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An artificial intelligence-assisted adaptive gamification model integrating Ngada culture for physics learning

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Abstract

Physics learning often remains abstract and insufficiently connected to students' cultural backgrounds, limiting both conceptual understanding and learning motivation. This study aimed to develop and evaluate an artificial intelligence-assisted adaptive gamification model integrating Ngada local culture to create a more meaningful, personalized, and culturally responsive physics learning environment. The study employed a Design-Based Research (DBR) approach integrated with the ADDIE framework. The model was developed, validated, and implemented with 150 senior high school students and 20 physics teachers from nine schools in Ngada Regency, Indonesia. Data were collected through expert validation sheets, practicality questionnaires, learning motivation questionnaires based on the ARCS framework, classroom observations, and pretest-posttest assessments of conceptual understanding. The findings demonstrated that the developed model achieved high content validity (S-CVI/Ave > 0.88) and high practicality according to teachers (83.3%) and students (84.8%). Students in the experimental group showed substantially greater improvement in conceptual understanding (N-gain = 0.71) than those in the control group (N-gain = 0.18). Learning motivation also improved across all ARCS dimensions, particularly in relevance, attention, and satisfaction. These findings indicate that integrating AI-assisted adaptive learning, gamification, and culturally contextualized content can enhance students' engagement, motivation, and conceptual understanding in physics. The proposed model offers a practical framework for designing technology-enhanced, culturally responsive science learning that may be adapted to similar educational contexts.

Keywords: Adaptive gamification, Adaptive learning, Artificial intelligence, Culturally responsive learning, Indigenous knowledge, Local culture, Ngada culture, Physics learning.

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Contents

Contribution of this paper to the literature

This study contributes to the literature by developing an Artificial Intelligence-assisted adaptive gamification model integrating Ngada local culture in physics learning. The study provides empirical evidence that combining adaptive learning, gamification, and culturally responsive pedagogy can enhance students' motivation and conceptual understanding.

1. Introduction

Physics education plays an important role in preparing students to face the challenges of the 21st century, especially by developing critical thinking, problem-solving, quantitative reasoning, and conceptual understanding of scientific phenomena (Brahmia et al., 2021; Hofstein & Lunetta, 2004; Körhasan & Kaltakci-Gurel, 2019). In addition, learning physics helps students build analytical and computational skills increasingly needed for the development of modern science and technology (Weller, Bott, Caballero, & Irving, 2022). Despite these facts, physics has been viewed as a difficult, abstract, and less relevant subject to students' daily lives (Robertson, Goodhew, Bauman, Hansen, & Alesandrini, 2023; Wangchuk, Wangdi, Tshomo, & Zangmo, 2023). The lack of a contextual or interactive learning experience, along with a lack of learning resources and cultural diversity, is a common occurrence in classrooms where this condition is prevalent (Wahyudi, Zuhdi, Makhrus, & Busyairi, 2022). Technology and making connections between students' social and cultural experiences are two key components of an effective physics education.

According to Hastuti, Setianingsih, and Anjarsari (2020); Kua et al. (2024); and Saiful, Ilyas, and Hamdi (2023), students in Indonesia face even greater difficulties due to unequal access to learning resources and the lack of innovative learning models that relate scientific concepts to their sociocultural contexts. The first study in Ngada Regency found that many pupils have trouble grasping physics ideas and do not want to study them. A lack of adaptable, contextually relevant learning models that promote active student participation and better knowledge of topics is also contributing to this problem, along with insufficient learning facilities.

There is an excellent opportunity to address these issues through the development of educational technology. According to Al-Kamzari and Alias (2024), Rutten, van Joolingen, and van der Veen (2012), and Zacharia and Olympiou (2011), students' conceptual understanding and engagement in physics education can be enhanced through the use of technology-based learning environments, virtual labs, and simulations. Using a combination of online resources and hands-on lab time to teach physics had comparable results (Mihret, Alemu, & Assefa, 2022). In addition, research has shown that incorporating gamification elements into the learning process can increase students' motivation, engagement, and persistence (Giráldez, Sanmiguel-Rodríguez, Álvarez, & Navarro-Patón, 2022; Lampropoulos & Sidiropoulos, 2024; Sailer & Homner, 2020). Chen, Chen, and Lin (2020); Katona and Gyonyoru (2025); and Sayed et al. (2023) have asserted that AI-driven adaptive learning systems may tailor education by altering course material, delivering feedback, and adjusting learning paths to align with individual students' abilities and needs. Adaptive traits are a significant factor in physics education, as they are influenced by individual differences in intelligence, learning style, and starting point. However, the majority of technology-based approaches continue to operate within a culturally neutral framework when developing engaging learning experiences (Nair & Sawtelle, 2019).

The integration of local cultures into science education is becoming a more pressing issue to establish learning that is contextual, relevant, and inclusive of students' lives. According to the findings of several studies (Lestari, Paidi, & Suyanto, 2024; Misbah et al., 2024; Warsono et al., 2020), culturally relevant learning has the potential to improve students' ability to comprehend ideas, strengthen their sense of identity, and increase their level of participation in the learning process. According to Lidi, Ningsih, and Dhiki (2020), the Ngada culture in Indonesia offers a wide range of local potentials that may be used to contextually describe physical ideas. These local potentials include traditional dwellings, traditional crafts, traditional music, and community cultural rituals. Despite this, there is still a lack of integration between technology-based adaptive learning techniques and local culture in the field of science education.

Gamification, adaptive learning powered by artificial intelligence, and cultural integration in education have all been the subject of substantial research, but each has largely been examined in isolation. The focus of gamification is on getting students involved and excited about learning, whereas the hallmarks of AI-powered adaptive learning are customization and dynamic feedback. Learning that is relevant to the context and has meaning is at the heart of cultural integration (Gligorea et al., 2023; Kalogiannakis, Papadakis, & Zourmpakis, 2021; Misbah et al., 2024). However, there are still gaps in physics education-specific learning models that integrate all three of these aspects. Therefore, this study aims to bridge this gap by developing an Artificial Intelligence-assisted adaptive gamification model that integrates Ngada local culture into physics learning.

Accordingly, this study seeks to evaluate the validity, practicality, and effectiveness of the proposed model in enhancing students' motivation and conceptual understanding in physics learning. Specifically, this research aims to: (1) develop an artificial intelligence-assisted adaptive gamification model compatible with local culture; (2) evaluate the validity and practicality of the developed model; and (3) analyze its effectiveness in improving student motivation and learning outcomes.

2. Literature Review

2.1. Gamification in Physics Learning

Gamification, adaptive learning powered by artificial intelligence, and cultural integration in education have all been the subject of substantial research, but each has largely been examined in isolation. The focus of gamification is on getting students involved and excited about learning, whereas the characteristics of AI-powered adaptive learning are customization and dynamic feedback. Learning that is relevant to the context and has meaning is at the heart of cultural integration (Gligorea et al., 2023; Kalogiannakis et al., 2021; Misbah et al., 2024). However, there are still gaps in physics education-specific learning models that integrate all three of these aspects. In a structured learning environment, Buenadicha-Mateos, Sánchez-Hernández, González-López, and Tato-Jiménez (2025) and Kalogiannakis et al. (2021) have discovered that gamification can improve student engagement and conceptual understanding of scientific concepts. Students are more invested and make greater effort when solving scientific problems through interactive challenges and receive practical feedback.

