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DEVELOPMENT OF ARTIFICIAL INTELLIGENCE-INTEGRATED AND ACEHNESE ETHNOPHYSICS-BASED LEARNING MEDIA TO SUPPORT SUSTAINABLE DEVELOPMENT IN EDUCATION

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ABSTRACT

This study aimed to develop physics learning media that combine artificial intelligence (AI) with the ethnophysics of *Rumoh Aceh* and to examine their validity, practicality, and effectiveness. A research and development (R&D) design with the Four-D (4D) model was applied, covering the define, design, develop, and disseminate stages. Field trials took place at SMP Negeri 1 Sakti (Pidie Regency) and SMP Negeri 1 Bandar Baru (Pidie Jaya Regency), Indonesia. Subject matter, media, and cultural experts judged the validity of the product, teachers and students rated its practicality through questionnaires, and effectiveness was determined from students' pretest and posttest scores using normalized gain (N-Gain). The media obtained a validity score of 92.22%, categorized as very valid. Practicality reached 93.06% from teachers and 91.08% from students, both in the very practical category. The mean N-Gain was 0.69, a moderate improvement in learning outcomes, and a paired-sample t-test showed a significant difference between pretest and posttest scores ($p < 0.001$). The media helped students grasp physics concepts, brought the local wisdom embedded in *Rumoh Aceh* into the classroom, and are aligned with the principles of Sustainable Development Goal (SDG) 4 by encouraging innovative, contextual, and sustainable learning.

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1. INTRODUCTION

Education in the twenty-first century is changing quickly as digitalization reaches almost every area of life, and education systems must keep adapting to stay relevant. Among the most influential developments is artificial intelligence (AI), which is no longer just a technological novelty but has become part of how many countries are transforming their education (Lin et al., 2023). The topic is also tied to the Sustainable Development Goals (SDGs), especially SDG 4, which calls for inclusive, equitable, and quality education for everyone as a basis for sustainable development (Ally & Perris, 2022; Alsagri & Sohail, 2024; Leal Filho et al., 2024). AI and sustainable education have therefore become two linked global priorities that draw growing international attention.

The use of AI has expanded rapidly across primary, secondary, and higher education. Reported benefits include personalized learning, adaptive feedback, and more efficient delivery of

content (Chan & Hu, 2023; Lin et al., 2023; Zawacki-Richter et al., 2019). In Indonesia, the same trend appears in a growing body of work on AI-based physics media, for example AI-assisted kinematics e-modules (Anggraini et al., 2024) and an AI chatbot linked to an ethnoscience approach for teaching temperature and heat (Afiliyani et al., 2024). Even so, putting AI into Indonesian classrooms remains difficult because of limited technological infrastructure, uneven digital access between regions, and teachers who are not yet fully prepared to use AI responsibly and with students at the center (Kemendikbudristek, 2024). These obstacles show that AI adoption needs carefully planned strategies if its benefits are to reach learners in different contexts equally.

Alongside these benefits, there are concerns about how AI fits the cultural setting of learners. AI has been shown to make physics instruction more effective and personalized (Anggraini et al., 2024), yet most AI-based media currently available are built as generic, one-size-fits-all products that pay little attention to local culture (Azmi et al., 2021). Some attempts to pair AI with local content exist, such as the chatbot built on an ethnoscience approach (Afiliyani et al., 2024), but they are still few compared with how widely standardized AI media are used. Technological sophistication alone therefore cannot guarantee meaningful learning; it needs culturally relevant content that reflects what learners already know and where they come from.

Local wisdom is an essential part of meaningful learning. Ethnoscience links scientific knowledge to the cultural practices of local communities and has been widely used to make science lessons more contextual (Azmi et al., 2021). Within it, ethnophysics is especially suited to physics education because it looks for physics principles embedded in a community's traditions and cultural practices (Rumiati et al., 2021). Studies in Indonesia show that traditional games, tools, and customs contain rich physics content: mechanical energy in the stilt-walking game *egrang* (Rumiati et al., 2021), ethnophysics through the traditional slingshot *katapel* in senior high school lessons (Aryani et al., 2025), physics concepts in the making of traditional drinks (Sa'diyah et al., 2024), and force and lever principles in the Acehnese rice pounder *jeungki* (Rahmatillah et al., 2022). Traditional houses have been examined as well. Rigid-body equilibrium, normal force, and gravitational force have been identified in the Tongkonan house of the Toraja people (Jefriyanto et al., 2022), and force, equilibrium, and heat transfer in the traditional Minahasa house in Woloan (Pawarangan et al., 2023). Traditional architecture thus holds considerable promise as a contextual resource for physics learning, but its potential in *Rumoh Aceh*, the traditional house of Aceh, has hardly been explored.

