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Enhancing Students' Learning Outcomes and Motivation through Interactive Physics Escape in an LMS-Based E-Learning Environment

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ABSTRACT

Objective: *This study aims to (1) determine the level of feasibility, practicality, and effectiveness of the Interactive Physics Escape media; (2) evaluate the influence of media on students' learning motivation; and (3) analyze the influence of media use on improving learning outcomes on vibration, wave, and sound materials.* ***Method:*** *Using a Research and Development (R&D) approach combined with a quasi-experimental design (pretest-posttest control group), this study involved 60 junior high school students, namely the experimental and control groups. The experimental group implemented Interactive Physics Escape, an LMS-based escape room game that integrates ethnophysics (traditional Indonesian musical instruments), while the control group used direct instruction.* *Data was collected through tests and questionnaires, then analyzed descriptively and inferentially (Wilcoxon, Mann-Whitney, N-Gain, effect size).* ***Results:*** *Media was rated as very feasible (M=3.46–3.57), practical (M=3.64–3.86), and effective, especially in encouraging collaboration (M=3.93) and motivation (M=3.64–3.71). Statistical analysis showed a significant increase in learning outcomes in the experimental group ($p<0.001$) with a very strong effect size ($r=-1.000$). Furthermore, the post-test score and N-Gain of the experimental group (0.55, medium-high category) were significantly higher than those of the control group ($p=0.003$; N-Gain=0.38).* ***Novelty:*** *This research presents a new integration between escape room gamification, Learning Management System (LMS) technology, and an ethnophysical approach (using traditional Indonesian musical instruments as a learning context) in an integrated pedagogical intervention. The research results provide empirical evidence for a culture- and technology-based learning model that can simultaneously improve cognitive, affective and collaborative dimensions in science education.*

INTRODUCTION

The developments of the 21st century and the demands of the Industrial Revolution 4.0 are driving digital transformation throughout the education sector. This demands pedagogical adaptations that are responsive to technology (Haleem et al., 2022). Physics learning in schools faces a fundamental challenge, namely that students widely perceive it as abstract science, difficult to understand, and less relevant to everyday life (Khan et al., 2023). This negative perception is directly correlated with the low motivation and learning outcomes seen in student grades at one of the private schools in Surabaya, especially on topics that require deep conceptual understanding such as waves and sound. In fact, mastery of scientific literacy is an important basis for forming 21st century competencies and building a knowledge-based society (Chankseliani & McCowan, 2021). Therefore, innovative breakthroughs are needed in the design of learning media that can bridge the epistemological gap between abstract physical theories and students' concrete experiences.

The digital transformation occurring in the world of education demands the use of e-learning as a strategic approach in improving the quality of science learning. This system allows learning activities to take place flexibly because it is supported by the integration of digital technology which facilitates interaction, collaboration and wider availability of learning resources. In physics learning, e-learning plays a role in presenting abstract concepts through various means such as interactive media, simulations, and problem-based activities which can increase active student involvement. Various studies show that interactively designed e-learning learning environments can strengthen learning engagement, increase motivation, and deepen students' conceptual understanding of science material (Almaiah et al., 2020; Dhawan, 2020). Recent state-of-the-art research further emphasizes the role of adaptive e-learning systems, artificial intelligence integration, and immersive technologies such as virtual and augmented reality in enhancing personalized learning experiences and conceptual understanding in science education (Zawacki-Richter et al., 2019; Radianti et al., 2020). These approaches highlight a shift from static digital content toward dynamic, learner-centered environments that actively respond to students' needs. Therefore, implementing e-learning in physics learning is important to create a more relevant and meaningful learning experience.

One response in the education sector to the development of digitalization is the implementation of a Learning Management System (LMS). This platform provides structured services in implementing learning. Based on the data obtained, many schools that have LMS facilities have not been able to utilize the LMS optimally; the LMS is only used as a place to enter materials and submit assignments. This indicates that the LMS has not been implemented optimally to increase students' intrinsic motivation in participating in Physics learning (Kohnke & Moorhouse, 2022; Rasheed et al., 2020). To be able to increase students' intrinsic motivation, educators need to provide an approach that aligns with current student interest trends, namely learning that is linked to game technology or gamification. The interactive physics escape learning innovation is an escape room puzzle-solving game linked to wave material. Learning that applies a gamification approach can increase collaboration, problem-solving, and student motivation (Veldkamp et al., 2020; Peña et al., 2023). State of the art studies in gamification also demonstrate the effectiveness of integrating real-time feedback systems, narrative-driven gameplay, and data analytics within LMS platforms to enhance engagement and sustain motivation in STEM learning (Dichev & Dicheva, 2017; Sailer et al., 2021). The combination of interactive physics escape and LMS is one solution to improve student understanding and motivation. This integration offers a learning system that is not only engaging and in-depth, but also widely accessible and can be implemented on a large scale.