However, many gamification-based learning models still emphasize motivational aspects and often provide the same learning experience to all students without considering individual learning needs and sociocultural backgrounds. In physics learning, because students have different levels of conceptual understanding and learning characteristics, the lack of adaptive support and contextual relevance might limit the effectiveness of a harmonized learning environment. Therefore, to provide a more meaningful and personalized physics learning experience, a combination of adaptive learning and culturally contextualized content is needed.

2.2. Artificial Intelligence-Based Adaptive Learning

Chen et al. (2020) and Sayed et al. (2023) show that artificial intelligence is increasingly used to support personalized learning. Since students have different backgrounds, understanding, and problem-solving skills when learning abstract science concepts, adaptive learning systems are especially important in physics education. Previous studies suggest that AI-powered adaptive learning can improve how well students learn, their engagement, and their understanding of concepts. Gligorea et al. (2023) and Katona and Gyonyoru (2025) note that tailored feedback and adaptive support help achieve these results. This approach lets students learn at their own pace and gives them step-by-step guidance to help with difficult topics.

Despite having many advantages, most AI-based adaptive learning systems are still developed within a technology-oriented framework and pay less attention to sociocultural relevance and contextual learning experiences (Nair & Sawtelle, 2019). In physics education, the lack of contextual and culturally meaningful learning experiences can reduce students' perception of the relevance of scientific concepts. Therefore, integrating adaptive learning systems with culturally contextualized learning approaches has the potential to create a more meaningful, inclusive, and engaging physics learning environment.

2.3. Integration of Local Cultures in Science Learning

The relevance and significance of scientific education can be enhanced by incorporating local cultural knowledge. According to Lestari et al. (2024), Misbah et al. (2024), and Warsono et al. (2020), students' comprehension and involvement in science classes are enhanced through culturally responsive teaching practices. In physics education, the local cultural context can be a genuine learning resource for explaining abstract scientific concepts through real phenomena close to students' lives. Local culture in Ngada, Indonesia, can be used as various contextual examples to explain the concepts of motion, vibration, sound waves, force, and energy transformation, such as traditional houses (*Sa'o*), traditional games (*Wela Maka*), weaving, traditional musical instruments (*Laba Go* and *Foi Doa*), and local technology (Lidi et al., 2020). By using familiar cultural phenomena, students can see physics as something more relevant and meaningful, rather than just a set of formulas distant from everyday life.

However, the integration of local culture in science learning is still often limited and has not been widely combined with an adaptive digital learning environment. Most culturally contextual learning approaches still rely on conventional methods without integrating adaptive learning mechanisms or blended learning experiences. Therefore, there is still a need for learning models that integrate cultural contextualization with AI-assisted adaptive learning and gamification to support a more engaging and meaningful physics learning experience.

3. Research Method

3.1. Research Design

This study used a mixed-method approach with a quasi-experimental design using a nonequivalent control-group pretest–posttest design to test the effectiveness of an AI-assisted adaptive gamification model that integrated the local culture of Ngada in physics learning. The experimental group learned using the developed model, while the control group learned using conventional approaches commonly applied in schools.

To support the process of developing and refining the learning model, this study also adopted a Design-Based Research (DBR) approach combined with the ADDIE framework. The DBR approach allowed the design, implementation, evaluation, and revision processes to be carried out iteratively in a real educational context. This design-based development approach has also been effectively applied in physics learning that integrates technology and the development of high-level thinking skills (Fayanto, Degeng, Patmanthara, & Ulfa, 2024). Meanwhile, the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) framework was used to guide the process of developing learning models and learning tools systematically. The main focus of this study was to evaluate the effectiveness, practicality, and implementation of the model developed through classroom learning interventions, as well as to conduct statistical analyses of students' conceptual understanding and motivation.

3.2. Participants and Sampling Techniques

The participants in this study consisted of 150 high school students and 20 physics teachers from nine secondary schools in Ngada Regency, East Nusa Tenggara, Indonesia, namely SMA Negeri 1 Bajawa, SMA Negeri 2 Bajawa, SMAK Regina Pacis Bajawa, SMA Negeri 1 Golewa Barat, SMA Citra Bakti, SMA Seminari St. Yohanes Berkhmans, SMAK Thomas Aquino, SMA Negeri 2 Jerebuu, and SMA Negeri 1 Golewa. Participant selection was conducted using purposive sampling based on criteria relevant to the research objectives (Creswell, 2014; Etikan, Musa, & Alkassim, 2016). The criteria for selecting students included: (1) actively participating in physics learning, (2) having basic skills in the use of digital learning tools, and (3) being willing to participate in all stages of the study. The criteria for selecting teachers included: (1) actively teaching physics, (2) having at least two years of teaching experience, and (3) willingness to implement the developed learning model.

The research was conducted in two stages. The preliminary trial involved 25 students and 5 teachers from three secondary schools, while the full-scale implementation involved the remaining 125 students and 15 teachers from six secondary schools. Thus, a total of 150 students and 20 physics teachers participated in the study. During the full-scale implementation, three schools were assigned to the experimental group and three schools to the control group. The experimental group consisted of 75 students who learned using an artificial intelligence-assisted adaptive gamification model integrated with Ngada local culture, whereas the control group consisted of 75 students who received conventional physics instruction. Ethical considerations were maintained throughout the study. Participation was voluntary, informed consent was obtained from all participants, and all research data were kept confidential in accordance with institutional research ethics guidelines.

Table 1. Participant Demographics.

Participant Type	Preliminary Trial	Full-Scale Implementation	Total
Students	25	125	150
Teachers	5	15	20

Table 1 presents the distribution of participants across the preliminary trial and full-scale implementation stages. Most participants were involved in the implementation phase, providing sufficient data to evaluate the validity, practicality, and effectiveness of the developed model.

3.3. Research Procedure

The research procedure followed the ADDIE framework with five stages, namely *Analyze*, *Design*, *Develop*, *Implement*, and *Evaluate*. In the *Analyze* stage, interviews, questionnaires, and classroom observations were conducted to identify students' learning difficulties, learning challenges, and contextual needs in physics learning. In the *Design* stage, the structure of the AI-assisted adaptive gamification model was designed by integrating gamification elements, adaptive learning mechanisms, and the Ngada cultural context into physics learning materials. The *Develop* stage included the development of application prototypes, integration of multimedia content, and the preparation of learning evaluation instruments and tools.

The *Implement* phase was carried out for four weeks, consisting of six learning sessions, with each session lasting about 90 minutes. At this stage, the experimental group studied physics using an AI-assisted adaptive gamification model that contained adaptive feedback, personalized learning paths, interactive challenges, points, levels, and physics problems contextualized with the local culture of Ngada. The AI-assisted system dynamically adjusted the difficulty level of questions and feedback based on student performance and learning progress. The integration of local culture was carried out through the use of traditional tools, weaving practices, local technology, and activities of the Ngada people to explain abstract physics concepts in a more meaningful and contextual way. Meanwhile, the control group received conventional teacher-centred learning using printed teaching materials and routine classroom discussions without the support of adaptive technology or gamification features. The *Evaluate* stage was carried out by analyzing the validity, practicality, and effectiveness of the developed model through statistical analysis and participant responses, followed by a revision of the model based on the results of implementation.

