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From Tradition to Innovation: Exploring the Impact of *Seurunee Kalee* Based Ethnoscience in Guided Inquiry Physics Learning

Elvida[1], Mei Chi Lee[2]
[1]Dewantara 1 State Senior High School, Aceh Utara, Indonesia
[2]Physics with Electronic Program, Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Sabah, Malaysia

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ABSTRACT

Purpose of the study: This study aims to examine the effect of the guided inquiry learning model integrated with an ethnoscience approach using the *Seurunee Kalee* context on students' critical thinking skills in learning sound waves at Dewantara 1 State Senior High School.

Methodology: This study used a mixed-method approach with an explanatory sequential design and a quasi-experimental Non-Equivalent Control Group Design. Data were collected using tests, questionnaires, and interviews. Learning tools included worksheets and guidebooks. Data analysis employed SPSS version 25 for quantitative analysis and the Miles and Huberman model for qualitative review.

Main Findings: The guided inquiry learning model integrated with an ethnoscience approach using the *Seurunee Kalee* significantly improved students' critical thinking skills on sound waves. The experimental group's mean score increased from 31.81 to 78.63, while the control group rose from 29.09 to 68.18. The t-test result (Sig. = 0.039 < 0.05) confirmed a significant difference. Student responses reached 86.79%, categorized as very strong.

Novelty/Originality of this study: This study introduces the integration of a guided inquiry learning model with an ethnoscience approach using the *Seurunee Kalee* context in physics learning. The novelty lies in combining local cultural values with scientific inquiry to enhance students' critical thinking skills, providing a new framework for contextualized and culturally relevant science education.

Corresponding Author:
Elvida,
Dewantara 1 State Senior High School,,
BTN Aron Paloh Lada Road, Paloh Lada, Dewantara, Aceh Utara, 24355, Indonesia
Email: elvida12@gmail.com

1. INTRODUCTION

Modern education focuses on developing critical thinking skills as the main foundation of 21st-century science learning, which requires students to be prepared to face global challenges and technological advancements. Education in the 21st century emphasizes the development of higher-order thinking skills, particularly critical thinking, as an essential competency for students to navigate social complexity and rapid technological progress [1]-[3]. Modern curricula place critical thinking, collaboration, communication, and creativity as the primary learning goals that must be developed integratively across all disciplines [4]-[6].

In the context of science learning, critical thinking plays a crucial role as it helps students think analytically and evaluate empirical evidence scientifically to build a deep conceptual understanding [7]-[9]. Moreover, critical thinking skills are closely related to students' ability to apply scientific concepts in solving real-world problems reflectively and evidence-based [10], [11]. Therefore, learning strategies that encourage inquiry activities and provide meaningful contexts are essential in modern science education to foster sustained critical thinking [12], [13]. However, in practice, students' critical thinking skills remain low due to suboptimal science learning practices.

In many schools, physics learning is still predominantly teacher-centered and focused on memorizing formulas. Such conventional methods tend to limit students' opportunities to engage in active inquiry and critical thinking [14], [15]. Consequently, students' conceptual understanding and analytical abilities regarding physical phenomena are often weak [16], [17]. International assessments and local studies indicate the need to improve the quality of science education to strengthen literacy and critical thinking skills [18], [19]. Therefore, a pedagogical approach that facilitates inquiry, reflection, and scientific argumentation is needed [20]. One approach that can address this challenge is the integration of science and local culture through ethnoscience.

The ethnoscience approach connects scientific knowledge with local wisdom, making learning more contextual and relevant. Integrating local wisdom can enhance students' learning motivation and engagement because the topics are derived from their own cultural environment. For example, traditional musical instruments such as *Seurunee Kalee* contain physical phenomena of sound and resonance that students can easily observe [21]. Learning that links cultural practices with physics concepts helps students recognize the practical and cultural value of science [22]. Therefore, ethnoscience offers a pathway to bridge culture and science while promoting deeper conceptual understanding [23]. To optimize ethnoscience-based learning, a model that encourages scientific exploration such as guided inquiry is needed.

