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Research Article

TRANSFORMATION SCIENCE CLASSES WITH ARTIFICIAL INTELLIGENCE AND THE TRADITION OF "SEDEKAH BUMI": LEARNING ABOUT RENEWABLE ENERGY IN CONTEXT

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Abstract
The lack of scientific literacy among students requires teachers to design interesting lessons and foster students' curiosity about renewable energy. Physics lessons based on ethnoscience through the tradition of "Sedekah Bumi" integrated with Artificial Intelligence are expected to improve scientific process skills. The objectives of this study are (1) to determine the validity of the worksheets in relation to students' learning barriers, and (2) to determine the improvement in students' scientific process skills. This study involved 40 students from a senior high school. The research was conducted from April to November 2025. The type of research used was Design Research, consisting of the Preparing for the Experiment, Design Experiment, and Retrospective Analysis stages. Implementation in 3 cycles through Lesson Study between researchers, physics teachers, and students collaborating to design renewable energy learning tools in the form of lesson plans and worksheets. Data collection instruments used tests, questionnaires, observation sheets, and interview guidelines. Data analysis was descriptive with a quantitative mix of tests and reanalyzed qualitatively from the results of interviews, observations, and documentation. The results of the study show (1). Worksheets based on the results of material validation, curriculum of 0.92 (Highly Valid), media validation of 0.89 (Highly Valid) and lesson study expert validation of 0.90 (Highly Valid). (2). The average increase in students' science process skills was 0.83, which is in the high category. Further research is recommended to develop renewable energy modules assisted by Artificial Intelligence through biomass waste to improve students' science literacy.

Keywords: Contextual, Lesson Study, Renewable Energy, Science Process Skills

INTRODUCTION

Renewable energy education based on local wisdom in Lubuklinggau City has great potential because it is able to integrate modern technology with the traditional values of the local community. One form of local wisdom is the Sedekah Bumi tradition, which is an expression of gratitude by the agrarian community for their agricultural yields, manifested through various social activities, including commu nal cooking. In practice, this activity utilizes agricultural waste such as rice husks and wood powder as alternative fuels to replace gas. This phenomenon demonstrates a clear link between local culture and the concept of renewable energy, thus having the potential to become an authentic learning resource in science education.

However, this contextual potential has not been optimally utilized in classroom learning practices. Renewable energy learning still tends to be conceptual and separate from students' real experiences, making it difficult for students to fully understand renewable energy concepts in an applicable way (Esmaeilpour Moghadam & Karami, 2024; Yolanda, Arini, Effendi, et al., 2025). This condition has an impact on students' low science process skills, particularly in observation, experimentation, data analysis, and scientific communication related to environmental issues in their surroundings (Oriented et al., 2020; Panda, 2020; Yolanda, 2020). In addition, teachers do not yet have a contextual learning design that systematically integrates the local wisdom of Sedekah Bumi into renewable energy learning, so that learning has not been able to foster scientific literacy (Aas et al., 2024; Khurramov et al., 2025), interest in learning, and student concern for environmental sustainability issues (Maison et al., 2021).

On the other hand, although renewable energy issues have become a major focus in various international studies and have begun to be integrated into science education curricula, the use of digital technology, including artificial intelligence in learning, still faces various limitations (Watjanatepin et al., 2023). Previous studies have generally developed digital media such as animations, interactive videos, and quizzes, but most still place technology solely as a means of conveying information. Studies that systematically develop digital pedagogy-based instructional designs, oriented towards the learning process of students, and tailored to the learning needs and obstacles of students are still relatively limited. In addition, most studies have not considered the local and socio-cultural context, even though the understanding of renewable energy concepts is greatly influenced by the geographical, social, and economic conditions of students.

Furthermore, empirical studies that comprehensively evaluate the effectiveness of digitizing learning design in improving students' renewable energy literacy and science process skills are still minimal, especially those that combine digital technology, local wisdom, and reflective approaches such as Lesson Study. The integration of local values, such as the Sedekah Bumi tradition, which represents sustainable practices and respect for nature, has also not been widely explored in technology-based renewable energy learning design. This condition shows a gap between the development of generic digital learning and the needs of contextual learning in the field.

To address these issues, a contextual learning approach is needed that links the concept of renewable energy to the real world of students. Renewable energy is an abstract concept, so the process of understanding it needs to be linked to concrete objects and phenomena in everyday life (Bamzadeh et al., 2021; Senyapar, 2023). Contextual learning is relevant because it connects the subject matter to the real experiences of students by strengthening their scientific process skills. In this study, the learning design was implemented through Lesson Study with sharing task and jumping task strategies aimed at stimulating students' science literacy and scientific process skills in a gradual and in-depth manner (Hidayat et al., 2020; Bintoro et al., 2021; Zhang, 2024).