3.4. Data Collection Instruments and Techniques

This study used several instruments to collect data, namely expert validation sheets, practicality questionnaires, concept comprehension tests, learning motivation questionnaires, and observation sheets. Expert validation sheets were used to evaluate the content quality, media aspects, and learning design of the developed model. The instrument used a five-point Likert scale ranging from 1 (very poor) to 5 (very good) and was assessed by nine experts: three material experts, three media experts, and three learning design experts. Content validity was analyzed using the Content Validity Index (CVI), including the Item-Level CVI (I-CVI) and the Scale-Level CVI (S-CVI/AVE). Items with an I-CVI value below 0.78 were revised based on expert recommendations.

A practicality questionnaire was given to teachers and students after implementation to evaluate the ease of use, clarity, engagement, navigation, and cultural relevance of the developed model. The reliability of the questionnaire was analysed using Cronbach's alpha coefficient, with a result of $\alpha = 0.87$, which indicated good internal consistency. Students' concept understanding was measured using pretest and posttest instruments that were compiled based on curriculum indicators and learning objectives. The instrument went through an expert validation process and trials to ensure its validity and reliability.

Student learning motivation was measured using a questionnaire adapted from the ARCS motivation model developed by Keller (1987), including the dimensions of Attention, Relevance, Confidence, and Satisfaction. In addition, a new dimension was added, namely Learning Support, to measure students' perceptions of adaptive feedback and personalized learning support in an AI-assisted learning environment. Observation sheets were used to document classroom interactions, student participation, learning engagement, and implementation processes during the intervention. Table 2 presents the ARCS-based student learning motivation indicators used to assess students' learning motivation in this study.

Table 2. ARCS-Based Student Learning Motivation Indicators.

Construct (ARCS)	Indicator	Item Number
Attention	Early attention; Ongoing curiosity	1–2
Relevance	Conformity to the personal context; Contribution of Cultural Elements	3–4
Confidence	Confidence in learning tasks; Difficulty Compatibility	5–6
Satisfaction	Satisfaction after completing tasks; Desire to use the app again	7–8
Learning Support*	Feedback effectiveness; Fun learning experience	9–10

***Note:** Learning Support is an additional construct introduced in this study to describe the role of adaptive feedback in an AI-assisted learning environment.

Data collection was carried out before, during, and after the intervention process. The pretest and initial motivation questionnaire were given before implementation, while the posttest, practicality questionnaire, and final motivation questionnaire were given after the intervention was completed. Class observations were carried out during the implementation process to support the interpretation of quantitative data.

3.5. Data Analysis Techniques

The independent variable in this study was an AI-assisted adaptive gamification model that integrated the Ngada local culture, while the dependent variables included learning outcomes and student learning motivation. The data obtained were analyzed using descriptive and inferential statistical techniques with IBM SPSS Statistics version 30. Descriptive statistics, such as grade point average, percentages, and standard deviation, were used to describe expert validation results, practicality, learning outcomes, and student motivation scores. Before inferential analysis was performed, prerequisite tests were conducted to ensure that the data met the parametric test assumptions. The normality test was performed using the Kolmogorov-Smirnov test, while the homogeneity of variance was analyzed using the Levene test.

To test the difference between pretest and posttest scores, a paired-samples t-test was used in both the experimental and control groups. The significance level was set at $p < 0.05$. In addition, N-gain analysis was used to assess the magnitude of improvement in student learning outcomes and motivation following the intervention. N-gain values are categorized into low, medium, and high based on Hake (1998) criteria. Qualitative observation data were analyzed using thematic analysis following (Braun & Clarke, 2006) procedures. Observation records were coded, categorized, and interpreted to identify recurring themes related to student participation, engagement, learning interactions, and the implementation of the developed model. The qualitative findings were then used to support the interpretation of quantitative results.

4. Results

This section presents research results on the content validity, practicality, and effectiveness of an AI-assisted adaptive gamification model that integrates Ngada's local cultural context into physics learning.

4.1. Validity of the Developed Application Content

The content validation process was conducted to evaluate the feasibility of an AI-assisted adaptive gamification model for supporting physics learning by integrating adaptive technology, gamification, and the Ngada local cultural context. The validation involved nine experts: three physics subject-matter experts, three media experts, and three learning design experts. The experts evaluated the accuracy of physics concepts, adaptive learning features, learning design, and the relevance of cultural contextualization in physics learning activities.

Particular attention is paid to the representation of abstract physical concepts through contextual cultural phenomena. Elements of Ngada culture, such as traditional gasing games (wela maka), gongs and drums (*Go Laba*), bamboo musical instruments (Foi Doa), and local technology, were evaluated for their suitability in explaining the concepts of rotational motion, vibration, sound waves, force, and energy transformation.

The validation results showed that the developed model had a high level of validity in all aspects of the assessment. The S-CVI/Ave value obtained ranged from 0.884 to 0.902, indicating strong agreement among experts regarding the feasibility of applying the model to physics learning.

Table 3. Summary of Content Validity Results.

Expert Type	S-CVI/Ave	S-CVI/UA	Interpretation
Material Expert	0.884	0.67	High validity
Media Expert	0.902	0.72	Very high
Learning Design Expert	0.895	0.71	High validity

Based on Table 3, the highest validity score was obtained from media experts (S-CVI/Ave = 0.902), indicating that adaptive gamification features, interface design, and multimedia integration are considered appropriate for supporting interactive physics learning. Physical material experts also gave high ratings, especially for the suitability of physics concepts to the Ngada cultural context used in contextual learning activities. Meanwhile, learning design experts emphasized that adaptive feedback systems and progressive learning paths are appropriate for supporting conceptual understanding and problem-solving in physics learning.

Several revisions were made based on experts' suggestions, especially to clarify explanations of physics concepts, strengthen alignment between the cultural context and the physics concepts studied, and improve the adaptive feedback system during physics learning activities. Overall, the validation results show that the developed model is theoretically and pedagogically feasible for supporting a meaningful, contextual physics learning experience.

4.2. Practicality of Developed Applications

The practicality of an AI-assisted adaptive gamification model that integrates Ngada local culture was evaluated based on teacher and student responses after the implementation process. The evaluation focused on aspects of ease of use, clarity of learning activities, student engagement, navigation, adaptive feedback, and cultural contextual relevance in supporting physics learning. The results of the study show that the developed model is perceived to be very practical by teachers and students. Teachers gave an overall practicality score of 83.3%, while students gave a score of 84.8%. These results show a positive perception of the ease of use and implementation of the model in physics learning activities.

The teacher specifically said that the adaptive gamification feature and the interactive learning structure help students become more active in physics problem-solving. The integration of Ngada culture into learning is also considered to help explain abstract physics concepts through real phenomena close to students' lives. Students show higher participation when learning the concepts of motion, vibration, sound waves, and energy through contextual cultural examples and gamification-based learning challenges.

Table 4. Evaluation of Practicality by Teachers.

Aspects	Number of Items	Mean (M)	Percentage (%)	Remarks
Ease of Use & Navigation	5	4.6	92%	Easy-to-use interface
Uses	4	4.3	86%	Features are easy to access and work well
Learning Fit	4	4.1	82%	Materials according to learning objectives
Technology Reliability	3	4.2	84%	The system is running well
Feedback System	3	4.0	80%	Feedback helps learning
Cultural Integration	3	3.8	76%	Cultural examples need to be added
Overall Score	-	-	83.3%	High practicality

Based on Table 4, the highest-scoring aspect was ease of use and navigation (92%), indicating that teachers rated the app as easy to apply in physics instruction. However, the aspect of cultural integration received the lowest score (76%), indicating a need to add more contextual physics examples from Ngada cultural practices to further strengthen students' understanding of the concepts. Students also responded positively to the developed model, especially in terms of learning engagement, interactivity, and information clarity. Adaptive learning activities, adaptive missions, and direct feedback are considered effective for maintaining students' attention during physics learning and encouraging active involvement in solving contextual physics problems.

