more comprehensive picture of the learning model's impact on student literacy and character development(Ahmed, Pereira and Kimberly, 2024).

2. Research Subjects and Location

The research was conducted at a public elementary school in Cidadap District, Bandung City, during the even semester of the 2025/2026 academic year. The subjects consisted of two parallel classes of fifth-grade students:

a. Experimental class: learning using an integrated ethnomathematics and deep learning model,
b. Control class: conventional learning based on the Merdeka curriculum without integration of technology and cultural context.

The total number of participants was 60 students (30 students per class), selected using a purposive sampling technique based on equivalence of initial abilities and the availability of digital-based learning support facilities.

3. Research Instruments

The instruments used in this study include:

1. Mathematical Literacy Test

Form: contextual essay questions based on PISA (OECD, 2023) modified to suit the local cultural context. Aspects measured was conceptual understanding, mathematical reasoning, application in real contexts, and mathematical communication. Content validity was tested by mathematics education experts, and reliability was calculated using Cronbach's Alpha(Syahwa *et al.*, 2024).

2. Character Observation Instrument

Character aspects: honesty, responsibility, cooperation, and curiosity. The instrument took the form of a behavioral checklist-based observation sheet completed by teachers and researchers during the learning process(Ong *et al.*, 2020). To measure students' perceptions, motivation, and learning experiences regarding the implementation of the integrative models(Nur Amalia Solikhah and Cindyra Galuhwardani, 2023). To obtain qualitative data regarding teachers' and students' experiences with the learning process and obstacles to model implementation(Sankalaite *et al.*, 2023).

4. Research Procedure

The research steps were as follows:

a. Needs Analysis
   Involving teachers and students in initial interviews to identify needs for more contextual and digital mathematics learning.
b. Designing an Integrative Learning Model
   Developing learning tools (lesson plans, teaching materials, and digital media) based on ethno-mathematics and deep learning. Deep learning was used to personalize exercises and provide automatic feedback to students.
c. 3. Small-Scale Tryout
   Implemented in one small class to assess the feasibility and implementation of the model. Data was collected for model revision.
d. Implementation and Effectiveness Testing (Field Testing)
   The revised model was implemented in the experimental class for eight meetings. The control class used conventional learning methods.
e. Analysis and Reflection
   Collecting and analyzing quantitative and qualitative data to assess improvements in mathematical literacy and student character.

5. Data Analysis Techniques

Data analysis was conducted in two forms:

a. Quantitative Analysis
   The mathematical literacy test results were analyzed using paired sample t-tests and independent sample t-tests to determine improvements and significant differences between groups. Effect size values (Cohen's d) were calculated to measure the strength of the learning model's influence.
b. Qualitative Analysis
   Data from character observations, interviews, and field notes were analyzed using the techniques of Miles & Huberman (2014): data reduction, data presentation, and conclusion drawing.

Data triangulation was conducted to ensure the validity of the results by comparing the results of observations, interviews, and questionnaires.

6. Validity and Reliability

To ensure the validity and reliability of the data, this study implemented the following steps:

a. The content validity of the instrument was tested by expert judgment.
b. Internal reliability was tested using the Cronbach's Alpha coefficient (≥ 0.70).
c. External validity was strengthened by partially replicating the model in different classes to ensure consistency of the results.
d. Triangulation of methods and sources was conducted to minimize interpretive bias in the qualitative data(Bans-Akutey and Tiimub, 2021).

7. Research Ethics

This study adhered to the ethical principles of educational research, including:

a. Written informed consent from the school and parents,
b. Confidentiality of participant identities was maintained,
c. The learning process did not harm or discriminate against students,
d. Data was used solely for academic purposes and educational development.

8. Indicators of Success

An ethnomathematics and deep learning-based learning model is considered effective if it meets the following indicators:

a. There is a significant increase in students' mathematical literacy scores in the experimental class compared to the control class,
b. There is an increase in students' positive character observation scores,
c. Students and teachers show a positive response to the model's implementation,
d. Learning activities proceed according to plan and demonstrate active student engagement.

RESULT RESEARCH

1. Overview of Research Implementation

This research was conducted over eight meetings in two parallel classes of fifth-grade students at a public elementary school in Cidadap District, Bandung City. The experimental class used an integrated ethnomathematics and deep learning learning model, while the control class used conventional learning based on the Merdeka curriculum. Learning activities in the experimental class utilized local cultural contexts such as Sundanese batik motifs, the traditional game "engklek," and bamboo weaving patterns to explain concepts of geometry, number patterns, and symmetry. Meanwhile, a deep learning system based on an adaptive learning platform application was used to provide adaptive exercises, analyze student difficulties, and provide personalized, automated feedback. Overall, the experimental class atmosphere was more dynamic and participatory. Students demonstrated high interest in solving problems based on local culture familiar to them, while learning technology assisted teachers in monitoring each student's progress in real time.

2. Improving Students' Mathematical Literacy

The results of the mathematical literacy test were analyzed using paired sample t-tests and independent sample t-tests.