Initial observations at Lubuklinggau State High School 2 show that 88% of students' science process skills are low. This condition is caused by physics teaching methods that are still oriented towards theoretical concept delivery, so that scientific processes such as observation, experimentation, data analysis, and scientific communication have not been optimally facilitated. In addition, artificial intelligence has not been introduced and integrated into physics learning in the classroom (Powers et al., 2023). Teachers' lack of understanding in designing ethnoscience-based learning and integrating artificial intelligence means that the potential of technology and local wisdom has not had a significant impact on the quality of learning. Learning evaluation also still focuses on cognitive outcomes and lacks collaborative reflection, so that learning improvements have not been made sustainably (Le et al., 2024).

Therefore, the integration of artificial intelligence, local wisdom of Sedekah Bumi, and a collaborative reflective approach through Lesson Study is considered a relevant solution (Khurramov et al., 2025; Olga et al., 2024). This approach enables educators to systematically and continuously design, implement, and reflect on learning based on empirical evidence in the classroom (Fatimah et al., 2018; Verawati & Supriatna, 2020). The integration of artificial intelligence in contextual learning about renewable energy based on the Sedekah Bumi tradition is expected to significantly improve students' science process skills while fostering ecological awareness and responsibility for environmental sustainability (Jin et al., 2024; Temitayo et al., 2024; Shan Wang et al., 2024).

Based on this background, this study aims to examine the use of artificial intelligence in contextual learning of renewable energy that integrates the Sedekah Bumi tradition and evaluate its effectiveness in improving students' science process skills through the Lesson Study approach. The results of this study are expected to contribute theoretically and practically to the development of innovative, contextual, and adaptive science learning designs that meet the demands of 21st-century education.

RESEARCH METHOD

This study involved 40 tenth-grade students from Lubuklinggau State High School 2 as samples taken using purposive sampling and three physics teachers who served as observers to observe the learning process and measure students' science process skills during the learning process using lesson study.

Table 1. Distribution of research samples

School Name	Class	Sample
Lubuklinggau State Senior High School 2	XA	8 Students
	XB	8 Students
	XC	8 Students
	XD	8 Students
	XE	8 Students
	Number	40 Students

The research stages, namely Design Research, are divided into three stages, namely Preparing for the experiment, the design experiment(Boistrup & Selander, 2022), and the retrospective analysis ((Bakker, 2018; Creswell, 2020). Furthermore, the learning design was carried out in three collaborative cycles through Lesson Study between the researcher and physics teachers, as described in Table 2. The researcher, together with teachers and students, collaborated to design renewable energy learning tools in the form of lesson plans, Student Worksheets 1 and worksheet 2.

Table 2. Stages of Design Research with Lesson Study

Design Research Phase	Lesson Study Phase	Activities
The Preparing for The Experiment	PLAN	• Literature review • Conducting Focus Group Discussions (FGDs) with fellow lecturers and physics teachers at school • Designing the Hypothetical Learning Trajectory (HLT) • Developing a pilot experiment: worksheet 1 (Sharing Task) and WORKSHEET 2 (Jumping Task) • Implementing three PLAN stages in the Lesson Study cycles

The Design Experiment	DO	• Classroom opening activities and Teaching Experiment using Contextual Teaching and Learning (CTL) • All observers lecturers, teachers, and students observe the implementation of the Pilot Experiment using CTL conducted by the model teacher • Three cycles of the DO stage are carried out • Assessment of students' scientific literacy and science process skills is conducted • University students observe student activities during the Sharing Task and Jumping Task within each group to measure achievements in scientific literacy and science process skills
The Restopective Analysis	SEE	• Data analysis during the Pilot Experiment and Teaching Experiment stages is conducted using walkthroughs, documentation, observations, and interviews • Comparing the Hypothetical Learning Trajectory (HLT) with the Actual Learning Trajectory (ALT) • All observers reflect on their observations and present feedback to the model teacher in a forum involving the expert and all observers • Three cycles of the SEE stage are conducted
	REDESIGN	• Refining the Pilot Experiment of the learning design based on Contextual Teaching and Learning (CTL) • Three cycles of the Redesign stage are conducted

The WORKSHEET validation test data was analyzed using equation 1 and equation 2(Creswell, 2020).

$$V = \frac{\Sigma s}{n(c-1)} \text{ .... (1)}$$

Where $V = Validitas$, then s = $Skor = r - lO$. And lO = the lowest validity score, c = the highest validity score, r = the number or score given by the assessor, and n = the number of statements. Validity criteria in Table 4.

$$x = \frac{\sum x}{n} \qquad (2)$$

The following data conversion categories are adjusted according to the level of tendency shown in Table 3. Next, product validation and feasibility are carried out. Feasibility assessment by expert validators(Wallwey & Kajfez, 2023).