Table 5. Evaluation of Practicality by Students.

Aspects	Number of Items	Mean (M)	Percentage (%)	Remarks
Clarity of Information	4	4.5	90%	Instructions and display are easy to understand
Learning Engagement	5	4.4	88%	Elements of play increase interest in learning
Interactivity	4	4.2	84%	Engaging and responsive interactive features
Cultural Relevance	3	4.0	80%	Cultural elements are considered good but need to be developed
Technology Facilities	4	4.1	82%	Apps are easily accessible and stable
Overall Score	-	-	84.8%	High practicality

Table 5 shows that students appreciate the clarity of the information and the enriching learning experience the app provides. Students said that physics assignments contextualized with local cultural phenomena help them understand abstract concepts more easily, making physics feel more meaningful and fun. Overall, these findings suggest that the developed model is practical and feasible to apply in classroom learning. The integration of adaptive gamification, AI-assisted feedback, and the Ngada cultural context is expected to support an interactive, contextual, and engaging physics learning experience.

4.3. Effectiveness of Developed Applications

4.3.1. Assumption Test

Before inferential statistical analysis is carried out, a prerequisite test is conducted to ensure that the data meet the assumptions of parametric testing. The normality test was performed using the Kolmogorov-Smirnov test, while the homogeneity of variance was analysed using the Levene test. This test was conducted to assess the feasibility of comparing students' physics learning outcomes between the experimental and control groups. The results of the normality test showed that the significance values in both groups were greater than 0.05, indicating that the pretest and posttest data were normally distributed. In addition, the homogeneity test showed a p-value above 0.05 for both pretest and posttest scores, indicating that the variances of the two groups were homogeneous. These results show that the data meet the statistical assumptions required for a paired-samples t-test.

Table 6. Normality Test Results (Kolmogorov-Smirnov).

Groups	N	Sig. (p-value)	Interpretation
Controls	75	0.112	Normal
Experiments	75	0.087	Normal

Based on Table 6, both groups have a significance value greater than 0.05, so the data on students' physics learning outcomes are declared to be normally distributed and worthy of further analysis using inferential statistics.

Table 7. Homogeneity Test Results (Levene's Test).

Variables	Sig. (p-value)	Interpretation
Pretest	0.215	Homogeneous
Posttest	0.178	Homogeneous

Based on Table 7, the significance value for the pretest and posttest scores was above 0.05, which indicates that the variance between the control and experimental groups was homogeneous. This suggests that both groups had relatively similar initial characteristics before the intervention was administered, so the analysis of the effectiveness of AI-assisted adaptive gamification models in improving students' conceptual understanding and physics learning outcomes can be more accurate.

4.4. Students' Understanding of Physics Concepts

The effectiveness of an AI-assisted adaptive gamification model integrating Ngada's local culture was evaluated by comparing pretest and posttest scores between the experimental and control groups. The analysis focuses on students' conceptual understanding and physics problem-solving skills after completing the intervention. The results showed that both groups had similar average pretest scores, indicating that the students' initial understanding of physics concepts was at a similar level before the treatment. However, after implementing the learning model, the experimental group showed a much larger increase in posttest scores than the control group.

Students in the experimental group had an average posttest score of 74.82, while those in the control group had a score of 59.34. The average score increase in the experimental group was 22.34, much higher than the 6.22 increase in the control group. These results show that the developed model makes a positive contribution to improving students' understanding of concepts and ability to solve contextual physics problems. During the intervention, students in the experimental group were actively involved in adaptive gamification learning activities that incorporated physics challenges rooted in local cultures. This contextual learning experience helped students connect abstract physics concepts to real-life phenomena that were close to home.

The AI-assisted adaptive system also provides personalised feedback and progressively adjusts difficulty levels based on students' learning performance. Students who initially had difficulty solving conceptual problems gradually improved their reasoning and problem-solving skills after receiving adaptive guidance and scaffolded support. In contrast, students in the control group showed relatively limited improvement during conventional learning. The results of class observation showed that students in the control group tended to rely more on the teacher's explanations and were less active in physics problem-solving activities than students in the experimental group.

The results of the paired-samples t-test showed a significant difference between the pretest and posttest scores in both groups ($p < 0.001$). However, the increase in the experimental group was much larger than that in the control group. This shows that AI-assisted adaptive gamification models are more effective than conventional learning in improving students' physics learning outcomes. As shown by the statistically significant improvement in the experimental group, a more engaging and relevant learning environment for physics was created through the combination of adaptive learning, gamification, and local culture contextualization. Students are motivated to actively engage in solving physics issues within a transdisciplinary learning framework through customized tutoring and an adaptive feedback system.

In addition, contextualizing physics concepts through Ngada cultural practices also helps reduce students' difficulties in understanding abstract scientific concepts. Students show higher participation and perseverance when learning activities involve familiar cultural phenomena and contextual physics problem-solving tasks. These results show that the developed model is effective in supporting conceptual understanding and students' active involvement in physics learning. Table 8 presents a comparison of students' understanding of physics concepts between the control and experimental groups based on the pretest, posttest, N-gain, and t-test results.

Table 8. Comparison of Understanding of Physics Concepts between Control and Experimental Groups.

Statistics	Control Group (n = 75)	Experimental Group (n = 75)	Interpretation
Mean Pretest	53.12	52.48	The initial level of understanding was relatively similar
Mean Posttest	59.34	74.82	Higher in the experimental group
Mean Difference	6.22	22.34	Greater improvement in the experimental group
N-Gain	0.18 (Low)	0.71 (High)	High effectiveness of the adaptive model
t-value	-28.46	-39.77	Significant improvement
Sig. (2-tailed)	0.000	0.000	Statistically significant difference

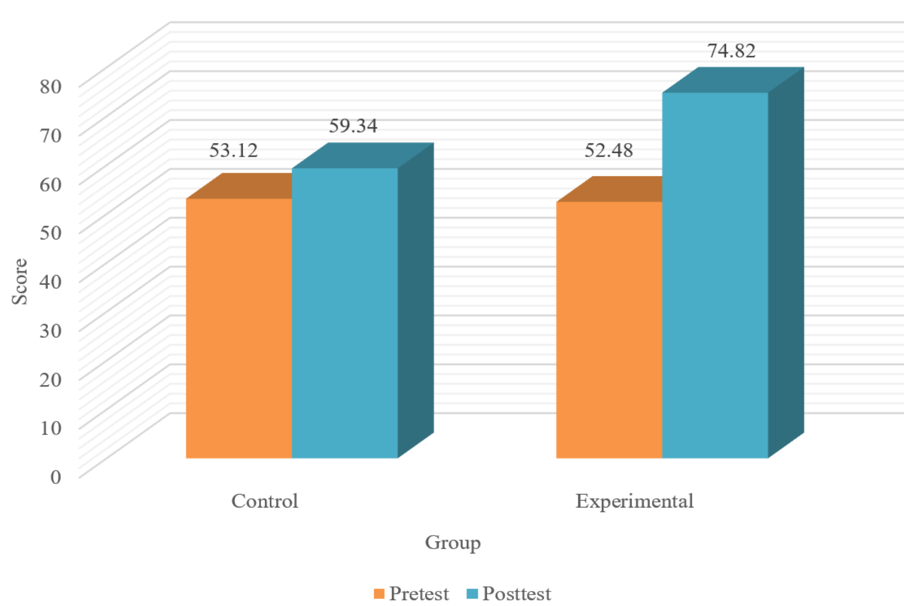

Figure 1. Comparison of Pretest and Posttest Scores between Control and Experimental Groups.

