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Ethnoscience-Based Physics Learning on the Topic of Sound Waves to Enhance Students' Creativity: A Mixed-Methods Approach

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Abstract

This study addresses the need to foster students' creativity in physics learning, particularly on abstract topics such as sound waves, through instruction that is more meaningful, contextual, and culturally relevant. Conventional physics teaching at the junior secondary level often remains teacher-centered and procedural, limiting opportunities for students to explore ideas and develop creative thinking. Therefore, this study aimed to examine whether ethnoscience-based physics learning on the topic of sound waves could improve students' creativity, to determine the extent of improvement, and to describe how creativity emerged during the learning process. The study employed an embedded mixed-methods design. Quantitatively, it used a one-group pretest-posttest design involving 20 Grade VIII students from one junior high school in Mataram City, Indonesia. Qualitatively, classroom observations, field notes, and learning documentation were used to capture students' engagement and manifestations of creativity. Quantitative data were analyzed using descriptive statistics, N-gain, and one-way repeated measures ANOVA, while qualitative data were analyzed through descriptive thematic analysis. The results showed a substantial improvement in students' creativity. The mean score increased from 43.75 in the pretest to 81.38 in the posttest, with a mean N-gain of 0.80. The repeated measures ANOVA indicated a significant effect, $F_{(1, 19)} = 491.97$, $p < .001$, with a very large effect size (partial eta squared, $\eta^2 = 0.963$). Qualitative findings revealed increased participation, richer idea generation, and stronger connections between physics concepts and local cultural contexts. It is recommended that ethnoscience-based learning be applied more widely in physics instruction and examined further across broader contexts and topics.

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INTRODUCTION

Creativity is increasingly recognized as a key competency in twenty-first century education because it enables students to generate ideas, solve problems flexibly, and interpret phenomena in meaningful ways. In science education, creativity is not limited to producing novel responses, but also involves constructing alternative explanations, connecting scientific concepts to real-life situations, and developing reasoned solutions based on evidence and inquiry (Geelan & Fan, 2014; Cleovoulou, 2021). In physics learning, this means that instruction should move beyond formula application and procedural accuracy toward learning experiences that support exploration, reasoning, and idea development.

However, junior secondary physics learning often remains dominated by teacher-centered instruction, routine exercises, and content coverage. Such practices tend to restrict students' opportunities to ask open-ended questions, examine multiple explanations, and connect physics concepts with their lived experiences, thereby limiting the development of creativity (Buabeng et al., 2014; Keiler, 2018; Donohue et al., 2019). This challenge becomes more pronounced because many physics concepts are abstract and are frequently introduced through equations and standard examples that seem detached from students' everyday realities. As a result, physics is often perceived as difficult, rigid, and less meaningful for students.

A substantial body of research suggests that student-centered, inquiry-oriented, and authentic learning approaches are more likely to foster higher-order thinking, conceptual understanding, and meaningful engagement than transmissive forms of instruction (Geelan & Fan, 2014; Donohue et al., 2019; Mutlu, 2017). Creativity is more likely to emerge when students are encouraged to investigate phenomena, consider multiple perspectives, justify their reasoning, and develop explanations in contexts they find relevant. This indicates that the problem in physics education is not only what content is taught, but also how learning is designed and situated.

One promising approach for making physics more meaningful is ethnoscience-based learning. Ethnoscience recognizes local knowledge, cultural practices, and community experiences as valuable resources for science learning. Rather than treating science as detached from social life, this approach positions scientific understanding in dialogue with culturally grounded knowledge and everyday experience (Ramsey, 2015; Oktrisma & Ratnawulan, 2021; Naba et al., 2024; Sarwi et al., 2025). In classroom practice, ethnoscience-based learning allows students to interpret scientific concepts through familiar contexts, compare different forms of explanation, and reconstruct meaning in ways that are both scientifically and culturally relevant. For physics education, this is especially important because it helps bridge the gap between abstract principles and observable realities.

The topic of sound waves is particularly suitable for such an approach because sound is deeply embedded in daily life and cultural practice. Sound is encountered in communication, music, ritual activity, traditional instruments, and environmental signaling. Yet these everyday experiences are not always transformed into scientific understanding in classroom settings. When concepts such as vibration, wave propagation, resonance, and hearing are taught through culturally meaningful sound-related phenomena, students gain more concrete entry points for understanding abstract ideas (Ramsey, 2015; Löfgren et al., 2024; Naba et al., 2024). More importantly, this kind of learning can provide fertile ground for creativity because students are invited not only to recall accepted concepts but also to interpret events, articulate multiple explanations, and connect scientific and cultural perspectives.