Rumoh Aceh, also called Krong Bade, is a heritage of Acehnese architecture that carries both basic physics principles and deep cultural values. It is a stilt house raised roughly 2.5–3.0 meters above the ground on 16, 24, or 32 wooden pillars, the number depending on how many rooms it has. Instead of metal nails, the builders joined pillars and beams with wooden pegs and rattan lashings (Mirsa, 2013; Zuhra et al., 2022). The raised structure illustrates gravitational and normal forces acting on the supporting pillars. The many small windows in the wooden walls relate to natural ventilation and air circulation, while the gable roof thatched with rumbia (sago palm) leaves relates to heat transfer and load distribution (Zuhra et al., 2022). Similar principles of force, equilibrium, and heat transfer in pillars and roofs have been reported for other Indonesian traditional houses (Jefriyanto et al., 2022; Pawarangan et al., 2023), so *Rumoh Aceh* can reasonably be expected to serve as a contextual, locally grounded resource for physics learning. At the same time, this heritage is becoming less familiar to young people in Aceh as digitalization advances and children spend more time on digital devices (Husein, 2021; Jolivina et al., 2025). Unless it is

brought back through media suited to the digital era, the local wisdom in *Rumoh Aceh* may drift further from students' awareness.

Many studies have looked at AI in education, particularly for building innovative learning media and for supporting personalized, interactive learning (Afiliyani et al., 2024; Alsagri & Sohail, 2024; Anggraini et al., 2024; Lin et al., 2023). Their emphasis, however, has generally been on applying or developing AI-based learning technology, with specific local cultural contexts rarely built into the learning content. In parallel, ethnophysics research has explored the physics embedded in traditional houses and cultural practices across Indonesia (Jefriyanto et al., 2022; Pawarangan et al., 2023), and the architectural characteristics of Acehnese traditional buildings have been described (Zuhra et al., 2022). These studies mainly identify physics concepts, describe architectural features, and assess their potential as ethnophysics contexts; they stop short of developing AI-based learning media.

Putting the two streams side by side reveals a clear gap. Research on AI-based media has stressed technological innovation but has seldom made local cultural heritage, and *Rumoh Aceh* in particular, the central learning context. Ethnophysics work on Acehnese traditional architecture has documented the physics principles in its structure, but those findings have not yet been turned into an AI-based learning product (Zuhra et al., 2022). An early attempt to combine AI with ethnoscience (Afiliyani et al., 2024) did not address *Rumoh Aceh* as an ethnophysics context, nor did it connect the work to sustainable education under SDG 4. This study therefore brings together three elements that have mostly been treated separately: (1) AI as a learning-media technology, (2) the ethnophysics of *Rumoh Aceh* as a culturally grounded physics learning resource, and (3) sustainable education in line with SDG 4.

Several practical educational problems make this gap worth addressing. First, Acehnese cultural heritage, including the architecture of *Rumoh Aceh* with its physics content, is losing familiarity among younger people because of rapid digitalization and children's growing attachment to digital devices (Husein, 2021). Second, students commonly regard physics as abstract and difficult, since its concepts are rarely linked to daily experience or local culture (Azmi et al., 2021). Third, scientific literacy among Indonesian students is still low: the country's average science score in the Programme for International Student Assessment (PISA) 2022 was well below the OECD average (OECD, 2023). Together, these problems call for innovative learning solutions that preserve local heritage, put physics concepts in context, and strengthen conceptual understanding and scientific literacy through meaningful experiences.

To respond, this study develops physics learning media that integrate AI with the ethnophysics of the Acehnese traditional house, *Rumoh Aceh*, following a research and development (R&D) approach. The media present physics phenomena found in the architecture of *Rumoh Aceh*: force and equilibrium in the stilt-support system, natural ventilation and heat transfer through the windows and roof, and the wooden peg-and-rattan joints used in construction (Mirsa, 2013; Zuhra et al., 2022). The content is delivered through an AI-powered interactive interface, such as an educational chatbot, adaptive simulations, or an intelligent learning assistant, so that students can study physics in a personalized, interactive way while staying connected to their cultural identity.

The novelty of this study lies in combining three components in one learning media product: AI, the ethnophysics of the Acehnese traditional house (*Rumoh Aceh*), and the SDG 4 framework for quality education. To the authors' knowledge, such integration remains limited in

existing studies. Earlier work either developed generic AI-based media without specific cultural content (Anggraini et al., 2024) or examined the architecture and ethnophysics of *Rumoh Aceh* conceptually without using AI as a learning tool (Zuhra et al., 2022). This study instead builds media that pair AI-supported learning interaction with culturally contextualized physics content from *Rumoh Aceh*. Connecting physics concepts to the visible features, structures, and cultural knowledge of the traditional house gives students a distinctive learning context, and aligning the media with SDG 4 principles adds a broader orientation toward inclusive, contextual, and quality learning. The contribution is thus AI-integrated physics media that bring together technological innovation, Acehnese cultural heritage, and the principles of sustainable education.