Figure 1 shows a comparison of pretest and posttest scores between the control group and the experimental group. The experimental group shows much greater improvement after the intervention than the control group.

4.5. Learning Motivation Results

The implementation of an AI-assisted, adaptive gamification model that integrates Ngada local culture positively influenced students' motivation to learn physics. The results of learning motivation were analysed using the ARCS motivation framework, which included the dimensions of Attention, Relevance, Confidence, Satisfaction, and Learning Support. The analysis focused on students' motivation to understand physics concepts, solve contextual physics problems, and engage in adaptive gamification learning activities during the intervention.

In general, students in the experimental group showed a fairly high increase in motivation after the intervention. The average motivation score increased from 68.2 in the pre-intervention stage to 84.7 in the post-intervention stage, with an N-gain score of 0.52, which was in the medium-to-high range. These results show that integrating adaptive gamification, AI-assisted feedback, and physics learning contextualized with local culture positively influenced student engagement and motivation during the physics learning process. Further analysis showed that the entire motivation dimension improved after the model was implemented, although the magnitude of the increase varied across indicators.

Table 9. Increased Motivation to Learn Physics Based on ARCS Indicators in Experimental Groups.

Motivation Indicators	Mean Pretest	Mean Posttest	Mean Difference	N-Gain	Categories	Interpretation
Attention	67.4	85.2	17.8	0.55	Medium-High	Curiosity about physical phenomena increases
Relevance	69.1	86.3	17.2	0.56	Medium-High	The concept of physics is seen as more meaningful and contextual
Confidence	66.8	82.7	15.9	0.48	Medium	Confidence in solving physics problems increases
Satisfaction	68.5	84.9	16.4	0.52	Medium-High	Students enjoy physics learning activities more
Learning Support	69.0	84.4	15.4	0.50	Medium	Adaptive feedback helps with concept understanding
Overall Motivation	68.2	84.7	16.5	0.52	Medium-High	Motivation to study physics increases positively

Based on Table 9, the Relevance indicator showed the largest increase, with an N-gain of 0.56. These results show that integrating the Ngada cultural context helps students view physical concepts more closely through their real experiences and local cultural practices. Concepts such as rotational motion, vibration, sound waves, and energy transformation become easier to understand when presented through familiar cultural phenomena such as *wela maka* (traditional *gasing*), gongs, bamboo musical instruments, and local technology.

The Attention indicator also shows a fairly high increase, with an N-gain value of 0.55. Adaptive gamification features, such as interactive physics missions, points, awards, and contextual learning challenges, appear to increase students' curiosity and sustain their attention during the physics learning process. The results of the class observation showed that students were more active in discussions and more involved in physics problem-solving activities for longer than in conventional learning.

Meanwhile, the Confidence dimension has increased, with an N-gain value of 0.48. The AI-assisted adaptive system provides personalized feedback and gradually adjusts difficulty levels based on students' abilities. Students who initially had difficulty solving conceptual problems showed increased confidence after receiving adaptive guidance and gradual learning support during the learning process.

The Satisfaction dimension also shows a fairly high increase, with an N-gain value of 0.52. Students feel happier and more satisfied when they complete gamification-based physics challenges and successfully pass the adaptive learning levels. The direct feedback mechanism and reward system appear to strengthen students' motivation to continue engaging in physics learning activities.

In addition, the Learning Support dimension showed a positive increase, with an N-gain value of 0.50. Students feel that the AI-assisted feedback system helps them identify misconceptions and deepen their understanding of physics concepts. Adaptive learning support also encourages students to learn more independently when completing contextual physics tasks.

The students in the control group had a relatively modest rise in motivation throughout the standard physics learning process, in contrast to the students in the experimental group. With an N-gain value of 0.16, the overall increase in motivation in the control group was in the low bracket on the scale of motivational increases. It would seem from this that the traditional mode of instruction offers only a limited amount of support for students' involvement, confidence, and contextual comprehension in the subject of physics.

Overall, the results showed that integrating adaptive gamification, AI-assisted personalization, and Ngada cultural contextualization positively influenced various dimensions of students' physics learning motivation. The developed model not only improved understanding of concepts but also strengthened students' curiosity, confidence, engagement, and perseverance during the physics learning process.

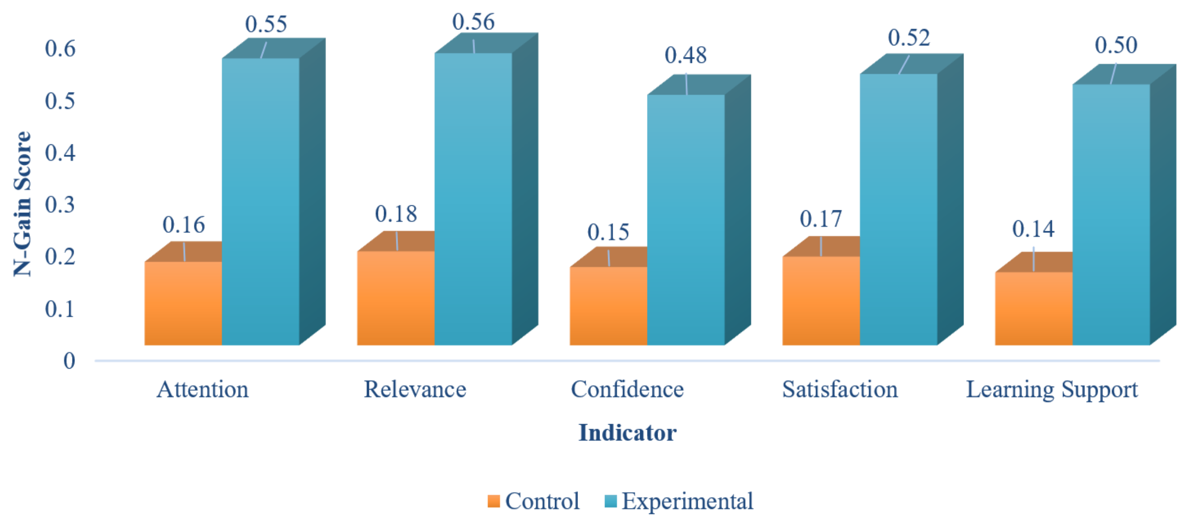

Figure 2. Comparison of N-Gain Scores on Each ARCS Indicator between the Control Group and the Experimental Group.

Figure 2 shows that the experimental group consistently obtained a higher N-gain score across the ARCS dimensions than the control group. The biggest difference is seen in the Relevance dimension, which shows that cultural context-based physics learning contributes greatly to students' perception of the meaningfulness of physics concepts.