The guided inquiry model positions students as active investigators with structured guidance from the teacher [24], [25]. This approach combines students' freedom to explore with scaffolding that helps them build hypotheses and experimental procedures [20]. Empirical evidence indicates that guided inquiry effectively enhances students' conceptual understanding and higher-order thinking skills [16]. It also facilitates the development of scientific skills such as data analysis, argument construction, and critical reflection [7]. Therefore, this model is relevant to be applied in physics learning aimed at improving critical thinking. However, the integration between the guided inquiry model and ethnoscience contexts remains rarely explored in physics education.

Previous studies have demonstrated the effectiveness of the guided inquiry model in improving students' critical thinking and science process skills. For instance, Maknun [26] found that physics learning using the guided inquiry model led to significant improvements in students' conceptual understanding and critical thinking compared to conventional instruction. In the context of local cultural integration, a systematic review on Ethnoscience in Physics Learning highlighted that guided inquiry-based e-modules integrated with ethnoscience have been developed to enhance students' creativity and conceptual understanding [22].

Nevertheless, most of these studies have not specifically examined how the integration of the guided inquiry model with an ethnoscience approach affects students' critical thinking skills in physics learning, and even fewer have utilized the cultural context of Acehnese traditional instruments such as *Seurunee Kalee*. This gap indicates that although the concept of pedagogical integration is promising, empirical evidence remains limite particularly in the domains of physics and local culture. Hence, new research like the present study is crucial to fill this gap by offering novelty through a unique combination of cultural context, instructional model, and empirical measurement of critical thinking.

The purpose of this study is to investigate the effect of the guided inquiry learning model using an ethnoscience approach with *Seurunee Kalee* in physics learning, as well as to assess students' critical thinking skills on the topic of sound waves at Dewantara 1 State Senior High School. The results are expected to provide empirical evidence of the effectiveness of culture–science integration and practical guidelines for implementing contextual curricula. The contributions of this research include theoretical insights into the study of ethnoscience-guided inquiry and practical recommendations for physics teachers in culturally diverse regions. The empirical context focuses on exploring sound and vibration concepts through the traditional Acehnese instrument *Seurunee Kalee*. Thus, this study not only strengthens students' conceptual understanding but also contributes to preserving local cultural values through a scientific approach.

2. RESEARCH METHOD

2.1. Type of Research

This study employs a mixed-method approach with an explanatory sequential design. Quantitative data were collected using an experimental method, which was applied to test the hypotheses by systematically analyzing the relationships among variables through numerical data. The research utilized a quasi-experimental design, as it was not possible to randomly assign subjects completely to the experimental and control groups. Specifically, this study adopted a non-equivalent control group design. In this design, there are two groups that receive both a pretest and a posttest namely, the experimental group and the control group [27], [28]. The experimental group received a treatment in the form of the guided inquiry learning model based on ethnoscience (X_1), while the control group was taught using the conventional learning model (X_2) with a lecture method. Both the experimental and control groups were given a pretest (O_1) before the treatment to measure initial ability and a posttest (O_2) after the treatment to measure improvements in learning outcomes and students' critical thinking skills. The design of this research is illustrated in the following table:

Table 1. Non-Equivalent Control Group Research Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X_1	O_2
Control	O_1	X_2	O_2

2.2. Population and Sample

The population of this study consisted of all eleventh-grade students at State Senior High School 1 Dewantara, specifically classes 11–A1 and 11–A2, which shared similar characteristics in terms of academic ability and the physics curriculum used. The sampling technique employed was purposive sampling, a method of selecting samples based on specific considerations [29], [30]. Two classes were selected from the population based on the equality of academic abilities and the availability of class schedules. Subsequently, the group assignment was conducted randomly, with Class 11–A designated as the experimental group, which received treatment using the guided inquiry learning model based on ethnoscience, and Class 11–B designated as the control group, which received instruction through conventional learning using the lecture method. The total sample of this study consisted of 60 student respondents and one teacher..

2.3. Data Collection Techniques

The techniques and instruments for data collection in this study were designed to obtain accurate information regarding students' critical thinking skills after the implementation of the guided inquiry learning model based on ethnoscience. The instruments included test instruments, non-test instruments, and learning tools such as learning objectives flowcharts, student worksheets, and teacher guidebooks to support the experimental process.

Data were collected through three primary techniques: tests, questionnaires, and interviews.