This relationship between ethnoscience and creativity is pedagogically significant. Creativity in science learning does not arise automatically from exposure to interesting content. It requires learning experiences that intentionally support fluency, flexibility, originality, and elaboration. These dimensions reflect the quality of students' thinking processes, not merely the novelty of final answers. Ethnoscience-based learning is particularly relevant in this regard because it expands the problem space of science learning by connecting concepts to culturally meaningful experiences, local practices, and authentic community contexts, thereby creating more opportunities for learners to generate ideas, compare perspectives, and construct context-sensitive explanations (Sarwi, 2025; Ahmad et al., 2025; Sotero et al., 2020; Putri et al., 2024). Inquiry-rich, project-based, and culturally responsive learning models grounded in ethnoscience have been shown to cultivate creative thinking by encouraging students to investigate locally situated phenomena, design explanations, and produce meaningful solutions in ways that are both scientifically informed and culturally relevant (Wahyudi et al., 2023; Putri & Dani, 2023; Idrus, 2025). In addition, digital and hybrid ethnoscience environments, including LMS-supported learning, ethno-vlog media, and virtual reality-enhanced tasks, broaden students' expressive repertoires and enable more diverse forms of knowledge construction and creative representation (Herayanti et al., 2025; Hidayat, 2024; Nolan & Pieroni, 2013). In this sense, ethnoscience-based physics learning is not simply a contextual teaching strategy, but also a pedagogical framework with strong potential to support meaningful creative development.

Even so, the value of ethnoscience-based learning should not be assumed only from theoretical arguments. It needs empirical examination, especially in relation to creativity, which is often discussed conceptually but less consistently studied as a measurable and observable outcome in physics education. Quantitative evidence can show whether change occurs, but it cannot fully explain how students generate ideas, how classroom interaction shapes reasoning, or how culturally situated tasks contribute to the emergence of creativity. For a construct such as creativity, which is both an outcome and a process, relying on a single methodological approach is insufficient. This need for empirical and methodologically rigorous investigation has been emphasized in systematic reviews and bibliometric analyses, which note that although ethnoscience is consistently associated with gains in creative thinking, collaboration, and problem solving, the field still requires stronger classroom-based validation across contexts and instructional models (Sarwi, 2025; Ahmad et al., 2025; Shofatun, 2026). The literature also suggests that the success of ethnoscience-informed pedagogy depends on how well it is facilitated, assessed, and aligned with instructional design, including teacher capacity, technological support, and the integration of local knowledge into inquiry-oriented activities (Kasi et al., 2022; Adoum, 2025; Herayanti et al., 2025). Therefore, examining creativity through both quantitative change and qualitative classroom processes is essential not only for documenting whether ethnoscience-based learning is effective, but also for explaining how and under what pedagogical conditions it supports creative development in science learning.

A mixed-methods approach is therefore particularly appropriate for this study. Quantitative data can identify whether students' creativity changes after the intervention and indicate the extent of that change, while qualitative data can illuminate how creativity is expressed and supported during the learning process. Through observations, field notes, and documentation, qualitative evidence can reveal how students respond to culturally grounded tasks, negotiate meaning, and engage in idea generation throughout instruction. The integration of these forms of evidence provides a more complete understanding of how ethnoscience-based physics learning may influence students' creativity.

Although research on ethnoscience in science education has expanded, several gaps remain. First, many studies still focus on conceptual understanding, learning outcomes, or attitudes toward science, whereas creativity is less frequently treated as a central outcome. Second, relatively limited attention has been given to physics topics that are strongly connected to students' sensory and cultural experiences, such as sound waves. Third, studies that combine quantitative measurement of creativity with qualitative analysis of classroom processes remain limited. These gaps matter because without such integration, it is difficult to explain not only whether ethnoscience-based learning is effective, but also why and under what classroom conditions it works.

This study is also relevant to junior secondary education because this stage is important for shaping students' habits of thinking, including their willingness to express ideas, consider alternatives, and connect school knowledge with their environment. If physics learning remains procedural and uniform, opportunities for creativity may be unnecessarily restricted. In contrast, when instruction is designed around culturally familiar contexts, students may begin to perceive science as meaningful, situated, and open to interpretation. Such a shift is educationally important because it can strengthen engagement and support more active forms of scientific reasoning.

Against this background, the present study investigates ethnoscience-based physics learning on the topic of sound waves as an approach to enhancing students' creativity. Specifically, the study aims to examine changes in students' creativity before and after the intervention, determine the extent of improvement, and describe how the learning process facilitated the emergence of students' fluency, flexibility, originality, and elaboration. Based on these objectives, the study addresses the following research questions:

1) Does ethnoscience-based physics learning on the topic of sound waves improve students' creativity?
2) To what extent does students' creativity improve after participating in such learning?
3) How does ethnoscience-based physics learning on the topic of sound waves facilitate the emergence of students' creativity during the learning process?

METHODS

Design

This study employed a mixed-methods approach to obtain a more comprehensive understanding of the implementation of ethnoscience-based physics learning on the topic of sound waves in improving students' creativity. This approach was selected because changes in students' creativity needed to be examined not only quantitatively through pre- and post-learning scores, but also qualitatively through students' learning processes, responses, and experiences during the intervention.

Quantitatively, the study adopted a pre-experimental one-group pretest-posttest design, in which one group of students was measured before and after participating in ethnoscience-based physics learning. This design was used to identify changes in students' creativity scores following the intervention. Qualitatively, the study applied a descriptive qualitative approach to document the learning process, students' interactions during classroom activities, their forms of participation, and indications of creativity emerging throughout the instruction. The qualitative data were intended to enrich the interpretation of the quantitative findings so that the study would not only indicate whether score changes occurred, but also explain how those changes took place within the learning context.

Accordingly, the research design can be positioned as an embedded mixed-methods design, in which the quantitative component served as the primary focus for measuring changes in creativity, while the qualitative component supported the interpretation of the quantitative results.