5. Discussion

5.1. The Effectiveness of AI-Assisted Adaptive Gamification in Physics Learning

The results have shown that the experimental group obtained a much higher posttest score and N-gain value than the control group. These findings show that AI-assisted adaptive gamification models are effective in improving students' conceptual understanding of physics. The significant increase in the experimental group indicates that integrating adaptive learning mechanisms, gamification, and culturally contextualized learning experiences can create a more meaningful and interactive physics learning environment than conventional learning.

AI-assisted adaptive systems enable the creation of personalized learning experiences through adaptive feedback, dynamic adjustment of question difficulty, and individualized learning paths. These adaptive features help students understand abstract physics concepts according to their respective learning development and conceptual needs, thus supporting more effective reasoning and problem-solving processes (Gligorea et al., 2023; Kanchon, Sadman, Nabila, Tarannum, & Khan, 2024; Sayed et al., 2023; Zawacki-Richter, Marín, Bond, & Gouverneur, 2019). Aligning with these findings, previous studies have shown that AI-based adaptive learning environments can improve learning effectiveness and student engagement through personalized learning support (Chen et al., 2020; Katona & Gyonyoru, 2025).

In addition, gamification elements integrated into the learning model, such as points, rewards, levels, and interactive challenges, can encourage students' active participation in the physics learning process. Students become more involved in solving contextual physics problems related to the concepts of motion, vibration, sound waves, and energy transformation presented through the context of Ngada culture. These findings support previous research showing that gamification can positively influence student engagement, perseverance, academic achievement, and learning satisfaction in a science learning environment (Lampropoulos & Sidiropoulos, 2024; Sailer & Homner, 2020).

The findings of this study have also shown that the combination of adaptive learning and gamification, contextualized with culture, creates a synergistic effect on learning. Personal support, contextual relevance, and interactive learning experiences together help improve students' understanding of physics concepts. By connecting scientific concepts to familiar cultural phenomena, students view physics as more meaningful and less abstract. Similar findings have also been reported in various studies that emphasize the effectiveness of context-based and technology-based science-learning environments in improving concept understanding and student engagement in the classroom (Commeford, Brewe, & Traxler, 2021; Traxler, 2022).

Overall, this study's findings show that AI-assisted adaptive gamification integrating local cultural contexts has great potential to support more meaningful physics learning, especially in culturally diverse, resource-constrained educational environments where students often struggle to understand abstract scientific concepts.

5.2. The Role of Local Cultural Context in Meaningful Physics Learning

The study's findings have shown that integrating Ngada's local culture makes an important contribution to creating a more meaningful, contextually relevant physics learning experience. The use of traditional cultural practices, local technology, musical instruments, and community activities as learning contexts allows students to connect abstract physics concepts to real-life phenomena close to home. This contextualization appears to reduce students' perception that physics is a difficult and abstract subject.

Concepts such as motion, rotational motion, vibration, sound waves, force, and energy transformation become easier to understand when presented through familiar cultural examples such as traditional *gasing* games (*wela maka*), gongs, bamboo musical instruments, and local technology derived from the cultural practices of the Ngada people (Mopa, Awe, Wau, Djomba, & Wasonono, 2020). These findings have supported previous studies that culturally responsive learning environments can improve understanding of concepts, engagement in learning, and the relevance of learning to students' sociocultural experiences (Adrizal et al., 2024; Shofa, Su'ad, & Murtono, 2021).

The findings of this study also reinforce the importance of culturally responsive pedagogy in physics education, especially in culturally diverse educational environments. In contrast to many technology-based learning models developed in culturally neutral contexts, the model developed in this study seeks to bridge technological innovation with local cultural relevance. This shows that the effectiveness of educational technology is not determined solely by its sophistication, but also by its ability to create relevant and meaningful learning experiences for students. Similar findings have also been reported in various studies that emphasize the importance of local wisdom and sociocultural identity in increasing student motivation and participation in learning (Arjaya, Suastra, Redhana, & Sudiatmika, 2024; Satria, Chan, & Majid, 2020).

In addition, integrating local cultural knowledge into AI-assisted adaptive learning environments contributes to the global discussion on culturally inclusive and sustainable science education. The findings of this study suggest that the local cultural context can serve as an active pedagogical resource that supports students' conceptual understanding, engagement, and motivation in physics learning without reducing the effectiveness of technology-based learning. These results also support various studies that emphasize the importance of contextual science learning in culturally diverse educational environments (Hastuti et al., 2020; Laksana, Seso, & Riwu, 2019).

5.3. Student Learning Motivation and Engagement

This study's findings show that an AI-assisted adaptive gamification model integrating Ngada's local culture positively influences students' motivation and engagement in physics learning. Improvements across all dimensions of ARCS motivation indicate that the developed model not only supports students' cognitive achievement but also their emotional and behavioral engagement during physics learning.

Improvements in the Attention and Relevance dimensions show that adaptive gamification and cultural contextualization help students view physics learning as something more engaging and meaningful. Interactive physics missions, contextual learning challenges, and familiar cultural examples seem to increase students' curiosity and maintain student engagement during learning activities. Physical concepts such as motion, vibration, sound waves, and energy transformations become more relevant when they are linked to students' local sociocultural experiences and cultural practices. Aligning with these findings, previous studies have shown that contextual and complementary learning environments can strengthen engagement, participation, and meaningful learning experiences in science education (Angwaomaodoko, 2025; Ruiz, Sanchez, & Figueredo, 2024; Ukgoda, 2025).

Meanwhile, improvements in the Confidence dimension show that AI-assisted adaptive feedback systems help students solve physics problems more independently. Personalized feedback and gradual adjustment of the difficulty level allow students to learn at their own pace and develop their understanding of the concepts, reducing frustration and increasing confidence in solving physics problems. Aligning with these findings, previous studies have shown that an adaptive learning environment can increase student confidence and engagement through individualized learning support (Gligorea et al., 2023; Kanchon et al., 2024; Sayed et al., 2023).

The satisfaction dimension has also increased, as students report feeling happier while participating in gamification-based physics-learning activities. The integration of points, rewards, levels, and a progress-tracking system appears to encourage active student participation and perseverance throughout the learning process. Supported by these findings, previous studies have shown that gamification can strengthen intrinsic motivation and student engagement through interactive, enjoyable learning experiences (Hebbar, Manohar, & Hungund, 2025; Lampropoulos & Sidiropoulos, 2024; Putz, Hofbauer, & Treiblmaier, 2020; Sailer & Homner, 2020).

Overall, this study's findings have shown that integrating adaptive feedback, gamification, and cultural contextualization can simultaneously support the motivational and cognitive aspects of physics learning. By creating a personalized, contextual, and interactive learning experience, the developed model can strengthen students' curiosity, confidence, engagement, and perseverance during the physics learning process.

5.4. Theoretical and Global Contributions

This research contributes to the development of technology-based, culturally responsive physics education research by creating an integrated learning framework that combines AI-assisted adaptive learning, gamification, and local cultural knowledge into a single learning model. While previous research generally examined the three approaches separately, this study shows that integrating them creates a more meaningful, engaging, and effective physics learning experience. From a theoretical perspective, this study's results expand the study of adaptive learning and gamification by emphasizing the importance of cultural contextualization in technology-based education. Previous findings have shown that the effectiveness of AI-assisted adaptive learning can be further increased when adaptive feedback and complementary learning experiences are linked to students' sociocultural backgrounds and daily experiences (Gligorea et al., 2023; Zawacki-Richter et al., 2019).