In the media, AI acts as an interactive learning assistant for students. The technical architecture has three parts: an AI interface embedded in the media, an AI processing component that receives and interprets students' questions or inputs, and a response-generation component that returns contextual explanations of the physics concepts being studied. The AI is tied to the learning content, so its answers stay focused on the physics concepts and the ethnophysics context of *Rumoh Aceh* instead of behaving like a general-purpose information source. Students can therefore ask questions, request explanations, clarify concepts, and receive support grounded in the material. In this way AI serves as more than an add-on feature; it is a mechanism for contextualized physics learning. The quality of the product was judged against three widely used criteria for educational product development: validity, practicality, and effectiveness (Nieveen, 1999; Plomp & Nieveen, 2013). Validity was assessed by subject matter, media, and cultural experts, practicality by teacher and student questionnaires on ease of use and usefulness, and effectiveness by gains in students' conceptual understanding of physics after using the media. In light of the research gap and novelty described above, this study aims to develop AI-integrated physics learning media based on the ethnophysics of *Rumoh Aceh* and to evaluate their validity, practicality, and effectiveness, in order to promote physics learning that is meaningful, culturally relevant, interactive, and consistent with the principles of sustainable education.

2. METHOD

2.1 Research Design

This study used a research and development (R&D) design to produce AI-integrated physics learning media based on the ethnophysics of the Acehnese traditional house (*Rumoh Aceh*) and to evaluate their validity, practicality, and effectiveness. Development followed the Four-D (4D) model of Thiagarajan et al. (1974), which has four consecutive phases: define, design, develop, and disseminate.

2.2 Research Site and Period

The research took place in two junior high schools in different regencies of Aceh Province, Indonesia: SMP Negeri 1 Sakti in Pidie Regency and SMP Negeri 1 Bandar Baru in Pidie Jaya Regency. The schools were chosen purposively to widen representation in the field-testing phase and to support the generalizability of the media. They differ in geographical setting, representing both coastal and inland areas, as well as in student characteristics, school environment, and learning facilities, which allowed the effectiveness, practicality, and applicability of the media to be examined under varied educational conditions.

2.3 Research Participants

The participants were science/physics teachers and Grade VII students from two public junior high schools in Aceh: SMP Negeri 1 Sakti (Pidie Regency) and SMP Negeri 1 Bandar Baru (Pidie Jaya Regency). In total, 50 Grade VII students took part, 25 from each school. Purposive sampling was used with three criteria: (1) the students were officially enrolled in Grade VII, (2) they were studying the relevant science topics, namely force, equilibrium, and heat transfer, and (3) they were willing and able to take part in learning activities with the developed media.

The 25 students from SMP Negeri 1 Sakti joined the small-group trial, which looked at the usability and practicality of the media, and the 25 students from SMP Negeri 1 Bandar Baru joined the field trial, taking the pretest and posttest to measure change in conceptual understanding. Science/physics teachers from both schools contributed to the needs analysis and the practicality evaluation by describing students' learning needs and how well the media suited classroom use. Schools and participants were selected according to how well the topics matched the media, the availability of Grade VII students, and the schools' willingness to take part.

2.4 Development Procedure

2.4.1 Define Stage

The define stage identifies the learning needs on which media development rests (Thiagarajan et al., 1974). It comprises five activities. Front-end analysis uses interviews and observations to identify problems in physics learning, the availability of local culture-based media, and readiness to adopt AI. Learner analysis examines students' characteristics, such as digital literacy, cultural background, and prior knowledge of *Rumoh Aceh*. Concept analysis determines which physics concepts (force, rigid-body equilibrium, heat, and heat transfer) are embedded in the structure of *Rumoh Aceh*. Task analysis plans AI-supported learning activities. Finally, the specification of learning objectives sets out the objectives and achievement indicators from which the evaluation instruments of the develop stage are built.

2.4.2 Design Stage

The design stage produces the first prototype of the media through four activities. Criterion-referenced tests are constructed by drafting the pretest and posttest blueprint from the objectives set in the define stage. Media selection decides which AI-based media to build given the available technological facilities. Format selection settles the presentation format, interface layout, visual design, and flow of user interaction. Initial design then yields the first prototype (Draft I) of the AI-integrated ethnophysics learning media based on *Rumoh Aceh*, ready for expert validation.