Participants

The participants were students from one junior high school in Mataram City, Indonesia, who were studying physics on the topic of sound waves. Participants were selected using purposive sampling, in which one class was designated as the research group based on its suitability for the learning intervention, accessibility, and school approval.

All students in the selected class were involved in every stage of the study, beginning with the pretest, followed by the learning intervention, and ending with the posttest. In the qualitative component, all students participating in the learning activities also served as data sources through observation, documentation, and field notes collected during the instructional process.

Table 1. Participant demographics

Characteristic	Category	n	%
Total participants	All participants	20	100.0
Educational level	Junior high school	20	100.0
Grade level	Grade VIII	20	100.0
Gender	Male	9	45.0
	Female	11	55.0
Age	13 years	12	60.0
	14 years	8	40.0

Procedure

The study was conducted through several structured stages. In the initial stage, the researchers coordinated with the school and the physics teacher to determine the research class, implementation schedule, and readiness of the instructional materials and data collection instruments. At this stage, the researchers also prepared the ethnoscience-based physics learning materials on sound waves, the creativity test, the observation sheet, and the documentation format.

The next stage was the administration of the pretest. The pretest was given to all participants before the intervention began to obtain an initial picture of students' creativity levels. Following this, ethnoscience-based physics learning was implemented on the topic of sound waves. In this instructional process, physics concepts were linked to local cultural contexts and students' everyday experiences in order to make learning more contextual, meaningful, and conducive to active student engagement.

During the learning process, the researchers observed students' activities, classroom interactions, response patterns, and indications of creative behavior. Supporting data were also collected through field notes and learning documentation. After the entire intervention had been completed, students were given a posttest using the same or an equivalent instrument to measure changes in creativity after participating in the learning activities. In general, the stages of the study included preparation, pretest administration, implementation of ethnoscience-based physics learning, observation of the learning process, posttest administration, and quantitative as well as qualitative data analysis.

Instruments

This study used complementary quantitative and qualitative instruments to obtain a comprehensive picture of changes in students' creativity and of the learning process during the implementation of ethnoscience-based physics instruction on the topic of sound waves.

The primary quantitative instrument was a creativity test administered in the form of a pretest and posttest. This test was used to measure students' creativity levels before and after participating in the learning activities. The test was developed based on four dimensions of creativity relevant to the purpose of the study, namely fluency, flexibility, originality, and elaboration. These four dimensions were selected because they are appropriate for identifying students' ability to generate ideas, develop alternative responses, connect physics concepts with local contexts, and explain ideas in greater detail.

The creativity test was developed in the form of open-ended essay questions to provide students with sufficient opportunity to express ideas, explain reasoning, and elaborate their responses more freely. Each test item was designed by linking sound wave concepts with everyday phenomena and local cultural contexts familiar to students, such as sound sources, sound propagation, vibration, resonance, and the use of sound in cultural practices or traditional instruments. Students' responses were scored using an analytic rubric based on the predetermined dimensions of creativity. The raw scores were then converted into a 0-100 scale so that the pretest and posttest results could be compared directly. The blueprint of the creativity test is presented in Table 2.

Table 2. Creativity test blueprint

Creativity Dimension	Indicator	Focus of Sound Wave Topic	Item Type	Score
Fluency	Students are able to generate several relevant ideas or answers to a given problem	Sound phenomena in everyday life and local culture	Open-ended essay	0–10
Flexibility	Students are able to propose more than one perspective or alternative solution to a problem	Explanations and problem solving related to vibration, resonance, and sound propagation	Open-ended essay	0–10
Originality	Students are able to produce uncommon but scientifically relevant responses	Connections between sound concepts and local cultural practices or ethnoscience	Open-ended essay	0–10
Elaboration	Students are able to explain ideas in a detailed, logical, and well-developed manner	Explanations of how sound is produced, propagated, and utilized in local contexts	Open-ended essay	0–10

Scoring was conducted analytically for each creativity dimension. The total creativity score was obtained by summing the scores across the four dimensions, resulting in a raw score range of 0-40. The raw score was then converted into a 0-100 scale using the following formula: creativity score = (raw score / 40) × 100.

Students' creativity scores were interpreted into five categories, namely very creative, creative, moderately creative, less creative, and not creative, as presented in Table 3.

Table 3. Students' creativity score ranges

Score Range	Category
81–100	Very creative
61–80	Creative
41–60	Moderately creative
21–40	Less creative
0–20	Not creative

The qualitative instruments consisted of an observation sheet, field notes, and learning documentation. The observation sheet was used to record students' engagement during the learning process, such as active participation in discussions, ability to express ideas, responses to ethnoscience-based tasks, ability to relate physics concepts to local culture, and interactions with the teacher and peers. Field notes were used to document important events occurring during the learning process, including spontaneous responses, classroom dynamics, emerging challenges, and forms of creativity not fully captured by the structured observation sheet. Learning documentation, such as activity photographs and students' work, was used as supporting data to strengthen the interpretation of the qualitative findings. The blueprint of the observation sheet and the summary of supporting qualitative instruments are presented in Tables 4 and 5, respectively.