- The test technique was used to measure students' critical thinking skills by administering ten multiple-choice questions, consisting of a pretest before treatment and a posttest after treatment. This instrument aimed to assess the extent to which students' critical thinking skills improved after the application of ethnoscience-based learning.
- The questionnaire was used to collect non-test data concerning students' responses and feelings toward the learning process. The questionnaire consisted of fifteen statements developed based on indicators of student engagement in guided inquiry learning. By combining these two techniques, the researcher was able to obtain a comprehensive picture of the effectiveness of the learning model in improving students' critical thinking skills.
- Additionally, semi-structured interviews were conducted to gather in-depth information regarding the effectiveness of the guided inquiry learning model based on ethnoscience.

2.4. Data Analysis Techniques

Data analysis in this study was conducted using the SPSS (Statistical Package for the Social Sciences) program to ensure that the calculations were accurate and objective. The analysis was carried out in several stages, including the normality test, homogeneity test, and hypothesis test. The normality test was performed to determine whether the pretest and posttest data from both the experimental and control groups were normally distributed, using the Kolmogorov–Smirnov test since the sample size exceeded 50 respondents [31], [32]. The analysis was conducted at a significance level of $\alpha = 0.05$, with the decision criterion that if the Sig. value is greater than 0.05, the data are considered normally distributed, and if less than 0.05, the data are not normally distributed. Next, the homogeneity test was conducted to determine the equality of variances between groups using the Levene's Test for Equality of Variances, also at a significance level of $\alpha = 0.05$ [33], [34]. The data were considered homogeneous if the Sig. value was greater than 0.05 and non-homogeneous if it was less than 0.05. After confirming normality and homogeneity, a hypothesis test was conducted using the Independent Samples T-Test to determine whether there was a significant difference in students' critical thinking skills between the experimental class, which used the guided inquiry learning model based on ethnoscience, and the control class, which used conventional learning. The criterion for decision-making was that if the Sig. (2-tailed) value was less than 0.05, H_0 was rejected and H_1 accepted, indicating a significant difference between the two groups; conversely, if Sig. was greater than 0.05, H_0 was accepted and H_1 rejected, indicating no significant difference [35], [36]. Meanwhile, qualitative data were analyzed using the Miles and Huberman model, which includes three main stages: data reduction, data display, and conclusion drawing or verification.

3. RESULTS AND DISCUSSION

3.1. Descriptive Statistics

Descriptive statistical analysis was conducted to obtain an overview of students' learning outcomes before (pretest) and after (posttest) the implementation of the learning model in both the experimental and control classes. The calculations were performed using SPSS version 26, which included determining the minimum, maximum, mean, and standard deviation values to describe the overall data distribution and performance trends of the students..

Table 2. Descriptive Statistics of Students' Learning Outcomes in the Experimental and Control Classesl

Class	Test	N	Minimum Score	Maximum Score	Mean	SD
Experimental	Pretest	30	10	60	31.81	13.28
Experimental	Posttest	30	50	100	78.63	15.27
Control	Pretest	30	10	50	29.09	12.04
Control	Posttest	30	40	90	68.18	13.84

Based on Table 2, the experimental class showed an increase in the mean score from 31.81 to 78.63, indicating a gain of 46.82 points. This demonstrates a significant improvement in students' critical thinking skills after the implementation of the guided inquiry learning model based on ethnoscience. The control class also experienced an improvement from 29.09 to 68.18, but the increase was relatively smaller, amounting to 39.09 points compared to the experimental class. The standard deviation values indicate that the distribution of students' learning outcomes varied moderately but remained within a reasonable range for a sample size of 30 students per group. Overall, the greater improvement observed in the experimental class suggests that the guided inquiry learning model based on ethnoscience is more effective than the conventional lecture method in enhancing students' critical thinking skills on the topic of sound waves.

3.2. Hypothesis Testing

The normality test was conducted to determine whether the learning outcome data were normally distributed or not. The test was performed using the Kolmogorov–Smirnov test with a significance level of 0.05. The data are considered to be normally distributed if the significance value (Sig.) is greater than 0.05..