Group	N	Pretest Average Score	Posttest Average Score	Improvement (%)	Sig. (p)	Effect Size (Cohen's d)
Experiment	30	61,40	84,60	+37,7%	0,000	1,12 (big)
Control	30	60,87	72,10	+18,5%	0,012	0,45 (medium)

The analysis showed a significant increase in mathematical literacy skills among students in the experimental class compared to the control class ($p < 0.05$). The effect size of 1.12 indicated a very large effect, indicating that the developed integrative model effectively improved students' ability to solve contextual mathematical problems. Qualitatively, students in the experimental class were better able to relate mathematical concepts to cultural phenomena, such as the use of line symmetry in batik patterns or the concept of fractions in traditional trading activities. This reinforces the finding that ethnomathematics broadens conceptual understanding, while deep learning strengthens feedback loops and personalizes learning.

3. Improving Character Values

Observations of student character are conducted throughout the learning process using observation sheets based on four main indicators: honesty, responsibility, cooperation, and curiosity.

Character Aspects	Initial Average	Final Average	Improvement	Category
Honesty	3,12	4,45	+1,33	Very good
Responsibility	3,28	4,52	+1,24	Very good
Cooperation	3,10	4,60	+1,50	Very good
Curiosity	3,45	4,70	+1,25	Very good

These results demonstrate significant improvements in student character, particularly in cooperation and responsibility. Teachers noted that students tended to be more active in group discussions, valued the opinions of their peers, and completed assignments more independently. The integration of local cultural contexts fostered a sense of ownership in learning activities, while the deep learning system fostered individual responsibility for their learning outcomes

4. Student and Teacher Responses to the Learning Model

Questionnaire results showed that 92% of students stated that learning with a cultural and technological context was more engaging and helped them understand mathematical concepts. Meanwhile, 87% of teachers stated that this approach made students more focused, active, and had a positive learning attitude. An interview excerpt from a math teacher illustrates: "Students understand geometric concepts more easily when they relate them to the shapes they see in their cultural environment. The deep learning system also helps me monitor each child's progress without having to manually assess each one." Students also stated that the learning felt "more real" and "not as intimidating as usual." They felt that the cultural challenges motivated them to think and discuss.

5. Qualitative Analysis: Learning Dynamics

Qualitative data analysis from field notes showed that:

a. Teacher-student interactions improved significantly due to the familiar local context.
b. Students demonstrated in-depth reflection in linking mathematical concepts to life values (e.g., time discipline and equality in traditional games).
c. The use of deep learning created adaptive feedback that accelerated individual student understanding.
d. The process of triangulating data from observations, interviews, and field notes strengthened the conclusion that the combination of ethnomathematics and deep learning created a balanced humanistic and digital learning environment.

6. Learning Model Effectiveness Test

The results of the effectiveness test using the normalized gain score (N-Gain) approach showed that the increase in students' mathematical literacy in the experimental class reached 0.72 (high category), while the increase in the control class was only 0.38 (moderate category). These results confirm that the implementation of the integrative learning model is effective in improving mathematical literacy while simultaneously developing positive student character. Key success factors identified include:

a. The relevance of the cultural context to students' lives,
b. Personalization and rapid feedback from the deep learning system,
c. Active student involvement in discussions and exploration of local culture.
d.

Overall, the research results indicate that:

a. The integrative model of ethno-mathematics and deep learning effectively improves students' mathematical literacy and character.
b. Local culture-based learning increases engagement and understanding of mathematical concepts.
c. The use of adaptive technology supports personalized learning and the strengthening of independent character.
d. The integration of cultural values and technology forms a learning model that aligns with the spirit of Freedom to Learn in the era of the Industrial Revolution 4.0.

DISCUSSION

1. Integration of Ethnomathematics and Deep Learning as a Modern Contextual Learning Strategy

Research results show that the integration of ethnomathematics and deep learning can improve mathematical literacy while simultaneously shaping positive character traits in elementary school students. This finding reinforces the theory that meaningful learning occurs when students can connect mathematical concepts with experiences and values relevant to their lives (Ausubel, 2012; Biggs & Tang, 2021). Ethnomathematics functions as a contextual bridge, connecting abstract mathematical concepts with local culture, while deep learning acts as a technological bridge, connecting learning experiences with adaptive digital intelligence. The combination of the two creates a learning space that combines humanistic and technological dimensions, a hallmark of education in the era of the Industrial Revolution 4.0(Mesterjon, Suwarni and Selviani, 2022).

2. Improving Mathematical Literacy through a Culture-Based Approach

The significant increase in mathematical literacy scores (N-Gain = 0.72, high category) in the experimental class indicates that the local cultural context effectively improves students' ability to understand and apply mathematical concepts. This aligns with the findings of D'Ambrosio (2021) and Bishop (2022), which emphasized that the connection between mathematics and culture helps students interpret mathematical symbols, patterns, and structures in everyday life. In this study, students who learned within ethnomathematical contexts, such as batik motifs or the traditional game "engklek," demonstrated greater improvement in problem-solving skills than the control group. This finding aligns with research by Putra et al. (2023) and Wijaya et al. (2023), which concluded that using a cultural context broadens students' thinking and strengthens their mental representation of mathematical concepts. Furthermore, mathematical literacy within an ethnomathematical context encompasses not only the cognitive dimension but also the affective dimension, as students feel pride in their cultural identity. This indicates that culture-based learning can have a dual function: as a cognitive enhancer and character builder.