Tabel 3. Conversion of Actual Score to Scaled Score 5

Score range	Range	Category
$X > \bar{x} + 1{,}80\ Sbi$	$0{,}81 < V \leq 1{,}0$	Very Valid
$\bar{x} + 0{,}60\ SBi < X \leq \bar{x} + 1{,}80\ Sbi$	$0{,}60 < V \leq 0{,}80$	Valid
$\bar{x} - 0{,}60\ SBi < X \leq \bar{x} + 0{,}60\ Sbi$	$0{,}41 < V \leq 0{,}60$	Valid Enough
$\bar{x} - 1{,}80\ SBi < X \leq \bar{x} - 0{,}60\ Sbi$	$0{,}21 < V \leq 0{,}40$	Invalid
$X \leq \bar{x} - 1{,}80\ Sbi$	$0 < V \leq 0{,}20$	Not very valid

Next, to measure the improvement in science process skills, use Table 4.

Tabel 4. N-Gain Classification

Scale <g>	Category
$g \geq 0{,}7$	High

$0{,}7 > g \geq 0{,}3$	Middle
$0{,}3 > g$	Low

$$Standard\ Gain\ \bar{x} = \frac{\bar{x}_{after} - \bar{x}_{before}}{\bar{X} - \bar{X}_{before}} \quad \text{..................(2)}$$

Data Collection Techniques, using documentation, observation, and interview techniques. The walkthrough technique is a data collection technique that involves experts to evaluate the product being developed. This technique is usually carried out at the expert review stage to obtain the first prototype (Akker et al., 2013; Jan et al., 2023). The data collected includes student work, interview results, observation results, video recordings, and reflection results (Maison et al., 2021). The data is then analyzed using qualitative descriptive methods to describe the results of each learning design (Wallwey & Kajfez, 2023; Iwano & Tsuda, 2024). Data Analysis, in the form of descriptive analysis with a qualitative approach, is used to analyze qualitative data collected from interviews, observations, or documentation as described in Table 5.

Table 5. Instruments and Data Analysis

Data	Instrument	Analysis	Sample
Product Feasibility Test	The Expert Validation Questionnaire consists of: a) Expert validation of materials and curriculum b) Expert validation of media c) Expert validation of lesson study	The WORKSHEET feasibility test data was analyzed using quantitative descriptive methods.	3 expert
Student Learning Barriers	Observation Sheet for Sharing Tasks and Jumping Tasks using Lesson Study	The findings were analyzed using descriptive qualitative methods, namely confirmability, member checks, and in-depth interviews. The findings are presented in tables.	40 students
Students' Science Process Skills	Diagnostic assessment sheet Science process skills	Data using the Gain-Score test, analyzed descriptively and quantitatively, and presented in graphs and tables	40 students

RESULTS AND DISCUSSION

This study produced two Student Worksheets, namely Worksheet 1 (sharing task) and Worksheet 2 (jumping task), which were developed on the topic of Renewable Energy in the context of the Sedekah Bumi tradition. These worksheets are one of the main products designed through the Lesson Study approach and implemented in partner schools. During the planning stage, students from the Physics Education Study Program at PGRI Silampari University, together with researchers and teachers, conducted discussions and in-depth analysis of the material based on learning theory to determine the form of contextualization of renewable energy based on the local wisdom of the Taba Jemekeh community in Lubuklinggau City, which uses stoves fueled by rice husk waste and wood powder.

Table 6. Recapitulation of the Third Expert Validation related to WORKSHEET

Expert Validation Team	Average Achievement	Category
Expert Validation of Materials and Curriculum	0,92	Very High Validity
Media expert validation	0,89	Very High Validity
Expert validation of Lesson Study	0.90	Very High Validity

The next step was to design a context-based renewable energy learning program called Sedekah Bumi, which resulted in a Learning Implementation Plan (RPP), teacher guidelines, and two student worksheets. Worksheets 1 and worksheets 2 were then reviewed by experts (expert review) and tested through a one-to-one stage to assess their validity. Based on the input from these two stages, the researcher revised the content of the worksheet, especially the questions in worksheet 1, to better guide students in the process of finding ways to calculate the energy efficiency produced by rice husk stoves and LPG stoves. The questions in Worksheet 2 were also revised to better facilitate students' understanding of the issues presented. The revisions resulted in a valid worksheet that was in line with the learning objectives.