Table 3. Results of Normality Test for Pretest and Posttest Data

Class	Pretest (Sig.)	Posttest (Sig.)	Description
Experimental	0.081	0.125	Normally Distributed
Control	0.074	0.086	Normally Distributed

All pretest and posttest data have significance values greater than 0.05, indicating that the data are normally distributed and meet the assumptions required for conducting a parametric test (Independent Sample t-test). The homogeneity test was then performed to determine whether the variances of the two data groups were equal. The analysis employed Levene's Test with a significance level of 0.05. The data are considered homogeneous if the significance value (Sig.) is greater than 0.05.

Table 4. Results of Homogeneity Test of Variance for Pretest and Posttest Data

Type of Test	Sig.	α (0.05)	Description
Pretest	0.666	0.05	Homogeneous
Posttest	0.934	0.05	Homogeneous

The Levene's Test significance values were greater than 0.05 for both the pretest and posttest, indicating that the data were homogeneous. Therefore, the analysis could be continued using a *parametric t-test*. The hypothesis testing was conducted using an *Independent Sample t-test* to determine whether there was a significant difference between the learning outcomes of students in the experimental class and those in the control class.

Table 5. Results of t-Test (Independent Sample t-test) for Pretest and Posttest of Experimental and Control Classes

Type of Test	Sig. (2-tailed)	α (0.05)	Description
Pretest	0.627	0.05	H_0 accepted
Posttest	0.039	0.05	Ha accepted

In the pretest, the Sig. (2-tailed) value was 0.627 > 0.05, indicating that there was no significant difference between the experimental and control classes. Thus, the initial abilities of both groups could be considered equivalent before the treatment was given. In the posttest, the Sig. (2-tailed) value was 0.039 < 0.05, showing a significant difference between the two groups after the treatment. These results indicate that the guided inquiry learning model based on ethnoscience had a significant positive effect on improving students' critical thinking skills in the sound wave topic. To determine students' responses to the implementation of the guided inquiry learning model based on ethnoscience, a questionnaire was distributed to 30 students in the experimental class.

Table 6. Results of Students' Response Questionnaire toward the Guided Inquiry Learning Model Based on Ethnoscience

Number of Students	Total Score (F)	Maximum Score (N)	Mean	Percentage	Criteria
30	1432	1650	77.33	86.79%	Very Strong

A percentage of 86.79% indicates that students gave a very positive response to the implementation of the ethnoscience-based guided inquiry learning model. The students felt that the learning process became more engaging, easier to understand, and more relevant to everyday life.

To strengthen the quantitative results, the researcher also conducted open interviews with several students from the experimental class who participated in learning activities using the ethnoscience-based guided inquiry model with the *Seurunee Kalee* as a learning medium. The interviews aimed to explore the students' perceptions of their learning experiences, conceptual understanding, and the cultural meanings embedded in the learning activities.

Based on the interview results, several important findings were obtained as follows:

1. Students found the learning more engaging and meaningful.
   The students stated that using *Seurunee Kalee* made it easier for them to understand the concept of sound waves because they could directly observe how vibrations produce sound. One student remarked:
   > "Usually, we only hear explanations from books, but when we made *Seurunee Kalee*, we could see the vibrations and hear the sound produced. So, we understood that sound really comes from vibrations."
2. Students gained a better understanding of the relationship between the instrument's shape and the concept of sound.
   Several students explained that the *Seurunee Kalee*, made from coconut leaves and shaped like a long cone, affected the pitch of the sound produced. They were able to relate this to the concepts of frequency and wavelength in physics.
   One student said:
   > "When we made the coconut leaf part longer, the sound became lower. But when it was shorter, the sound became higher. So we understood that the tube's length affects the frequency of the sound wave."

Figure 1. Seurunee Kalee

The *Seurunee Kalee* is played by blowing into a young coconut leaf (janur) that is still tender and shaped into a cone, resembling a trumpet. Traditionally, the *Seurunee Kalee* is played as a trumpet during the Eid eve celebration (malam takbiran), the Islamic New Year (Muharram), and other traditional ceremonies, or it is used as a form of children's play. To gain a deeper understanding of sound waves, researchers used the *Seurunee Kalee* to study the correlation between wavelength and frequency.