2.4.3 Develop Stage

The develop stage turns the prototype into media that are valid, practical, and effective, and has three activities. In expert validation, four validators evaluated the prototype: one physics content expert, one language expert, one Acehnese culture/ethnophysics expert, and one learning media expert. The product was then revised according to their input. In the small-group trial, number of teachers teachers and number of students students tried the media to give early feedback on practicality. In the field trial, held at SMP Negeri 1 Sakti and SMP Negeri 1 Bandar Baru,

teacher and student response questionnaires measured practicality, and pretest and posttest scores on students' conceptual understanding measured effectiveness.

2.4.4 Disseminate Stage

The disseminate stage introduces and applies the final media after they have been declared valid, practical, and effective. Here, dissemination was limited in scale and carried out at SMP Negeri 1 Sakti and SMP Negeri 1 Bandar Baru through teacher training on using the media, classroom implementation in physics lessons, and documentation of the results as material for evaluation and for recommendations on future improvement and wider dissemination.

2.5 Data Collection Techniques and Instruments

Table 1. Data Collection Techniques and Instruments

No.	Technique	Instrument	Data Source	Purpose
1	Interviews and observations	Interview and observation guidelines	Science teachers from both schools	Needs analysis (**Define Stage**)
2	Expert validation	Validation sheets for content, media, and cultural aspects	Physics content experts, media experts, and ethnophysics/cultural experts	Product validity evaluation
3	Response questionnaires	Teacher response questionnaire and student response questionnaire	Science teachers and students from both schools	Product practicality evaluation
4	Tests	Pretest and posttest items for physics conceptual understanding	Students from both schools	Product effectiveness evaluation

Based on Table 1, validation sheets and response questionnaires used a Likert scale of [1–4 / 1–5]. The test instrument consisted of [number] [multiple-choice / essay] items based on indicators of conceptual understanding of force, equilibrium, and heat as embedded in the structure of *Rumoh Aceh*. Content validity of the instruments was judged by [number] experts and quantified with Aiken's V (Aiken, 1985), which ranged from [lowest V] to [highest V], with all items falling in the [valid/high] category ($V \geq 0.80$). Reliability was tested using [Cronbach's alpha for the questionnaires and KR-20 for the test], yielding coefficients of [α teacher questionnaire], [α student questionnaire], and [KR-20 test], all above the 0.70 threshold.

2.6 Data Analysis Techniques

2.6.1 Validity Analysis

For each validator, the average percentage score was computed from the expert validation data and then converted into a validity category following Akbar (2013), as shown in Table 2.

Table 2. Validity Categories

Percentage	Category	Description
81%–100%	Very Valid	Can be used without revision
61%–80%	Valid	Can be used with minor revisions
41%–60%	Moderately Valid	Requires revision
21%–40%	Less Valid	Requires major revision
0%–20%	Invalid	Cannot be used

A product was regarded as valid when it reached at least the "valid" category (Akbar, 2013).

2.6.2 Practicality Analysis

Teacher and student questionnaire data from SMP Negeri 1 Sakti and SMP Negeri 1 Bandar Baru were analyzed descriptively and quantitatively by computing the percentage of response scores, which were then converted into practicality categories using the same criteria as for validity (Akbar, 2013). The media were considered practical when teachers and students at both schools found them easy to use and suited to classroom learning needs (Nieveen, 1999).

2.6.3 Effectiveness Analysis

Effectiveness was examined by comparing students' pretest and posttest scores to see how their conceptual understanding of physics changed. Because the study used a one-group pretest–posttest design without a control group, the effect size was also calculated to show the magnitude of the observed effect. Scores were analyzed with the normalized gain (N-Gain) proposed by Hake (1998), using the following formula:

$$g = \frac{S_{Posttest} - S_{Pretest}}{S_{max} - S_{pretest}} \quad (1)$$

N-Gain values were categorized according to (Hake, 1998), as presented below:

Table 3. Effectiveness Categories

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

3. RESULTS AND DISCUSSION

3.1 Results of the Define Stage

3.1.1 Results of the Front-end Analysis

Front-end analysis combined classroom observations with semi-structured interviews of science teachers at SMP Negeri 1 Sakti and SMP Negeri 1 Bandar Baru. It aimed to uncover

learning problems, the media available, the extent to which local wisdom was integrated, and the schools' readiness to use AI-based learning media. Table 4 summarizes the findings.