Table 4. Observation sheet blueprint

Observed Aspect	Indicator	Observation Focus
Engagement in learning	Students actively participate in learning activities	Attention, participation, and responses to questions or tasks
Idea generation	Students express ideas related to sound wave concepts	Frequency and variety of ideas emerging during discussion
Ethnoscience connection	Students relate physics concepts to culture or local life	Ability to connect sound phenomena with local cultural practices
Flexibility of thinking	Students provide more than one answer or alternative explanation	Variation in ways of thinking when solving problems
Originality of response	Students present ideas that differ from common answers	Emergence of unique, novel, or uncommon ideas
Elaboration of ideas	Students explain ideas in detail	Clarity, completeness, and development of ideas during discussion
Collaboration	Students interact positively with peers	Involvement in group work and responses to peers' ideas

Table 5. Supporting qualitative instruments

Instrument	Function	Type of Data
Observation sheet	Records students' engagement, responses, and manifestations of creativity during learning	Structured descriptive data
Field notes	Documents important events, spontaneous responses, and contextual situations in the classroom	Narrative descriptive data
Learning documentation	Provides visual and contextual evidence of learning implementation and student activities	Photographs, students' work, and instructional records

Before being used in the study, all instruments were validated by three experts consisting of a physics education expert, an educational evaluation expert, and an experienced science teacher. The validation covered content appropriateness, clarity of wording, appropriateness of difficulty level, and relevance of the ethnoscience context. Based on the validators' assessments, the creativity test obtained a mean score of 4.42 with a feasibility level of 88.40%, the observation sheet obtained a mean score of 4.36 with a feasibility level of 87.20%, and the supporting qualitative instruments obtained a mean score of 4.31 with a feasibility level of 86.20%. The overall average of instrument validation reached 4.36 or 87.27%, indicating that the instruments were in the very valid category. Therefore, the instruments were deemed appropriate for use after minor revisions based on the validators' suggestions.

Data Analysis

The data in this study were analyzed using quantitative and qualitative approaches in accordance with the applied mixed-methods design. The quantitative data obtained from the pretest and posttest scores were analyzed using descriptive and inferential statistics. Descriptive statistics were used to describe the characteristics of the data, including the mean, median, standard deviation, minimum score, and maximum score. In addition, learning improvement was analyzed using normalized gain (N-gain) to describe the level of increase in students' creativity scores after participating in ethnoscience-based physics learning.

To test differences in students' creativity scores before and after the intervention, this study employed a one-way repeated measures ANOVA. This analysis was selected because measurements were taken from the same group at two different times, namely before and after the learning intervention. In a design involving two measurement points, repeated measures ANOVA is appropriate for assessing the effect of time on changes in students' creativity scores. The magnitude of the intervention effect on changes in creativity scores was analyzed using effect size. The effect size measure used was partial eta squared (η^2) as the primary measure in repeated measures ANOVA. The use of effect size was intended to ensure that the analysis would not only indicate statistical significance, but also provide information on the strength of the instructional effect on students' creativity.

The qualitative data obtained from the observation sheets, field notes, and documentation were analyzed using descriptive thematic analysis. The analysis was conducted through several stages, namely data reduction, coding, grouping codes into categories, and identifying major themes representing the ethnoscience-based physics learning process and manifestations of students' creativity during the activities. The resulting themes were then used to explain the context, learning dynamics, and forms of students' creativity that could not be fully captured through numerical data.

Integration of the quantitative and qualitative data was conducted at the interpretation stage. Quantitative data were used to show patterns of change in students' creativity scores, whereas qualitative data were used to explain how the learning process took place, how students responded to ethnoscience activities, and which learning factors were likely to contribute to the development of their creativity. In this way, the findings not only explain score changes, but also provide a deeper understanding of the processes underlying those changes.

Ethical Approval

This study was conducted after obtaining permission from one junior high school in Mataram City, Indonesia, and approval from the subject teacher involved in the implementation of the research. Since the participants were junior high school students, the study adhered to the principles of educational research ethics, including providing clear information regarding the purpose of the study, research procedures, confidentiality of data, and the use of data solely for academic purposes.

Students' identities were protected by not including participants' names in either the analysis or the reporting of results. All data were presented in aggregate form or with anonymous codes to prevent personal identification. If the study also involved parental or guardian consent, such information should be stated explicitly in this section. If formal ethical approval from an ethics committee or institution is available, the name of the institution, approval number, and approval date may also be added according to the relevant documentation.

RESULTS AND DISCUSSION

Quantitative Results

The quantitative findings indicate a substantial improvement in students' creativity scores after the implementation of ethnoscience-based physics learning on the topic of sound waves. As shown in Table 6, the mean pretest score was 43.75 (SD = 5.47), while the mean posttest score increased to 81.38 (SD = 3.39). The median score also rose markedly from 43.75 in the pretest to 81.25 in the posttest. In addition, the score range shifted upward, with pretest scores varying from 35.00 to 57.50, whereas posttest scores ranged from 75.00 to 90.00. These descriptive statistics suggest that students' creativity improved not only in average performance but also in the overall distribution of scores after the intervention.

Table 6. Descriptive statistics of pretest and posttest creativity scores

Variable	n	Mean	Median	SD	Minimum	Maximum
Pretest	20	43.75	43.75	5.47	35.00	57.50
Posttest	20	81.38	81.25	3.39	75.00	90.00

A more detailed view of students' creativity levels is presented in Table 7. Before the intervention, no students were classified as very creative or creative. Instead, most students were in the moderately creative category (65.0%), while the remaining 35.0% were categorized as less creative. After the intervention, a clear shift occurred. Half of the students (50.0%) reached the very creative category, and the other half (50.0%) were classified as creative. No students remained in the moderately creative, less creative, or not creative categories. This categorical shift confirms that the improvement was not limited to a change in mean scores, but also reflected a meaningful movement in students' creativity levels.