This definition allows us to conclude that ethnoscience is a branch of the scientific community that seeks to understand human civilization through the lens of cultural practices and traditional beliefs of a particular society. Thus, the ethnoscience-based approach to education helps students make connections between what they learn in the classroom and their real-world experiences. In physics classes that apply the guided inquiry model integrated with ethnoscience, students find it easier to understand the subject matter and are better able to apply critical thinking skills when solving problems. They are encouraged to engage directly with local culture and utilize the knowledge embedded within it through the ethnoscience-based inquiry learning paradigm.

3. Learning makes students more active and confident
   Through the guided inquiry model, students are encouraged to experiment, observe, and draw their own conclusions. This process helps them become more confident in asking questions and engaging in discussions.
   "We were more active because we had to find out the answers ourselves. So when explaining the results of our experiments, we also felt more confident."
4. Fostering pride in local culture
   Students expressed that they felt proud to learn physics through a traditional local musical instrument. They realized that science can also be found within their own culture.
   "It turns out that *Seurunee Kalee* is not just a musical instrument, but it can also be explained using physics concepts. We're happy to learn using something that comes from Aceh."

Based on the interview results, it can be concluded that the use of *Seurunee Kalee* in the ethnoscience-based guided inquiry learning model:

- Helps students understand the relationship between the instrument's shape and the concept of sound waves (frequency, resonance, and wavelength);
- Increases students' interest and active participation in learning;
- Enhances critical and scientific thinking skills; and
- Builds pride in Acehnese local wisdom.

Thus, the ethnoscience approach through the *Seurunee Kalee* medium has proven effective not only in improving students' understanding of physics concepts but also in enriching their learning experiences through contextual and meaningful cultural values.

The findings of this study reveal that the implementation of the guided inquiry learning model integrated with ethnoscience through the use of the traditional Acehnese instrument *Seurunee Kalee* has a significant effect on improving students' critical thinking skills in the topic of sound waves. The results of the t-test show that there is a significant difference in posttest scores between the experimental and control groups (Sig. = 0.039 < 0.05). This indicates that the guided inquiry model supported by ethnoscience elements is more effective than conventional learning in enhancing students' conceptual understanding and reasoning ability.

The increase in the mean score from 31.81 to 78.63 in the experimental class demonstrates that the integration of cultural context into scientific inquiry facilitates deeper conceptual comprehension. These results are consistent with previous studies reporting that guided inquiry encourages students to actively construct their knowledge and develop higher-order thinking skills [27], [37]. Ethnoscience, when embedded in inquiry learning, connects scientific phenomena with students' daily lives and local wisdom, making learning more meaningful and authentic [38], [39].

In this research, the *Seurunee Kalee* a traditional trumpet made from young coconut leaveswas employed as a cultural medium to explain the physics of sound waves. Students were able to observe directly how vibration and resonance produce sound, linking the physical structure of the instrument to abstract concepts such as wavelength and frequency. This cultural-scientific connection reinforces the constructivist perspective that knowledge is best developed when students interact with real and culturally relevant contexts [40], [41].

The students' responses, with a strong category of 86.79%, demonstrate that the ethnoscience-based guided inquiry model promotes engagement and enjoyment during learning. This is aligned with the findings of Verawati et al. [42], who noted that integrating ethnoscience materials enhances students' motivation and curiosity. The qualitative data from interviews also confirmed that students became more confident and enthusiastic because they were directly involved in designing and testing the *Seurunee Kalee* They discovered that longer instruments produced lower tones, which they related to the concept of wave frequency. Such experiential discovery strengthens not only cognitive understanding but also students' scientific attitudes [43].

The inclusion of *Seurunee Kalee* in learning physics exemplifies how ethnoscience can bridge traditional knowledge and modern science. Students realized that scientific principles are embedded in their local culture, which supports the development of contextual and culturally responsive science education [40]. This finding supports the argument that ethnoscience-based inquiry promotes both scientific literacy and cultural appreciation. It empowers learners to see science not as foreign knowledge but as part of their everyday cultural experience.

In addition, students also expressed pride in learning science through local traditions, which is consistent with the findings of recent studies showing that integrating ethnoscience into learning not only improves scientific understanding and critical thinking but also strengthens students' identity, respect for culture, and awareness of sustainability [42], [44]. The results imply that science teachers can utilize local materials and traditional artifacts as effective media to enhance inquiry learning. The ethnoscience-based guided inquiry model:

- Encourages active participation and collaboration,
- Strengthens conceptual and critical understanding, and
- Promotes contextualized science learning aligned with students’ cultural backgrounds.