Table 4. Results of the Front-end Analysis

Aspect	Findings
Physics learning	Lectures, textbooks, and PowerPoint presentations still dominate physics lessons. Students find abstract physics concepts hard to grasp, especially force, equilibrium, elasticity, and heat transfer.
Learning media	Media in use are limited to printed textbooks, student worksheets (LKPD), and presentation slides. AI-based media have not yet been provided or used in lessons.
Local cultural integration	Acehnese local culture is not yet part of physics lessons. Teachers noted that textbook examples remain general and are not tied to students' real-life experiences.
Potential of *Rumoh Aceh*	Teachers saw great potential in *Rumoh Aceh* as a contextual learning resource, since it contains physics concepts such as force distribution, structural equilibrium, elasticity of wooden materials, and natural ventilation.
ICT facilities	Both schools have internet access, LCD projectors, and computer laboratories, and most students own Android smartphones.
AI readiness	Teachers know AI applications such as ChatGPT, but use them only to look up information and prepare materials, not as an interactive learning medium.
Development needs	Teachers want AI-based media that integrate the ethnophysics of *Rumoh Aceh* to support contextual learning and deepen students' conceptual understanding.

Table 4 shows that physics teaching in both schools is still teacher-centered and relies mostly on conventional resources. Students consequently continue to see physics as abstract, because lessons seldom relate concepts to phenomena they meet in daily life. More contextual media that link scientific concepts to students' real experiences are therefore needed. The analysis also shows that Acehnese local wisdom has not been optimally integrated into physics teaching, even though *Rumoh Aceh* is a promising ethnophysics resource. The traditional house embodies static equilibrium, load distribution, elasticity of wooden materials, heat transfer, and natural air circulation. Presenting these concepts through a local cultural context should make them more concrete for students and strengthen their appreciation of Aceh's cultural heritage.

3.1.2 Results of the Learner Analysis

Learner analysis used questionnaires and interviews with Grade VII students at SMP Negeri 1 Sakti and SMP Negeri 1 Bandar Baru to describe the characteristics on which the media were designed. Most students showed good digital literacy, being able to use smartphones and the internet for learning. Their use of AI, however, was limited to searching for information, and AI had not been used as a learning medium. Culturally, students knew *Rumoh Aceh* as the traditional house of Aceh but did not yet understand the physics concepts built into its structure. They also preferred visual and interactive learning and were more interested in activities using images,

animations, videos, and simulations. These characteristics indicate that AI-based physics media built on the ethnophysics of *Rumoh Aceh* suit students' profiles and needs, and the media are expected to improve conceptual understanding while nurturing appreciation of local cultural heritage.

3.1.3 Results of the Concept Analysis

Concept analysis identified the physics concepts embedded in the structure of *Rumoh Aceh* and their relevance to junior high school learning outcomes. *Rumoh Aceh* proved to be a promising contextual resource because it contains several physical phenomena that can be brought into lessons. The first concept is force: the supporting pillars of the stilt house receive the load of the building and transfer it to the ground. The second is rigid-body equilibrium, seen in the frame and wooden joints that keep the building stable under loads and environmental forces. The third is heat: the high roof, ventilation, and windows of *Rumoh Aceh* allow natural air circulation, keeping the interior comfortable without artificial cooling. These findings guided the development of learning materials, the design of visual illustrations, and the creation of AI-based interactive features. Linking physics concepts to the structure of *Rumoh Aceh* is expected to make the concepts easier to grasp in context while increasing appreciation of Acehnese local wisdom.

3.1.4 Results of Task Analysis and Learning Objective Formulation

Task analysis determined the competencies students should reach according to the Science Learning Outcomes (Capaian Pembelajaran/CP) for Phase D of the Merdeka Curriculum. It centered on force, rigid-body equilibrium, and heat, tied to physical phenomena in *Rumoh Aceh*, and provided the basis for learning indicators, materials, activities, and assessment instruments. The learning objectives formulated were: (1) to explain the concept of force and how it applies in the supporting pillars of *Rumoh Aceh*; (2) to analyze the principles of rigid-body equilibrium in the construction of the Acehnese traditional house; (3) to explain heat transfer and natural air circulation through the roof and ventilation design of *Rumoh Aceh*; and (4) to apply these concepts to analyze phenomena in the surrounding environment. These objectives then served as the reference for the conceptual understanding test, the student activity sheets, and the evaluation features of the AI-based media. Every test item was aligned with the learning indicators so that it could measure students' competency achievement validly and in context.

3.2 Results of the Design Stage

3.2.1 Construction of Criterion-Referenced Tests

The criterion-referenced tests were built from the learning objectives set in the define stage. Pretest and posttest items were written to measure students' conceptual understanding before and after they used the AI-based media integrated with the ethnophysics of *Rumoh Aceh*. The blueprint was organized around indicators for force, rigid-body equilibrium, and heat, linked to physical phenomena in *Rumoh Aceh* such as the supporting pillars, frame construction, ventilation, and roof. Each item was based on a competency indicator and on students' cognitive level in the revised Bloom's taxonomy (C2–C4), so that the test could assess how well students understand, apply, and analyze physics concepts in context. The blueprint was then used to write the pretest and posttest instruments, which experts validated before the product trial. The instruments are therefore

expected to measure improvement in conceptual understanding in a valid, reliable manner consistent with the learning objectives.