Table 7. Distribution of students' creativity categories in the pretest and posttest

Creativity Category	Pretest, n (%)	Posttest, n (%)
Very creative	0 (0.0%)	10 (50.0%)
Creative	0 (0.0%)	10 (50.0%)
Moderately creative	13 (65.0%)	0 (0.0%)
Less creative	7 (35.0%)	0 (0.0%)
Not creative	0 (0.0%)	0 (0.0%)
Total	20 (100.0%)	20 (100.0%)

Students' improvement was further examined using normalized gain (N-gain). As reported in Table 8, the mean N-gain was 0.80 with a median of 0.81, indicating a generally high level of improvement. The N-gain scores ranged from 0.60 to 0.90, showing that all students experienced moderate-to-high gains. In terms of category distribution, 18 students (90.0%) were classified in the high N-gain category, while 2 students (10.0%) were in the moderate category. No students fell into the low category. These results suggest that the intervention was associated with a consistently strong increase in creativity across most participants.

Table 8. N-gain statistics and category distribution

Variable	n	Mean	Median	SD	Minimum	Maximum
N-gain	20	0.80	0.81	0.08	0.60	0.90

To determine whether the difference between pretest and posttest scores was statistically significant, a one-way repeated measures ANOVA was conducted. The results in Table 9 show a significant effect of time on students' creativity scores, $F(1, 19) = 491.97$, $p < .001$. The effect size was very large, with a partial eta squared (η^2) of 0.963, indicating that the instructional intervention accounted for a substantial proportion of the variance in students' creativity scores. This result statistically confirms that ethnoscience-based physics learning on the topic of sound waves was associated with a strong improvement in students' creativity.

Table 9. Results of one-way repeated measures ANOVA on students' creativity scores

Source	SS	df	MS	F	p	η^2
Time (Pretest vs. Posttest)	14156.41	1	14156.41	491.97	< .001	0.963
Error (Time)	546.72	19	28.77			

The visual representation of this change can be seen in Figure 1, which presents the raincloud plot of students' creativity scores before and after the intervention.

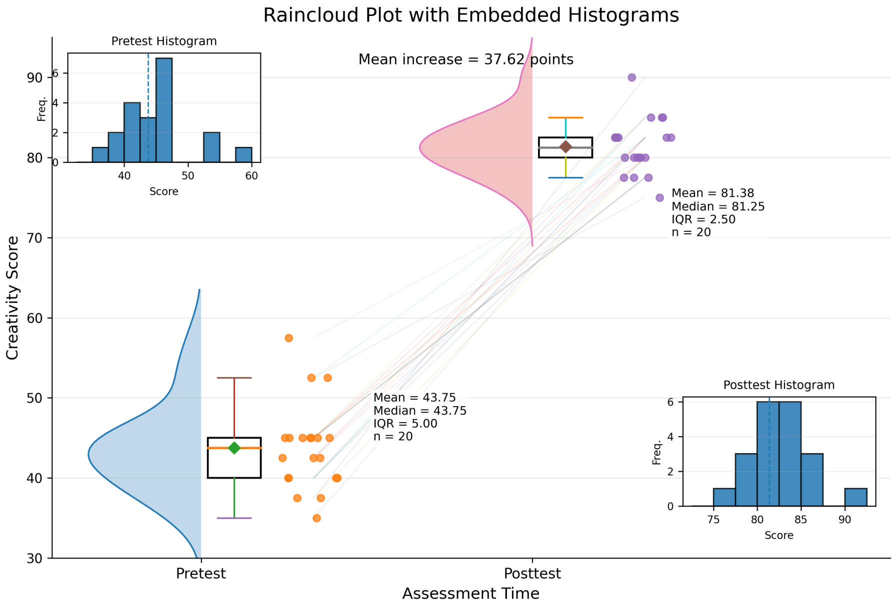

Figure 1. Raincloud plot of students' creativity scores before and after the intervention

The Figure 1 shows a clear upward shift in the score distribution from pretest to posttest. The posttest scores are concentrated in a much higher range than the pretest scores, and the distribution appears more compact. The individual data points and paired-score connections further illustrate that nearly all students improved substantially after participating in the learning intervention. This visual pattern is consistent with the descriptive and inferential findings reported in Tables 6–9.

Qualitative Results

The qualitative findings were organized into several themes that describe how creativity emerged during the implementation of ethnoscience-based physics learning. As outlined in Table 10, the qualitative analysis focused on students' engagement in learning, the emergence of creativity during classroom activities, the role of local cultural contexts, and classroom dynamics and challenges. These themes were derived from the observation sheet, field notes, and learning documentation.