This research also reinforces the principles of culturally responsive pedagogy, emphasizing that learning becomes more meaningful when scientific concepts are associated with students' cultural identities and life experiences (Lestari et al., 2024; Nair & Sawtelle, 2019). In this study, the cultural context of Ngada is used not only as an additional example but also as a pedagogical resource that supports students' conceptual understanding, engagement, and motivation in physics learning. In addition, this research's results contribute to a global discussion of inclusive and contextual science education, especially in culturally diverse, resource-limited educational environments. The developed model has shown that educational technology can not only be designed to improve learning efficiency but also to support contextual relevance, cultural sustainability, and meaningful learning experiences (Arjaya et al., 2024; Hastuti et al., 2020).

Overall, this study provides practical implications for educators, learning developers, and policymakers implementing culturally contextualized, technology-based learning models in science education. Integrating adaptive learning, gamification, and local cultural knowledge can be an alternative for creating a more inclusive, engaging, and meaningful physics learning environment across various educational contexts.

5.5. Limitations of Research and Recommendations for Advanced Research

Although this study has shown positive results, several limitations still need to be considered. This study uses a quasi-experimental design without random assignment, so the ability to demonstrate a strong cause-and-effect relationship between the intervention and learning outcomes remains limited. Although the experimental and control groups have relatively similar initial characteristics, the possibility of external variables influencing the results remains unavoidable.

The research was conducted in a limited sociocultural context, namely, schools in Ngada Regency, Indonesia. Therefore, generalizing research results to other educational and cultural contexts should be done carefully. Further research is recommended to test the applicability of the developed model in a broader, culturally diverse educational context. Furthermore, the variety of technological infrastructure, digital literacy levels, and teachers' abilities to facilitate learning may also affect the implementation process and students' learning experiences. Differences in access to digital devices and internet connectivity can also affect the consistency with which adaptive learning is applied in educational environments with limited resources.

This study focuses more on understanding short-term changes in motivation during the intervention process. Therefore, longitudinal research is still needed to examine the long-term impact of AI-assisted adaptive gamification on concept retention, high-level thinking skills, and the sustainability of students' learning motivation in physics. Further research is also suggested to examine the contribution of each component, such as adaptive learning, gamification, and cultural contextualization, through a more rigorous experimental design. The study is expected to provide a deeper understanding of the influence of each learning component on students' cognitive and motivational development in physics education.

6. Conclusion

This study concludes that the AI-assisted adaptive gamification model integrating Ngada's local culture is valid, practical, and effective in improving student learning outcomes and motivation in physics. The study found that the developed model had high validity and received positive responses from teachers and students regarding ease of use, learning engagement, and learning implementation. The effectiveness results showed that students who learned using the developed model obtained much higher posttest and N-gain scores than those who learned using conventional instruction. In addition, the intervention also positively influenced students' learning motivation, especially in the areas of learning interest, involvement, and perseverance during physics learning.

The study's findings show that integrating AI-assisted adaptivity, gamification, and the contextualization of local cultures can create a more meaningful, engaging, and personalized learning environment. Adaptive learning features support tailored learning experiences, while gamification elements increase participation and persistence. On the other hand, integrating the Ngada cultural context enhances the relevance and meaningfulness of physics learning by connecting scientific concepts with students' socio-cultural experiences.

This research contributes to the development of physics education that is culturally responsive and technology-supported by creating an integrated learning framework that combines adaptive learning, gamification, and local cultural knowledge into a single learning model. The results of this study also have implications for implementing an inclusive, technology-based learning environment in culturally diverse, resource-limited educational settings. Further research is recommended to examine the long-term effectiveness of the developed model, explore its implementation in a broader educational context, and analyze the relative contributions of adaptive learning, gamification, and cultural contextualization to students' cognitive and motivational development in physics learning.

References

Adrizal, M., Ilham, I., Ali, M., Bangun, S. Y., Sastradika, D., & Ockta, Y. (2024). Optimizing physical education learning: Developing local wisdom-based learning materials to improve students' learning motivation. *Journal of Education, Teaching and Learning*, *9*(1), 69-73. https://doi.org/10.26737/jetl.v9i1.5930

Al-Kamzari, F., & Alias, N. (2024). Exploring the readiness of high school physics students for project-based hybrid learning in the Sultanate of Oman. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(2), em2404. https://doi.org/10.29333/ejmste/14241

Angwaomaodoko, E. A. (2025). A review of the impact of gamification on students' motivation and retention in higher education. *International Research in Education*, *13*(2), 26–44. https://doi.org/10.5296/ire.v13i2.23072

Arjaya, I. B. A., Suastra, I. W., Redhana, I. W., & Sudiatmika, A. A. I. A. R. (2024). Global trends in local wisdom integration in education: A comprehensive bibliometric mapping analysis from 2020 to 2024. *International Journal of Learning, Teaching and Educational Research*, *23*(7), 120-140. https://doi.org/10.26803/ijlter.23.7.7

Brahmia, S. W., Olsho, A., Smith, T. I., Boudreaux, A., Eaton, P., & Zimmerman, C. (2021). Physics inventory of quantitative literacy: A tool for assessing mathematical reasoning in introductory physics. *Physical Review Physics Education Research*, *17*(2), 020129. https://doi.org/10.1103/PhysRevPhysEducRes.17.020129

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Buenadicha-Mateos, M., Sánchez-Hernández, M. I., González-López, O. R., & Tato-Jiménez, J. L. (2025). From engagement to achievement: How gamification impacts academic success in higher education. *Education Sciences*, *15*(8), 1054. https://doi.org/10.3390/educsci15081054

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access*, *8*, 75264-75278. https://doi.org/10.1109/ACCESS.2020.2988510

Commeford, K., Brewe, E., & Traxler, A. (2021). Characterizing active learning environments in physics using network analysis and classroom observations. *Physical Review Physics Education Research*, *17*(2), 020136. https://doi.org/10.1103/PhysRevPhysEducRes.17.020136

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1-4.

Fayanto, S., Degeng, I. N. S., Patmanthara, S., & Ulfa, S. (2024). Instructional process of design-based learning integration on computational thinking: A framework for effective teaching in course of physics experiment design. *Science Education International*, *35*(4), 394-407. https://doi.org/10.33828/sei.v35.i4.10

Giráldez, A. V., Sanmiguel-Rodríguez, A., Álvarez, R. O., & Navarro-Patón, R. (2022). Can gamification influence the academic performance of students? *Sustainability*, *14*(9), 5115. https://doi.org/10.3390/su14095115

Gligorea, I., Cioca, M., Oancea, R., Gorski, A.-T., Gorski, H., & Tudorache, P. (2023). Adaptive learning using artificial intelligence in e-learning: A literature review. *Education Sciences*, *13*(12), 1216. https://doi.org/10.3390/educsci13121216

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

Hastuti, P. W., Setianingsih, W., & Anjarsari, P. (2020). How to develop students' scientific literacy through integration of local wisdom in Yogyakarta on science learning? *Journal of Physics: Conference Series, 1440*(1), 012108. https://doi.org/10.1088/1742-6596/1440/1/012108

Hebbar, S., Manohar, S., & Hungund, S. (2025). Examining gamification's impact on perceived satisfaction through learning parameters: A preliminary perception-based study among prospective users. *Interactive Learning Environments, 33*(3), 2718-2737. https://doi.org/10.1080/10494820.2024.2417719

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28-54. https://doi.org/10.1002/sce.10106