3.2.2 Results of Media and Format Selection

Media and format were chosen on the basis of the teacher needs analysis, students' characteristics, and the facilities available at SMP Negeri 1 Sakti and SMP Negeri 1 Bandar Baru. The product is web-based learning media with an AI-based educational chatbot, interactive materials, instructional videos, and adaptive exercises. A web format was selected because computers and Android smartphones, which both schools have, can open it easily. During development, visual references of *Rumoh Aceh* were first generated with Gemini AI to produce illustrations showing the architectural characteristics of the Acehnese traditional house. These illustrations served as the main material for instructional videos made with FlowLab AI, giving more dynamic visualizations to support the delivery of physics concepts. The videos were edited in Filmora, where narration, illustrations of physics concepts, and other supporting elements were added. Finally, subtitles were added in CapCut so that the information would be easier for students to follow and the media more accessible.



Figure 1. Flowchart of AI-Based Video Learning Media Development

3.3.3 Initial Prototype

Drawing on the needs analysis and the design stage, an initial prototype (Draft I) of the AI-based physics media integrated with the ethnophysics of *Rumoh Aceh* was produced. It was built as a web application with a simple, interactive, user-friendly interface that opens on both computers and smartphones.



Figure 2. Initial prototype interface of the Artificial Intelligence-based learning media integrated with the ethnophysics of *Rumoh Aceh*.

3.4 Results of the Develop Stage

3.4.1 Results of the Validation Stage

Table 5. Results of Expert Validation of the Learning Media

No.	Validator	Assessed Aspects	Percentage (%)	Category
1	Physics Content Expert	Suitability of physics concepts (force, rigid-body equilibrium, and heat), accuracy of learning materials, presentation of concepts, and alignment with learning outcomes	92.50	Very Valid
2	Learning Media/ Technology Expert	Interface design, navigation ease, visual appearance, video quality, AI chatbot functionality, and media interactivity	90.00	Very Valid
3	Acehnese Culture/ Ethnophysics Expert	Accuracy of *Rumoh Aceh* representation, suitability of cultural values, accuracy of illustrations, and ethnophysics integration	94.17	Very Valid
	Overall Average		**92.22**	**Very Valid**

Table 5 shows that the AI-based media integrated with the ethnophysics of *Rumoh Aceh* earned an average score of 92.22%, categorized as very valid. The media therefore meet the requirements for content feasibility, media design, and cultural appropriateness, and could proceed to trial after being refined according to the validators' suggestions. The physics content expert reported that the materials matched the learning outcomes and the physics concepts built into the structure of *Rumoh Aceh*, but recommended more examples of force and equilibrium in different parts of the house so that students can better connect theory with real phenomena. The learning media/technology expert advised improving the interface by enlarging fonts on several pages, making navigation icons clearer, and adding instructions for the AI chatbot so that students could operate the media more easily. The Acehnese culture/ethnophysics expert asked that the illustrations of *Rumoh Aceh* better reflect traditional Acehnese architecture, including the roof shape, the number of supporting pillars, and the building orientation, and that the explanations of cultural values in its construction be strengthened so that the media serve not only as a physics learning tool but also as a means of preserving local cultural heritage.

The product was revised according to all of these suggestions, producing Draft II, which was then used in the practicality and effectiveness tests.

Table 6. Summary of Product Revisions Based on Validators' Suggestions

No.	Validator	Suggestions/Feedback	Revision Actions
1	Physics Content Expert	Add examples of how force, equilibrium, and heat concepts apply in the structure of *Rumoh Aceh*, and make some conceptual explanations clearer.	Added concept illustrations for the supporting pillars, building structure, ventilation, and roof of *Rumoh Aceh*, and refined the materials in line with the validator's advice.
2	Learning Media/Technology Expert	Enlarge fonts, improve navigation icons, adjust color combinations, and add instructions for using the AI chatbot.	Redesigned the interface, made text easier to read, refined navigation, and added a user guide page.
3	Acehnese Culture/Ethnophysics Expert	Align the illustrations of *Rumoh Aceh* with its authentic architectural features and strengthen the explanation of Acehnese cultural values.	Replaced illustrations with more representative references, added cultural descriptions, and improved the ethnophysics narrative of *Rumoh Aceh* for accuracy.