Table 7. Student KPS Achievement in Contextual Learning

No	KPS Indicator	Initial KPS	Final KPS		N-Gain	Category
		Cycle 1	Cycle 2 uses Sharing Task	Cycle 3 Using Jumping Tasks		
1	Observation skills	30	70	80	0.71	High
2	Classification skills	23	60	92	0.90	High
3	Measuring skills	21	62	94	0.92	High
4	Predictive skills	31	55	85	0.78	High
5	Data interpretation skills	24	50	80	0.74	High
6	Skills in hypothesis formation	33	62	87	0.81	High
7	Skills in planning experiments	43	79	94	0.89	High
8	Skills in using measuring instruments	20	60	80	0.75	High
9	Skills in applying concepts	15	50	89	0.87	High
10	Communication skills	32	56	94	0.91	High
	Average Increase in KPS				0.83	High

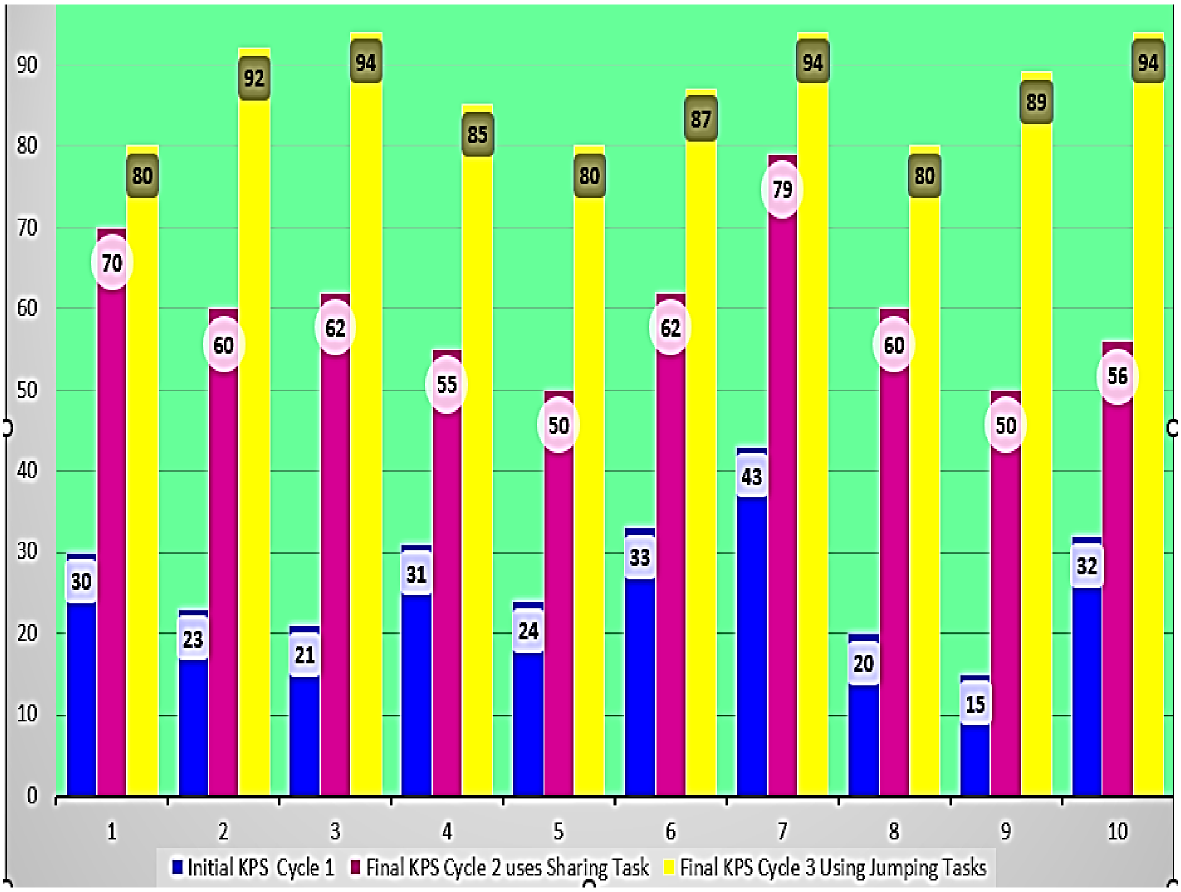

Figure 1. Improvement of Science Process skills in each cycle

The results of the study in Table 7 show that the application of artificial intelligence-assisted renewable energy contextual learning in the context of the Sedekah Bumi tradition based on Lesson Study has a very significant impact on improving students' science process skills, This is consistent with previous research findings(Imjai et al., 2025; Prayogi et al., 2025a). This is evidenced by the increase in scores on all science process skill indicators from cycle to cycle, as well as an average N-gain value of 0.83, which is classified as high.