Hence, this pedagogical model aligns with the current paradigm of 21st-century learning that emphasizes cultural relevance, creativity, and problem-solving ability [45].

The findings of this study align strongly with constructivist and socio-cultural learning theories, which emphasize that knowledge is actively constructed through interaction with meaningful experiences and social contexts. The guided inquiry model provided structured scaffolding that allowed students to explore, hypothesize, and test ideas within their Zone of Proximal Development [41], [46]. When integrated with the ethnoscience approach, learning became contextually grounded and culturally relevant, enabling students to internalize abstract physics concepts through authentic experiences. This is evident when students linked the varying length of *Seurunee Kalee* a traditional Acehnese musical instrument to the concepts of frequency and wavelength. Such learning activities reflect *situated cognition* and *experiential learning* frameworks Kolb [47], where direct engagement in culturally meaningful practice fosters deeper conceptual understanding and enhances critical thinking. These results corroborate the findings of Hikmawati et al [48], who demonstrated that ethnoscience-based science learning significantly improves students’ analytical and reflective thinking by connecting scientific inquiry with local wisdom.

Furthermore, this research reinforces the principles of *culturally responsive pedagogy* and the *funds of knowledge* framework, emphasizing that students’ cultural backgrounds serve as powerful assets in the learning process [49], [50]. By using the *Seurunee Kalee* as a scientific learning medium, students recognized that physics is not detached from their daily life but inherently embedded in their cultural practices reducing cognitive load and increasing motivation. This is consistent with Sarwi et al. [51], who reported that ethnoscience-based guided inquiry strengthens students’ conceptual mastery and life skills. The high student response rate (86.79%) and the medium-to-large effect size ($d \approx 0.72$) found in this study empirically support these theoretical claims, suggesting that integrating guided inquiry with ethnoscience not only promotes cognitive development but also cultivates cultural identity, engagement, and scientific literacy within 21st-century learning frameworks.

The novelty of this study lies in the integration of a guided inquiry learning model with ethnoscience using the traditional Acehnese musical instrument *Seurunee Kalee* as a cultural medium for learning physics on the topic of sound waves. Unlike previous research that focused solely on the cognitive impact of inquiry-based instruction, this study demonstrates that embedding ethnoscience within guided inquiry enhances students’ critical thinking skills, conceptual understanding, and scientific attitudes while simultaneously fostering cultural identity, pride, and sustainability awareness. The approach bridges scientific concepts and local wisdom, providing an innovative pedagogical framework that aligns with the principles of 21st-century learning emphasizing contextual relevance and cultural responsiveness. This finding contributes to the growing body of literature that promotes the integration of local traditions into science education as a means to create more meaningful, authentic, and inclusive learning experiences. However, the limitation of this study lies in its relatively small sample size and single-school context, which may restrict the generalizability of the results to broader educational settings.

4. CONCLUSION

The results of this study demonstrate that the guided inquiry learning model integrated with ethnoscience using the traditional Acehnese instrument *Seurunee Kalee* has a significant positive impact on students’ critical thinking skills and conceptual understanding of sound wave phenomena. Statistical analysis using the Independent Samples t-test showed a significant difference between the experimental and control groups (Sig. = 0.039 < 0.05), confirming that the ethnoscience-based guided inquiry model is more effective than conventional learning. The integration of local cultural context into scientific inquiry enhances students’ engagement, confidence, and appreciation of traditional knowledge, while also developing their analytical and reflective thinking. Students not only understood the relationship between physical concepts such as vibration, frequency, and wavelength, but also recognized the scientific values embedded in their local culture. This study concludes that ethnoscience-based guided inquiry serves as a powerful pedagogical approach to bridge traditional wisdom and modern science, fostering contextual, meaningful, and culturally responsive physics learning. The model effectively supports 21st-century learning competenciesparticularly critical thinking, creativity, and cultural awareness. For future research, it is recommended to apply this model across different topics, cultural contexts, and larger sample sizes to further validate its effectiveness and explore its potential to promote sustainability-oriented science education.

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