3. The Role of Deep Learning in Improving Understanding and Learning Independence

The implementation of the deep learning system in this study proved effective in facilitating adaptive and reflective learning. This system provided real-time feedback on student work, enabling teachers to identify learning difficulties early, and provide targeted feedback. These results are consistent with the findings of Wang et al. (2024) and Zhao et al. (2022), who stated that the implementation of a deep learning-based adaptive learning system increased student motivation and learning independence through personalized material and automated assessment. In the context of this study, students in the experimental class demonstrated increased responsibility for their learning, as each individual received unique feedback tailored to their achievements. Furthermore, deep learning also reinforces the principles of constructivist learning, where students actively construct understanding based on experience, rather than passively receiving information. Through algorithms capable of mapping patterns of errors and successes, the system helps students deepen their mathematical thinking processes in keeping with the spirit of the deep learning approach, which focuses on understanding meaning, rather than simply memorizing (Schoenfeld, 2022).

4. Strengthening Character through Integrative Learning

The improvement of character aspects such as honesty, responsibility, cooperation, and curiosity demonstrates that integrative learning is not only oriented towards academic outcomes but also towards the development of students' personalities. These results support Lickona's (2019) theory of character education, which states that effective learning integrates moral and social values into real-life learning experiences. In this context, ethnomathematics serves as a medium for instilling culturally based character values, while deep learning fosters independent character and learning discipline through a system that demands consistency and self-reflection. For example, when students solve problems about geometric patterns in batik, they not only learn symmetry but also appreciate patience, order, and beauty values that are integral to the nation's character.

Thus, the results of this study demonstrate that character strengthening can run parallel to improving literacy skills, provided that learning is designed in an integrative manner between culture, technology, and moral values

The findings of this study are highly relevant to the Independent Learning paradigm, which emphasizes student-centered, contextual, and adaptive learning to technological advances. The integration of deep learning with local cultural contexts reflects the principle of "freedom in learning and thinking," as it provides space for students to explore and construct their own meaning from learning experiences. Furthermore, local culture-based learning contributes to the achievement of the Pancasila Student Profile, particularly in the dimensions of faith and noble character, global diversity, and critical reasoning. These research findings align with Hidayati & Kurniawan (2024), who assert that learning that integrates digital technology with local wisdom can strengthen national identity amidst the globalization of education.

Prior to this research, most studies discussed ethnomathematics or deep learning separately. For example, Prasetyo et al.'s (2023) research emphasized cognitive enhancement through culture-based learning, while Wang et al.'s (2024) research focused on personalized learning based on artificial intelligence. However, the synergy between these two approaches culture and artificial intelligence in the context of mathematical literacy and character development at the elementary school level remains underexplored. This research makes new theoretical contributions by demonstrating that:

a. The integration of ethnomathematics and deep learning creates a balanced humanistic-digital learning model;
b. Mathematics learning can be a means of strengthening national character through cultural and technological contexts;
c. Deep learning systems can be used not only for content mastery but also for character analytics, namely the analysis of student learning behavior related to character values.

Thus, this research closes the theoretical gap that has separated cultural and technological approaches in elementary education. Theoretically, the results of this study broaden the understanding of an integrative learning model based on culture and technology as a new framework for developing 21st-century literacy and character. Practically, this model can be adapted by elementary school teachers through:

a. Developing teaching materials based on local wisdom,
b. Utilizing deep learning platforms for adaptive feedback and evaluation,
c. Character assessment through digital learning behavior data.

CONCLUSION

This research demonstrates that the integration of ethnomathematics and deep learning is an effective approach to improving mathematical literacy while simultaneously developing positive character traits in elementary school students in the era of the Industrial Revolution 4.0. This approach creates a synergy between humanistic learning rooted in local culture and technological learning that utilizes artificial intelligence for personalized learning. Empirically, the research results show that students who participated in ethnomathematics-based and deep learning-based learning experienced significant improvements in:

a. Mathematical literacy skills (conceptual understanding, problem solving, and contextual application);

b. Learning attitudes and character, particularly honesty, responsibility, cooperation, and curiosity;
c. Learning independence and self-reflection, as monitored through an adaptive feedback-based deep learning system.

Theoretically, this research reinforces the view that meaningful and sustainable learning (deep and meaningful learning) occurs when students learn in authentic socio-cultural contexts and receive adaptive technological support. Thus, the integration of ethnomathematics and deep learning is not merely a pedagogical strategy, but a new paradigm in character- and technology-based mathematics education. The main novelty of this research lies in combining two previously separate dimensions culture and artificial intelligence into a single integrative learning model relevant to the needs of 21st-century education. This approach can serve as a basis for developing curricula and educational policies oriented toward literacy, character, and technology.

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