In the initial cycle (Cycle 1), students' science process skills were still in the low to moderate category. This condition shows that before the intervention, students were not familiar with learning activities that required systematic observation, data processing, hypothesis formulation, and scientific communication. Learning was still oriented towards conceptual understanding without the active involvement of students in the scientific process as a whole. However, after the Sharing Task was implemented in Cycle 2, there was a significant increase in almost all science process skill kpsindicators. Collaborative discussion activities, sharing observation results, and utilizing the real context of the Sedekah Bumi tradition (such as the use of biomass, heat energy, and local alternative energy) encouraged students to be more active in observing, classifying, and interpreting phenomena that were close to their lives. This is in line with contextual learning theory, which emphasizes the connection between subject matter and students' real-life experiences so that learning becomes more meaningful(Huang & Ma, 2025; Nurhayati et al., 2025).

The most optimal improvement occurred in Cycle 3 through the application of Jumping Task, which requires higher order thinking skills (HOTS). At this stage, students not only understand the concept of renewable energy, but are also able to formulate hypotheses, design simple experiments, use measuring instruments, and communicate results scientifically, This proves that previous research is correct(Oluwasegun et al., 2025; Prayogi et al., 2025b). The integration of artificial intelligence plays an important role in supporting this process, particularly through the provision of rapid feedback, energy concept simulations, and adaptive data analysis assistance tailored to student needs. High N-gain values on the indicators of measuring skills (0.92), communication skills (0.91), and classification skills (0.90) show that AI-based and culturally contextual learning can strengthen procedural and communicative scientific skills. AI helps students understand how to use measuring instruments and interpret results, while the “Sedekah Bumi” context provides social and cultural meaning to the science learning process(Khurramov et al., 2025). This strengthens students' scientific communication skills, both verbally and in writing(Maison et al., 2021; Tanveer, 2025).

Overall, the average N-gain value of 0.83 indicates that the learning model applied is very effective in improving students' science process skills. This finding is in line with previous research results which state that contextual learning based on local culture can improve students' scientific thinking skills and conceptual understanding(Khurramov et al., 2025; Yolanda, Arini, Effendi, et al., 2025). In addition, research by also confirms that artificial intelligence in education is capable of supporting adaptive and personalized learning, thereby encouraging students' active involvement in the scientific process.

1.a. Students and teachers collaborate to reflect and refine renewable energy learning designs.

1.b The See and observer stages reflect the results of the model teacher's observations.

Figure 2. Lesson Study activities in designing in deep learning

The Lesson Study approach used in this study also contributed to improving the quality of learning. Through the plan–do–see stages, teachers can continuously reflect on their teaching practices and refine their lesson designs in each cycle (Ulfa et al., 2021). Collaboration among teachers allows learning to be more structured, responsive to student needs, and oriented towards the development of comprehensive science process skills. Thus, the results of this study confirm that the integration of artificial intelligence in contextual learning of renewable energy based on local wisdom, Sedekah Bumi, implemented through Lesson Study, has proven to be effective in significantly and sustainably improving students' science process skills (Kandaga et al., 2021).

The do stage of lesson study is implemented in the small group and field test stages. In the small group and field test stages, students are divided into four groups of four and asked to work on the worksheets individually (Solehah et al., 2021; Ng & Latife, 2022). Then, if students encounter difficulties, they can ask for help from their teammates. An interesting thing during this discussion is that students with high abilities guide students with low abilities who encounter difficulties so that the peer tutoring collaboration process runs well (Damayanti et al., 2020; Yolanda, Arini, Fauziah, et al., 2025)

2.a. Observation of science process skills during Lesson Study

2.b Students' curiosity in learning

Figure 3. Lesson Study activities in designing in deep learning

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Table 8. Conversation transcript of Sharing Task Indicators