Table 10. Themes and subthemes of qualitative findings

Theme	Subtheme	Data Source	Brief Evidence/Description
Students' engagement in ethnoscience-based physics learning	Active participation in discussion	Observation sheet, field notes	Students showed increasing participation during discussion and task completion.
	Increased responsiveness to contextual tasks	Observation sheet, field notes	Students responded more actively when learning tasks were linked to familiar sound-related cultural contexts.
Emergence of creativity during learning	Fluency in generating ideas	Observation sheet, field notes, students' work	Students were able to propose multiple ideas and examples related to sound phenomena in daily and cultural life.
	Flexibility in proposing alternative explanations	Observation sheet, field notes	Students demonstrated different ways of explaining sound-wave concepts and contextual problems.
	Originality in linking physics concepts with local culture	Observation sheet, documentation	Students produced distinctive connections between physics concepts and local cultural practices involving sound.
	Elaboration of ideas during discussion and presentation	Observation sheet, field notes	Students developed more detailed and logical explanations as the learning process progressed.
Role of local cultural context	Local phenomena as conceptual anchors	Observation sheet, documentation	Familiar cultural examples helped students understand abstract concepts of vibration,

Theme	Subtheme	Data Source	Brief Evidence/Description
			resonance, and wave propagation.
	Cultural relevance in supporting meaning-making	Field notes, documentation	Local contexts made the learning process more meaningful and encouraged students to relate concepts to real-life experiences.
Classroom dynamics and challenges	Initial hesitation or uneven participation	Observation sheet, field notes	Some students were initially passive and needed encouragement to express ideas.
	Difficulty in articulating scientific explanations	Observation sheet, field notes	A number of students could identify local examples but initially struggled to explain them using scientific language.

The first theme concerns students' engagement in ethnoscience-based physics learning. Based on the observations, students became increasingly active during the learning process, especially in discussion-based and context-driven activities. They showed stronger participation when the learning tasks involved sound-related phenomena that were familiar within their local cultural experience. This indicates that contextualized ethnoscience tasks were able to increase students' responsiveness and engagement during instruction.

The second theme is the emergence of creativity during learning. In terms of fluency, students were able to generate multiple ideas and examples related to sound in everyday and cultural contexts. In terms of flexibility, students demonstrated more than one way of explaining sound-wave concepts and contextual problems. The data also indicate originality, as some students were able to relate sound concepts to local cultural practices in ways that were uncommon yet relevant. In addition, students showed elaboration by presenting increasingly detailed and logical explanations during classroom discussion and presentation. These qualitative patterns support the quantitative finding that creativity developed across multiple dimensions rather than improving only in general score terms.

The third theme highlights the role of local cultural context in supporting students' creativity. Familiar local phenomena appeared to function as conceptual anchors that helped students approach abstract ideas such as vibration, resonance, and sound propagation. The cultural relevance of the tasks also appeared to support meaning-making, as students were better able to relate scientific concepts to their own experiences. This suggests that ethnoscience-based learning may strengthen not only conceptual accessibility but also the conditions under which creative thinking can develop.

The final theme concerns classroom dynamics and learning challenges. Although the overall pattern was positive, the qualitative data also indicate that not all students responded immediately with equal confidence. Some were initially hesitant to participate, while others had difficulty translating familiar cultural examples into scientific explanations. These challenges are important because they show that the development of creativity was a gradual process that required guidance, encouragement, and repeated opportunities for students to connect local knowledge with formal physics concepts.

Overall, the results from Tables 6–10 and Figure 1 consistently indicate that ethnoscience-based physics learning on the topic of sound waves was associated with a substantial improvement in students' creativity. The quantitative results demonstrate significant gains in scores, categories, and N-gain levels, while the qualitative results help explain how the learning process supported the emergence of fluency, flexibility, originality, and elaboration in students' responses.

Discussion

The present study demonstrates that ethnoscience-based physics learning on the topic of sound waves was associated with a strong improvement in students' creativity, both in measurable outcomes and in the quality of classroom participation. This conclusion is supported by three converging patterns. First, the quantitative results show a substantial increase in creativity scores from pretest to posttest, accompanied by a very large effect size. Second, the distribution of creativity categories shifted entirely upward, indicating that the improvement was not limited to a small group of students but occurred across the class. Third, the qualitative findings show that students became more active in generating ideas, proposing alternative explanations, linking concepts with local cultural contexts, and elaborating their reasoning during classroom activities. Taken together, these patterns suggest that the intervention did not merely improve performance on a test, but helped create conditions in which creative thinking could emerge more consistently and more visibly. This interpretation is in line with the broader view that creativity in science education is both a measurable outcome and a process that develops through inquiry, explanation-building, and meaningful engagement with content (Geelan & Fan, 2014; Cleovoulou, 2021; Sari, Maryati, & Wilujeng, 2023).

A key point in interpreting these findings is that creativity in physics appears to develop more productively when learning is organized around meaningful contexts rather than abstract content alone. In many conventional classrooms, sound-wave concepts are introduced through formal definitions, formulas, and routine exercises. While such instruction may support procedural mastery, it often leaves limited room for students to explore ideas, test interpretations, or express their understanding in diverse ways. In contrast, the instructional design used in this study connected sound-wave concepts with culturally familiar phenomena and local experience. This likely reduced the perceived distance between scientific knowledge and students' everyday world. When students can see that sound, vibration, and resonance are not only textbook ideas but also phenomena embedded in communication, cultural practice, and local artefacts, they are more likely to engage with the content as something interpretable rather than something merely to be memorized. This supports previous work arguing that ethnoscience provides authentic cultural contexts that strengthen meaningful learning, engagement, and the construction of new conceptual connections, all of which are closely related to creativity (An & Yang, 2019; Sarah et al., 2024; Putri & Turaqulov, 2022).