3.4.2 Results of the Field Trial

The field trial determined the practicality of the AI-based media integrated with the ethnophysics of *Rumoh Aceh*. It was held at SMP Negeri 1 Sakti (Pidie Regency) and SMP Negeri 1 Bandar Baru (Pidie Jaya Regency), and practicality was rated through teacher and student response questionnaires completed after using the media.

3.4.2.1 Practicality Results Based on Teacher Response Questionnaires

Table 7. Results of the Science Teacher Response Questionnaire

No.	School	Percentage (%)	Category
1	SMP Negeri 1 Sakti	94.44	Very Practical
2	SMP Negeri 1 Bandar Baru	91.67	Very Practical
	Combined Average	**93.06**	**Very Practical**

As Table 7 shows, the media reached an average practicality of 93.06% from teachers, categorized as very practical. Science teachers at both schools found the media easy to operate, attractive in appearance, and helpful for explaining physics through the context of *Rumoh Aceh*. The percentage at SMP Negeri 1 Bandar Baru was slightly lower than at SMP Negeri 1 Sakti, a difference attributed to less stable internet access, which lengthened loading times for videos and the AI chatbot.

3.4.2.2 Practicality Results Based on Student Response Questionnaires

Table 8. Results of the Student Response Questionnaire

No.	School	Number of Students	Percentage (%)	Category
1	SMP Negeri 1 Sakti	30	92.31	Very Practical
2	SMP Negeri 1 Bandar Baru	30	89.84	Very Practical
	Combined Average	**60**	**91.08**	**Very Practical**

According to Table 8, students' responses averaged 91.08%, also very practical. Students responded positively to the interface, ease of navigation, instructional videos, and the AI chatbot, which answered their questions directly. Connecting physics concepts to the structure of *Rumoh Aceh* also made the material easier to follow because the context was familiar to them. Both schools fell in the same category, but practicality at SMP Negeri 1 Sakti was slightly higher than at SMP Negeri 1 Bandar Baru, probably because internet conditions and the availability of digital devices were somewhat better at SMP Negeri 1 Sakti. The gap was small, which suggests that the media were highly practical and usable in both schools. Overall, teachers and students at both research schools rated the AI-based media integrated with the ethnophysics of *Rumoh Aceh* as highly practical, indicating that the media are easy to use, engaging, and able to support contextual physics learning.

3.4.3 Effectiveness Results Based on Pretest–Posttest

Effectiveness was measured through gains in students' conceptual understanding of physics between the pretest and posttest, analyzed with the normalized gain (N-Gain) method of Hake (1998).

Table 9. Pretest, Posttest, and N-Gain Results of Physics Conceptual Understanding

No.	School	Mean Pretest Score	Mean Posttest Score	N-Gain (g)	Category
1	SMP Negeri 1 Sakti	48.27	85.13	0.71	High
2	SMP Negeri 1 Bandar Baru	46.80	82.45	0.67	Moderate
	Overall Average	**47.54**	**83.79**	**0.69**	**Moderate**

Table 9 shows that students' conceptual understanding of physics improved at both schools after they used the AI-based media integrated with the ethnophysics of *Rumoh Aceh*. At SMP Negeri 1 Sakti, the mean score rose from 48.27 on the pretest to 85.13 on the posttest (N-Gain 0.71, high), and at SMP Negeri 1 Bandar Baru it rose from 46.80 to 82.45 (N-Gain 0.67, moderate). This gain can be explained by contextual and constructivist learning theory, which holds that conceptual understanding is internalized more effectively when new information is anchored in authentic, culturally familiar contexts (Brown et al., 1989; Vygotsky, 1978). By placing abstract concepts such as force, rigid-body equilibrium, and heat within the tangible structure of *Rumoh Aceh*, the media let students build meaning from what they already knew culturally rather than memorize decontextualized formulas. The result is also consistent with Mayer (2009) cognitive theory of multimedia learning, which argues that combining visual, narrative, and interactive elements, as the AI chatbot, instructional videos, and adaptive exercises did here, lowers extraneous cognitive load and supports deeper processing of scientific concepts.

The findings also agree with earlier empirical work. Sriwahyuni et al. (2025) found that ethnophysics-based teaching using traditional house structures improved students' conceptual understanding of natural phenomena, and the present study likewise indicates that embedding physics concepts in local architectural heritage strengthens contextual reasoning. As for the AI features, Labadze et al. (2023) and Lin et al. (2023) reported that AI tutoring and chatbot features can improve learning outcomes by giving immediate, personalized feedback, which is in line with the results here. This affordance may have contributed to the higher N-Gain at SMP Negeri 1 Sakti, where technological infrastructure and students' familiarity with digital tools were more favorable.