Group 1	Group 2
Indicators Skills in Observing & Identifying Problems S1: If we pay attention, we can see that there are frequent power outages in some areas. I think this is a sign that fossil fuels are becoming scarce. S2: Yes, according to the data I've read, Indonesia's oil reserves are also declining every year. That means we can't continue to rely on fossil fuels. S3: In addition to being scarce, fossil fuels also produce carbon emissions. I've noticed that the environment is hotter now than it was a few years ago. S1: So there's a link between fossil fuel use and global warming? S2: Yes, that could be a major problem that we need to find a solution for. (Meaningfull Learning)	Indicators Questioning & Information Gathering Skills S4: Why do fossil fuels cause global warming? S5: Because when burned, coal and petroleum produce CO_2 gas that accumulates in the atmosphere. S6: I've seen a graph of the greenhouse effect. The more CO_2, the more solar heat is trapped and the Earth's temperature rises. S4: So, what is the impact on human life? S5: The impact can be extreme weather, rising sea levels, and health problems. S6: That means we need more environmentally friendly alternative energy sources. (Meaningfull Learning)
Group 3	Group 4
Indicators Skills, namely Classifying & Reasoning. S7: Let's categorize the types of energy. Fossil fuels are non-renewable, while solar and wind energy are renewable. From the discussion, renewable energy is safer because it does not produce harmful emissions.	Skill Indicators: Predicting & Communicating S10: In my opinion, if humans continue to use fossil fuels excessively, the Earth's temperature will continue to rise. But if we start switching to renewable energy, the impact of global warming can be reduced.

S9: If we compare them, fossil fuels are quickly depleted, but renewable energy can be used continuously. S7: So logically, the use of fossil fuels in the long term is not sustainable. S8: In conclusion, energy transition is important to prevent an energy crisis and global warming. (Joyfull Learning)	S12: So the prediction is that the future of the environment depends heavily on our energy choices today. S13: We can present the results of this discussion as a recommendation that clean energy needs to be implemented early on. (Meaningfull Learning)

Table 9. Conversation transcript of JumpingTask Indicators

Group 1	Group 2
Topic: The problem of rice husk waste being processed into biomass energy. science process skill dominant: Observing, Identifying problems, Reasoning S21: I observed that during the rice harvest, rice husks pile up around the mill and are rarely used. S22: Yes, they are usually just thrown away or burned. From my observations, this can pollute the air. S23: Rice husks are organic waste. In my opinion, they can be used as a source of biomass energy. S24: Logically, if rice husks are processed into energy, the waste problem can be reduced and the community can have an alternative energy source. S25: So, the main problem is the suboptimal utilization of rice husks as renewable energy.	Topic: The issue of coconut shell waste being processed into briquettes for cooking in the Sedekah Bumi tradition. science process skill dominant: Questioning, Gathering information, Classifying, Linking cultural context. S26: In the Sedekah Bumi tradition, residents cook large quantities of traditional food. In my opinion, the fuel is still wasteful. S27: Why aren't the abundant coconut shells in the village used as fuel? S28: I read that coconut shells can be processed into biomass briquettes with a fairly high heat value. S29: If used during Sedekah Bumi, coconut shell briquettes could replace firewood. S30: In conclusion, coconut shell waste can be classified as biomass energy that supports Sedekah Bumi traditions in a more environmentally friendly way. (Meaningful Learning)
Group 3	Group 4
Topic: Designing a biomass stove from waste materials for cooking in the Sedekah Bumi tradition. science process skill dominant: Designing, Reasoning, Predicting, Communicating ideas. S31: If the fuel is biomass, residents also need a stove that is suitable and easy to use S32: From our discussion, a biomass stove can be designed from used cans to be more economical with rice husk waste as fuel. S33: Conceptually, a biomass stove must be able to distribute heat effectively for cooking traditional foods. S34: According to my prediction, if the stove design is right, residents can cook more efficiently during Sedekah Bumi. S35: This biomass stove design can be a simple technological solution that is in line with local wisdom. (Joyfull Learning)	Topic: Testing the heat output of biomass stoves and LPG stoves in heating 1 liter of water. science process skill dominant: Measuring, Comparing, Interpreting data, Concluding S36: In this test, we observed the difference in heating time for 1 liter of water between a biomass stove and an LPG stove. S37: From the measurement results, the LPG stove heated the water faster. S38: However, the biomass stove is still capable of heating water to the same temperature. S39: This shows that, functionally, biomass stoves can be used as an alternative even though their efficiency differs. S40: In conclusion, the results of this test prove that biomass stoves are suitable for use in supporting cooking activities in the Sedekah Bumi tradition.