The qualitative findings help explain why the quantitative gains were so strong. The rise in creativity scores was accompanied by increased student engagement, especially during discussion-based and contextual tasks. Students appeared more willing to participate when the lesson drew on sound-related phenomena that were recognizable from their own environment. This matters because engagement in this case was not merely behavioral participation; it was tied to the conditions under which students could begin to think creatively. The classroom data suggest that contextual familiarity functioned as an entry point for idea generation. Students who might otherwise hesitate to respond to abstract physics questions became more able to contribute when the topic was framed through examples they already understood experientially. This pattern is consistent with studies showing that ethnoscience-informed learning environments tend to increase participation and encourage students to generate multiple ideas in culturally meaningful contexts (Ramsey, 2015; Löfgren et al., 2024; Naba et al., 2024).

The findings also suggest that the growth of creativity was multidimensional. Students did not only improve in a broad score; rather, the learning process appears to have supported fluency, flexibility, originality, and elaboration in distinct yet connected ways. Students demonstrated fluency by producing several examples and ideas related to sound phenomena. They showed flexibility by proposing more than one explanation for a given phenomenon or problem. They expressed originality when they linked scientific concepts with local practices in ways that were not routine but remained relevant. They demonstrated elaboration by developing increasingly detailed and logical responses during discussion and presentation. This is an important contribution of the study because it shows that ethnoscience-based learning did not simply stimulate participation or make lessons more enjoyable; it also appeared to support the internal structure of creative thinking itself. This interpretation aligns with previous ethnoscience-based instructional studies in which creativity was explicitly conceptualized through the same four dimensions and reported as a central outcome of intervention-based learning materials and modules (Almira et al., 2025; Putri et al., 2025; Hikmah, 2025).

Another significant point concerns the topic of sound waves as a particularly fertile domain for ethnoscience-based instruction. Not all physics topics lend themselves equally well to contextualization through local cultural experience. Sound waves, however, are deeply tied to human life through music, language, ritual, tools, and environmental awareness. That makes them especially suitable for instruction that aims to connect formal physics concepts with lived reality. In this study, local sound-related contexts seemed to function as conceptual anchors that helped students approach otherwise abstract ideas such as wave propagation and resonance. This is pedagogically important because it suggests that the success of ethnoscience-based learning may depend not only on the general approach, but also on the suitability of the topic. Previous studies on sound and culturally grounded learning similarly show that traditional musical instruments, local sound-making practices, and sound-related cultural phenomena can serve as effective bridges between abstract physics and observable experience (Anwar, 2026; Ramsey, 2015; Naba et al., 2024). The present findings extend this argument by showing that such contextualization may contribute not only to conceptual accessibility, but also to the development of creativity.

The strong N-gain pattern observed in this study also resonates with a growing body of work on Ethno-STEM, project-based learning, and inquiry-oriented interventions. The fact that nearly all students reached moderate-to-high gain levels suggests that the improvement was broad rather than isolated. This is important because it indicates that ethnoscience-based instruction may support creativity not only among a few already active students, but across the wider classroom. Previous studies have reported moderate-to-strong gains in creativity-related outcomes when ethnoscience and contextual problem-solving are integrated with project-based or inquiry-rich learning environments, including in topics related to waves and other physics domains (Rohmantika & Kurniawan, 2021; Almira et al., 2025; Hikmah, 2025; Sabila & Diyana, 2025). In this sense, the present study contributes further evidence that ethnoscience-based sound-wave learning can generate substantial creative growth that is visible in both quantitative scores and classroom processes.

At the same time, the classroom findings show that ethnoscience alone is not sufficient. The positive outcomes were not produced simply by inserting cultural content into the lesson. The data indicate that students initially varied in confidence and in their ability to articulate familiar examples in scientific language. Some students were hesitant at first, while others needed repeated prompting to develop their ideas more fully. This suggests that the effectiveness of ethnoscience-based instruction depended heavily on pedagogical mediation. Local context provided relevance, but teacher facilitation helped transform that relevance into learning. The improvement in creativity therefore appears to have resulted from an interaction between contextual content and structured instructional support. This interpretation is consistent with research emphasizing that teacher facilitation, scaffolding, and the design of inquiry-rich activities are crucial mediating factors in creativity-oriented instruction (Deng et al., 2020; Khalaila, 2023; Sabila & Diyana, 2025). Thus, the present findings should not be read as evidence that cultural contextualization automatically produces creative learning; rather, they indicate that culturally meaningful content becomes effective when paired with guided discussion, open-ended tasks, and support for explanation building.

This point has practical implications for the design of ethnoscience-based physics learning. The literature suggests that creativity is more likely to develop when ethnoscience materials are integrated with guided inquiry, project-based learning, or open-ended exploration that requires students to investigate local phenomena, compare explanations, and communicate reasoning. In the context of sound waves, this may include designing modules on frequency, resonance, and sound propagation that are linked to local sound-making traditions and instruments and, where feasible, enriched with simple audio-analysis tools or related technologies to support observation and experimentation (Fathiya & Asrizal, 2022; Anwar, 2026; Walzer, 2020; Costa & Braga, 2025). Although the present study did not center on advanced digital sound analysis, its findings are consistent with the broader argument that creativity in physics grows when students are given opportunities to explore wave phenomena through multiple representations, culturally meaningful examples, and inquiry-oriented tasks.