The overall N-Gain of 0.69 falls in the moderate category. Rather than signaling limited effectiveness, this may reflect contextual and infrastructural conditions more than the instructional design: unstable internet connectivity and differing levels of prior digital literacy at SMP Negeri 1 Bandar Baru probably limited students' use of the interactive features. This reading agrees with Lin et al. (2023), who noted that the effectiveness of AI-based learning tools depends on users' technological readiness and access as well as on pedagogical design. These explanations remain interpretive, however, because internet quality and digital literacy were not measured directly. Taken together, the results suggest that combining ethnophysics and AI can improve conceptual understanding by placing abstract science content in culturally meaningful, technology-mediated experiences, although, without a control group, the gain cannot be attributed to the media alone.

3.5 Statistical Test Results

A paired-sample t-test showed a significant difference between pretest and posttest scores at both schools ($p < 0.001$), indicating that students' conceptual understanding of physics improved significantly after they used the AI-based media integrated with the ethnophysics of *Rumoh Aceh*.

3.6 Results of the Dissemination Stage

In the dissemination stage, teachers responded positively because the media were easy to operate, matched the Merdeka Curriculum, and linked physics concepts to Acehnese local culture. This agrees with earlier research showing that physics learning based on traditional houses fits the Science Learning Outcomes (Capaian Pembelajaran IPA) of the Merdeka Curriculum, which stress observing natural phenomena and students' real-life contexts through local culture (Sriwahyuni et al., 2025). Students were also very enthusiastic, particularly about the AI chatbot, which answered their questions directly. Earlier studies likewise indicate that AI chatbots and virtual assistants provide instant answers and explanations that raise student engagement (Labadze et al., 2023). These results suggest that the media were implemented well in both schools and could serve as an alternative physics learning medium that combines technology with local cultural context.

3.7 Cultural Preservation and Alignment with SDG 4

The AI-based media integrated with the ethnophysics of *Rumoh Aceh* are more than a physics learning tool; they also act as a means of preserving Acehnese local culture. Bringing the structure and philosophy of *Rumoh Aceh* into the physics materials lets students rediscover the cultural values of the traditional house while learning concepts such as force, rigid-body equilibrium, and heat transfer. Learning is thus aimed not only at conceptual mastery but also at appreciation of regional cultural heritage as part of national identity. Using AI in the media also makes learning more interactive, adaptive, and student-centered. The educational chatbot, interactive videos, and adaptive assessments allow students to learn at their own pace and according to their needs, which widens access to flexible learning resources and encourages active engagement.

The media are also aligned with the principles of SDG 4 (Quality Education), which seeks inclusive, equitable, and quality education and lifelong learning opportunities for all. This alignment is reflected in the aspects examined here, namely learning quality, accessibility, contextual relevance, and learning effectiveness, assessed through media validity, teacher and student practicality responses, and pretest–posttest gains. The study did not directly measure sustainability-related outcomes or SDG indicators, so the media are presented as consistent with SDG 4 principles and not as evidence of progress toward the goal itself. Combining AI with local wisdom yields innovative, contextual media that can improve the quality of science learning without neglecting students' cultural identity. This is in line with AlSagri and Sohail (2024), who argue that AI in education should be integrated with local contexts so that it improves learning effectiveness and contributes to sustainable educational development.

3.8 Limitations and Future Research

This study has several limitations. First, it used a one-group pretest–posttest design without a control group, so the learning gains cannot be attributed to the media with certainty. Second, the sample was small and came from only two junior high schools in Pidie and Pidie Jaya, which limits

generalization. Third, no delayed posttest was given, so the retention of learning is unknown. Fourth, practicality data came from self-reported questionnaires, and the chatbot depended on stable internet access, which differed between the two schools. Future research should use quasi-experimental designs with control groups, involve larger and more diverse samples, lengthen the intervention and add delayed tests, develop an offline or low-bandwidth version, and examine outcomes such as scientific literacy, cultural awareness, and indicators more closely related to SDG 4.

4 CONCLUSION

This study developed AI-based physics learning media integrated with the ethnophysics of *Rumoh Aceh* using the Four-D (4D) model. Expert assessment rated the media very valid, teacher and student responses rated them very practical, and students' conceptual understanding improved, with a mean N-Gain of 0.69 (moderate category) and a significant pretest–posttest difference ($p < 0.001$). Besides supporting students' understanding of force, rigid-body equilibrium, and heat, the media help preserve local wisdom by connecting physics concepts to the structure of *Rumoh Aceh*. They are also aligned with SDG 4 principles by offering innovative, contextual, and high-quality learning experiences. Given the single-group design and small sample, future studies should test the media with control groups and larger samples.

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