Tabel 9. Solusi Hambatan Keterampilan Proses Sains dan strategi Lesson Study

Barriers to Students' Science Process Skills	Sharing Tasks (Basic Level)	Jumping Task (High Level)	The Role of Artificial Intelligence (AI) & Learning Studies
Observing			
Students find it difficult to relate the Sedekah Bumi tradition to the concept of renewable energy.	Students watch an AI video/infographic about Sedekah Bumi and identify activities that have the potential to utilize natural energy.	Students were asked to predict other renewable energy potentials hidden in similar local traditions.	AI provides contextual visuals; teachers reflect on the effectiveness of observations (Plan–Do–See)
Classify			
Difficulty distinguishing between renewable and non-renewable energy	Students grouped examples of energy from the Sedekah Bumi tradition using an canva AI.	Students classify new energy sources based on criteria they have created themselves.	AI provides immediate feedback; lesson study reflections on students' thinking
Measuring			
Students' difficulty in accurately measuring the mass of water, initial temperature, and final temperature of water.	Students participate in AI simulations of energy measurement (water, biomass) in groups.	Students design alternative measurement methods based on environmental conditions	AI simulates experiments; teachers observe student engagement and difficulties
Interpreting data			
Difficulty reading graphs and tables	Students collaboratively analyze simple graphs of AI simulation results.	Students compare several sets of data and explain the differences in results.	AI visualizes adaptive data; reflection focuses on data literacy
Formulating a hypothesis			
Students are not yet accustomed to thinking predictively.	Students develop hypotheses together based on examples provided by AI.	Students formulate their own hypotheses about new phenomena in their environment.	Mentimeter AI is used by students to write hypotheses. Next, the teacher provides examples of scientific sentences and evaluates the quality of the hypotheses.
Designing experiments			
Students are confused about how to set up the experiment procedure.	Students complete the incomplete experimental steps.	Students design independent experiments on the use of local renewable energy	AI serves as a scaffold; lesson study assesses student independence
Communicating			
1. Difficulty presenting results systematically. 2. Not accustomed to reading and interpreting practical results	Students present the results of their group discussions with the help of an AI slide generator.	Students present digital reports and answer critical questions from their peers.	AI helps with visualization; teachers reflect on communication skills

data into quantitative conclusions. 3. Difficulty compiling tables or graphs of experimental results, making it difficult to analyze the relationship between variables.			
Conclusion			
Students have difficulty summarizing the results of experiments.	Students draw conclusions together from the analyzed data.	Students draw conclusions and implications for environmental sustainability	AI provides reflective prompts; uses Padlet AI to assess depth of thinking

Based on the research results presented in Table 9, the use of artificial intelligence plays a strategic role in overcoming various obstacles to students' science process skills through the integration of sharing tasks and jumping tasks within the lesson study framework. In observation skills, AI is used to present contextual visuals in the form of videos and infographics related to the Sedekah Bumi tradition, thereby helping students relate local cultural phenomena to the concept of renewable energy(Sumandya, 2025; Techakosit et al., 2025). At an advanced level, AI encourages students to predict other renewable energy potentials in similar traditions, while teachers reflect on the effectiveness of the observation process through the Plan–Do–See stages. In classification and measurement skills, AI functions as a facilitator and provider of direct feedback. Through the help of chatbots and energy measurement simulations, students are not only able to distinguish between renewable and non-renewable energy types, but also begin to independently design classification criteria and alternative measurement methods. Furthermore, in terms of data interpretation skills, AI adaptively visualizes graphs and tables to improve students' data literacy, while lesson study reflections focus on students' thinking and conceptual understanding(Gulyamova & Rasulmuhamedova, 2025; Zheng & Yang, 2024)

In higher-order thinking skills such as formulating hypotheses and designing experiments, AI acts as cognitive scaffolding by providing examples of scientific sentences, procedure templates, and reflective prompts. As the level of the task increases, the role of AI is gradually reduced to encourage student independence in designing experiments on the use of renewable energy based on the local environment(Crotty et al., 2024; Joo & Park, 2024). Teachers then evaluate the quality of hypotheses and experimental designs through collaborative lesson study reflection. In addition, the use of AI has also been proven to help improve communication and conclusion-drawing skills. AI supports data visualization through the creation of slides and digital reports, enabling students to present their findings more systematically and answer critical questions from their peers. In the final stage, AI provides reflective prompts to help students draw data-based conclusions and relate them to environmental sustainability issues, while lesson study is used to assess the depth of students' thinking and the quality of their scientific arguments(Ganti, 2025; Khurramov et al., 2025; Hung Hsiang Wang & Wang, 2024).

These findings are consistent with research showing that the use of a didactical design research approach can effectively address misconceptions and improve students' quantitative skills in science(Yolanda, 2020). In addition, previous research confirms that integrating local cultural contexts into science learning can improve conceptual understanding while building scientific literacy relevant to real life(Ghosn et al., 2024; Roorda et al., 2024).