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A.-I. (2021). Gamification in science education. A systematic review of the literature. *Education Sciences, 11*(1), 22. https://doi.org/10.3390/educsci11010022

Kanchon, M. K. H., Sadman, M., Nabila, K. F., Tarannum, R., & Khan, R. (2024). Enhancing personalized learning: AI-driven identification of learning styles and content modification strategies. *International Journal of Cognitive Computing in Engineering, 5*, 269-278. https://doi.org/10.1016/j.ijcce.2024.06.002

Katona, J., & Gyonyoru, K. I. K. (2025). Integrating AI-based adaptive learning into the flipped classroom model to enhance engagement and learning outcomes. *Computers and Education: Artificial Intelligence, 8*, 100392.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development, 10*(3), 2-10. https://doi.org/10.1007/BF02905780

Körhasan, N. D., & Kaltakci-Gurel, D. (2019). Student teachers' physics knowledge and sources of knowledge to explain everyday phenomena. *Science Education International, 30*(4), 298–309. https://doi.org/10.33828/sei.v30.i4.7

Kua, M. Y., Dolo, F. X., Suparmi, N. W., Gelu, A., Dhena, G. V. A., & Meme, Y. O. (2024). Interactive articulate storyline application based on real world problem and local Ngada wisdom. *Journal of Research in Instructional, 4*(1), 77-90.

Laksana, D. N. L., Seso, M. A., & Riwu, I. U. (2019). Content and flores cultural context based thematic electronic learning materials: Teachers and students' perception. *European Journal of Education Studies, 5*(9), 145–155.

Lampropoulos, G., & Sidiropoulos, A. (2024). Impact of gamification on students' learning outcomes and academic performance: A longitudinal study comparing online, traditional, and gamified learning. *Education Sciences, 14*(4), 367. https://doi.org/10.3390/educsci14040367

Lestari, N., Paidi, & Suyanto, S. (2024). A systematic literature review about local wisdom and sustainability: Contribution and recommendation to science education. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(2), em2394. https://doi.org/10.29333/ejmste/14152

Lidi, M. W., Ningsih, & Dhiki, Y. Y. (2020). Identify the potential of local wisdom of the people of Golewa Ngada Regency as a development effort in the field of education. *OPTICS: Journal of Physics Education, 4*(1), 21–29.

Mihret, Z., Alemu, M., & Assefa, S. (2022). Effects of blending virtual and real laboratory experimentation on pre-service physics teachers' attitudes toward physics electricity and magnetism laboratories. *Science Education International, 33*(3), 313-322. https://doi.org/10.33828/sei.v33.i3.7

Misbah, M., Purwasih, D., Muhammad, N., Syahidi, K., Komariyah, L., Wahyudi, W., & Nurhayati, N. (2024). Is science concept can analyze by study ethnoscience? Study bibliometric and analysis. *AIP Conference Proceedings, 3058*(1), 040006. https://doi.org/10.1063/5.0201390

Mopa, Y., Awe, E. Y., Wau, M. P., Djomba, E., & Wasonono, P. D. Y. (2020). *Ngada cultural heritage: Highlighted in the 2019 Inerie festival.* Serang, Indonesia: CV AA Rizky.

Nair, A., & Sawtelle, V. (2019). Operationalizing relevance in physics education: Using a systems view to expand our conception of making physics relevant. *Physical Review Physics Education Research, 15*(2), 020121. https://doi.org/10.1103/PhysRevPhysEducRes.15.020121

Putz, L.-M., Hofbauer, F., & Treiblmaier, H. (2020). Can gamification help to improve education? Findings from a longitudinal study. *Computers in Human Behavior, 110*, 106392. https://doi.org/10.1016/j.chb.2020.106392

Robertson, A. D., Goodhew, L. M., Bauman, L. C., Hansen, B., & Alesandrini, A. T. (2023). Identifying student conceptual resources for understanding physics: A practical guide for researchers. *Physical Review Physics Education Research, 19*(2), 020138. https://doi.org/10.1103/PhysRevPhysEducRes.19.020138

Ruiz, J. J. R., Sanchez, A. D. V., & Figueredo, O. R. B. (2024). Impact of gamification on school engagement: A systematic review. *Frontiers in Education, 9*, 1466926. https://doi.org/10.3389/feduc.2024.1466926

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education, 58*(1), 136-153. https://doi.org/10.1016/j.compedu.2011.07.017

Saiful, M., Ilyas, I., & Hamdi, H. (2023). Analysis of student difficulties in solving physics questions at senior high school. *Dharmas Education Journal, 4*(3), 62-69.

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review, 32*(1), 77-112. https://doi.org/10.1007/s10648-019-09498-w

Satria, H., Chan, S., & Majid, M. S. A. (2020). Do local cultural wisdom and leadership matter for improving motivation and performance? *East African Scholars Journal of Economics, Business and Management, 3*(1), 93-99.

Sayed, W. S., Noeman, A. M., Abdellatif, A., Abdelrazek, M., Badawy, M. G., Hamed, A., & El-Tantawy, S. (2023). AI-based adaptive personalized content presentation and exercises navigation for an effective and engaging e-learning platform. *Multimedia Tools and Applications, 82*(3), 3303-3333. https://doi.org/10.1007/s11042-022-13076-8

Shofa, A., Su'ad, & Murtono. (2021). Development of learning media technology based on natural science local wisdom materials. *Journal of Physics: Conference Series, 1823*(1), 012080. https://doi.org/10.1088/1742-6596/1823/1/012080

Traxler, A. (2022). Networks and learning: A view from physics. *Journal of Learning Analytics, 9*(1), 111-119. https://doi.org/10.18608/jla.2022.7669

Ukgoda, H. (2025). Gamification in education: Its impact on engagement, motivation, and learning outcomes. *Journal of Educational Technology Development and Exchange, 18*(3), 41-66. https://doi.org/10.18785/jetde.1803.03

Wahyudi, W., Zuhdi, M., Makhrus, M., & Busyairi, A. (2022). Identification of student difficulties in the implementation of basic physics lecture. *Jurnal Penelitian Pendidikan IPA, 8*(5), 2537-2542. https://doi.org/10.29303/jppipa.v8i5.2443

Wangchuk, D., Wangdi, D., Tshomo, S., & Zangmo, J. (2023). Exploring students' perceived difficulties of learning physics. *Educational Innovation and Practice, 6*, 1-11. https://doi.org/10.17102/eip.6.2023.03

Warsono, W., Nursuhud, P. I., Darma, R. S., Supahar, S., Oktavia, D. A., Setiyadi, A., & Kurniawan, M. A. (2020). Multimedia learning modules (MLMs) based on local wisdom in physics learning to improve student diagram representations in realizing the nature of science. *International Journal of Interactive Mobile Technologies, 14*(6), 148–158. https://doi.org/10.3991/ijim.v14i06.11640

Weller, D. P., Bott, T. E., Caballero, M. D., & Irving, P. W. (2022). Development and illustration of a framework for computational thinking practices in introductory physics. *Physical Review Physics Education Research, 18*(2), 020106. https://doi.org/10.1103/PhysRevPhysEducRes.18.020106

Zacharia, Z. C., & Olympiou, G. (2011). Physical versus virtual manipulative experimentation in physics learning. *Learning and Instruction, 21*(3), 317-331. https://doi.org/10.1016/j.learninstruc.2010.03.001

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators? *International Journal of Educational Technology in Higher Education, 16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0