The present results also reinforce the importance of assessing creativity explicitly rather than assuming it implicitly. In this study, creativity was measured through fluency, flexibility, originality, and elaboration, and the improvement was evident both statistically and qualitatively. This is consistent with the broader movement in physics and STEM education to treat creativity as an assessable educational outcome, using structured instruments and rubrics that capture not only correctness but also the breadth, novelty, and development of students' thinking (An & Yang, 2019; Almira et al., 2025; Sari, Maryati, & Wilujeng, 2023). The value of this approach is that it makes creativity visible in classroom research and provides a basis for refining materials and instruction. It also prevents creativity from being treated as an abstract ideal that is valued rhetorically but ignored in assessment practice.

A further point concerns the authenticity of ethnoscience integration. Although many studies support ethnoscience-enhanced learning as a pathway to creativity, they also emphasize the need for careful implementation so that cultural elements are not reduced to superficial decoration. The educational value of ethnoscience depends on whether the selected cultural context genuinely helps students interpret scientific concepts and engage in meaningful reasoning. This means that local examples, artefacts, and practices must be chosen in ways that are conceptually aligned with the scientific content and pedagogically relevant to students' learning needs. The present study appears to have benefited from such alignment, as students were able not only to recognize local examples but also to use them as resources for explanation and idea generation. This supports the broader argument that ethnoscience-based learning requires context-sensitive and ethically grounded implementation rather than token inclusion of cultural references (Sari, Maryati, & Wilujeng, 2023).

Overall, ethnoscience-based physics learning on the topic of sound waves was effective for supporting students' creativity because it combines meaningful cultural contexts, active engagement, open-ended reasoning, and opportunities for explanation building. The quantitative findings show that students' creativity improved strongly, while the qualitative findings clarify that this improvement was supported by greater participation, richer interaction, and the use of local cultural contexts as bridges to scientific understanding. In relation to previous studies, the present findings reinforce a growing body of evidence that ethnoscience-informed, inquiry-oriented learning can cultivate creativity in physics by helping students generate diverse ideas, justify alternative explanations, and elaborate their reasoning in ways that are both scientifically grounded and culturally meaningful (Ramsey, 2015; Naba et al., 2024; Putri & Turaqulov, 2022; Sarah et al., 2024).

CONCLUSION

This study concludes that ethnoscience-based physics learning on the topic of sound waves was effective in improving students' creativity. The quantitative findings showed a substantial increase in creativity scores from pretest to posttest, a consistently high level of N-gain, and a very large effect size, indicating that the intervention was associated with strong creative growth. The shift in creativity categories from predominantly moderately creative and less creative levels to entirely creative and very creative levels further confirms that the improvement was not marginal, but substantial and class-wide. These results indicate that ethnoscience-based learning can serve as a productive instructional approach for supporting creativity in junior secondary physics education.

The study also shows that the improvement in creativity was not only evident in numerical outcomes, but also observable in the learning process itself. The qualitative findings revealed that students became more active in discussion, more responsive to contextual tasks, and more capable of generating ideas, proposing alternative explanations, making culturally meaningful connections, and elaborating their reasoning. In this sense, creativity emerged as both an outcome and a process. The local cultural contexts used in the learning activities functioned as conceptual anchors that helped students approach abstract ideas such as vibration, resonance, and sound propagation more meaningfully. Thus, ethnoscience-based physics learning did not merely make the content more familiar, but also created pedagogical conditions that supported the development of fluency, flexibility, originality, and elaboration.

Taken together, the findings suggest that ethnoscience-based physics learning on sound waves offers both conceptual and pedagogical value. Conceptually, it helps bridge formal scientific ideas with students' lived cultural experiences. Pedagogically, it supports a more active, contextual, and creativity-oriented form of learning than conventional teacher-centered instruction. The mixed-methods design strengthens this conclusion by showing not only that students' creativity improved, but also how the learning process facilitated that improvement. Therefore, this study contributes evidence that ethnoscience-based learning can be used as a meaningful approach to enhance creativity in physics learning, particularly when abstract concepts are connected to culturally relevant and experientially familiar contexts.

LIMITATION

This study has several limitations that should be acknowledged. First, it employed a one-group pretest-posttest design without a comparison group, which limits the strength of causal interpretation regarding the effect of the intervention. Second, the study involved a relatively small number of participants drawn from a single junior high school context, which restricts the generalizability of the findings to broader educational settings. Third, although the qualitative data enriched the interpretation of the quantitative results, the qualitative evidence was limited to classroom observations, field notes, and documentation within one specific instructional context. These limitations suggest that the findings should be interpreted as contextually meaningful rather than universally generalizable.

RECOMMENDATION

Based on these findings, it is recommended that physics teachers and curriculum developers consider integrating ethnoscience-based learning into sound-wave instruction and other physics topics that can be meaningfully connected to local cultural contexts. Future studies should involve larger and more diverse samples, include comparison or control groups, and examine the implementation of ethnoscience-based learning across different topics and school settings to strengthen the empirical basis of its effectiveness. It is also recommended that future research explore the use of more varied instructional supports, including project-based tasks, inquiry-based activities, and technology-assisted sound analysis, in order to further examine how ethnoscience-informed learning can foster creativity and other higher-order skills in physics education.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Conflict of Interests

The authors declare no conflict of interest.

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