Some of the answers provided by students were in line with the predictions formulated in the learning design. In general, students were able to find and prove the amount of energy efficiency, although there were still some errors(Hung Hsiang Wang & Wang, 2024). Students demonstrated a habit of reading and interpreting practical data results into quantitative conclusions. However, there were still difficulties in compiling tables or graphs of the experimental results,(Shan Wang et al., 2024) which made it difficult to analyze the relationship between variables. In addition, there were errors in calculating the heat energy from rice husks and sawdust. After confirmation, the students admitted that the errors occurred because they wanted to give answers even though they were not entirely correct, and ultimately realized their mistakes after a process of reflection. This proves previous research that lesson study is capable of diagnosing student learning activities and obstacles(Damayanti et al., 2020; Hasan et al., 2021; Kandaga et al., 2021; Ng & Latife, 2022)

This research contributes significantly to the development of science education, particularly in designing physics learning rooted in local culture and applying innovative contextual approaches(Damayanti et al., 2020). First, this research designs a contextual and culture-based didactic model by integrating local wisdom on sedekah bumi (earth alms) into renewable energy learning(Powers et al., 2023; Temitayo et al., 2024). This innovation plays a role in narrowing the gap between science content in schools and students' sociocultural lives, thereby creating a more contextual and meaningful learning experience. Second, this study combines a learning barrier-based approach in understanding renewable energy material. By identifying and responding to epistemological, ontogenetic, and didactic barriers, this study produces didactic strategies that are more adaptive and responsive to students' actual learning needs, while also improving the quality of learning design(Joo & Park, 2024; Reginald et al., 2025).

Another important contribution of this study is the strengthening of science process skills through the integration of local culture. Skills such as observing, analyzing data, conducting experiments, and critical thinking are developed holistically in the context of learning based on local values. This approach strengthens the scientific practice aspect of science education, so that learning is not only theoretical but also relevant and applicable in the daily lives of students. In addition, this study contributes to the implementation of didactics-based lesson study, in which the developed learning design is validated and applied in collaborative practicvlee among teachers(Zheng & Yang, 2024). This plays a role in enhancing teacher professionalism while strengthening a culture of collaboration in designing, implementing, and evaluating innovative and student centered learning. Furthermore, this research also produced digital teaching materials developed based on the local context, specifically the themes of almsgiving and renewable energy. These digital products add to the references in the development of science and culture-based learning media and have the potential to be adapted in various regions, taking into account their respective local characteristics.

This study has limitations related to the scope and application of the learning context. The contextual learning approach was designed based on the local tradition of Sedekah Bumi, so the findings of this study cannot be fully generalized to other regions with different cultural backgrounds and local wisdom. In addition, the measurement of science process skills focused on specific indicators appropriate to the characteristics of context-based renewable energy learning, so it did not cover all dimensions of science process skills comprehensively. The next limitation relates to the use of artificial intelligence and the application of lesson study. In this study, artificial intelligence is still used as a learning aid and has not been implemented adaptively to facilitate personalized learning based on student learning development data. In addition, time constraints and variations in teacher readiness in implementing lesson study have resulted in a limited number of cycles being applied, so that the long-term effects of artificial intelligence-assisted learning on improving science process skills cannot yet be analyzed comprehensively. Future research is recommended to explore in depth the challenges faced by physics teachers in designing and implementing renewable energy learning modules that integrate local contexts and the values of the Nature of Science (NOS). This is essential for deepening students' understanding not only in procedural and conceptual aspects of science but also in its epistemological and foundational dimensions.

CONCLUSION

This study shows that the implementation of the Hypothetical Learning Trajectory (HLT) in the design of renewable energy learning, contextualized through the local culture of "*Sedekah Bumi*", significantly enhances students' science process skills. These skills include the ability to observe, analyze data, conduct experiments, and think critically, all of which are developed holistically through a learning approach connected to the students' sociocultural realities. The application of the lesson study approach in this research has proven effective not only in improving the quality of physics lesson planning but also in promoting active teacher engagement in reflective practices and continuous instructional improvement. The collaborative involvement of lecturers, teachers, and students in each lesson study cycle contributed positively to the development of more adaptive and responsive learning designs tailored to students' actual learning needs. Moreover, this study offers a significant contribution by integrating local wisdom into science education through a didactical design approach based on learning obstacles. This approach emphasizes that science learning becomes more relevant and meaningful when grounded in the cultural context of the learners.

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AUTHOR CONTRIBUTIONS

YY: Conceptualization, Resources, Writing and Review & Editing, Supervision, Methodology, Formal Analysis, Data Curation, Financial Report, Project Administration. IAP: Investigation, Writing and Original Draft Preparation, Validation, and Visualization.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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