Based on the literature review that has been conducted, data were collected that scientific research that applies interactive physics escape focuses on cognitive aspects, so that learning with this gamification approach pays less attention to the social and cultural aspects associated with learning (López-Pernas et al., 2019; Nicholson, 2018). We can see that it is very important to apply cultural concepts in physics learning, which is called ethnophysics. Ethnophysics argues that physics concepts are embedded in people's cultural practices and artifacts (Ozsoy, 2023). For example, the principles of vibration, resonance and sound waves can be explored authentically through the investigation of traditional Indonesian musical instruments such as gamelan (metal) or rebab (string). This integration not only increases relevance and conceptual understanding through contextual examples but also functions as a culturally sustaining pedagogy that validates that culture is very relevant in science learning. Contemporary research in culturally responsive STEM education highlights that integrating local knowledge systems with digital learning environments can significantly improve students' identity, engagement, and conceptual transfer, especially in multicultural contexts (Bang et al., 2018).

Based on several studies that have been carried out, it is known that interactive physics and ethnophysics were carried out separately. There is literature about the positive impact of interactive physics on critical thinking skills and group collaboration in chemistry and biology subjects (Pezzuti et al., 2021). Accordingly, research related to ethnophysics shows a significant increase in conceptual understanding and positive attitudes towards science (Khusniati et al., 2023; Sari & Prasetyo, 2022). However, there is a research gap, namely that there has been no research that holistically designs, develops, and empirically tests an integrated learning media that combines the following three things: (1) game-based learning pedagogy in the form of an interactive physics escape, (2) a Learning Management System platform as a place for implementing games, and (3) an ethnophysical approach as a basis for cultural contextualization in one complete media prototype.

Based on the research background and gaps, this research aims to develop and test the effectiveness of the LMS-based "Interactive Physics Escape" learning media with an ethnophysical approach. The focus of the research is on vibration, waves and sound material at the junior high school level. Specifically, the objectives of this research are: (1) Assessing the level of feasibility, practicality and effectiveness of media based on the user's perspective (user-centered evaluation); (2) Evaluate the impact of media on increasing student learning motivation; and (3) Analyze the statistical significance of media use on improving student cognitive learning outcomes.

RESEARCH METHOD

This research uses the Research and Development (R&D) method by applying the Borg & Gall (1983) model which is integrated with a quasi-experimental approach. This combination was chosen to develop the learning media "Interactive Physics Escape" which is valid, practical and effective, while testing its effect on learning outcomes and student motivation. The research steps are as follows:

The systematic stages of the Borg & Gall model form the basis of this research framework, which in the initial phase began with preliminary research and needs analysis through literature reviews and observations of real problems in the classroom by the researcher. Based on these findings, in phase 2 of initial product development, a prototype of "interactive physics escape" media was created which was then tested on a limited basis and revised based on expert and student input. The core stage of this research, reported in the article, is phase 3 product effectiveness testing, where the media is rigorously tested through application in control and experimental classes to prove its effectiveness in improving learning outcomes and student motivation. The results of this test are then used for final improvements, before finally disseminating phase 4. Products that have been tested are published in journals, presented and socialized to teachers for real implementation in schools. The research design uses a quasi-experimental design with a pretest-posttest control group design pattern. The research design scheme is as Table 1 and Figure 1.

Table 1. Research design

Class	Pretest	Treatment	Posttest
Experiment (VIII-4)	O_1	X_1	O_2
Control (VIII-5)	O_1	C	O_2

Information:
X_1 = Treat experimental class (Direct Instruction with Interactive Physics Escape)
C = Treat control class (Direct Instruction)

O_1 = Pretest before treatment is applied
O_2 = Posttest after treatment is applied

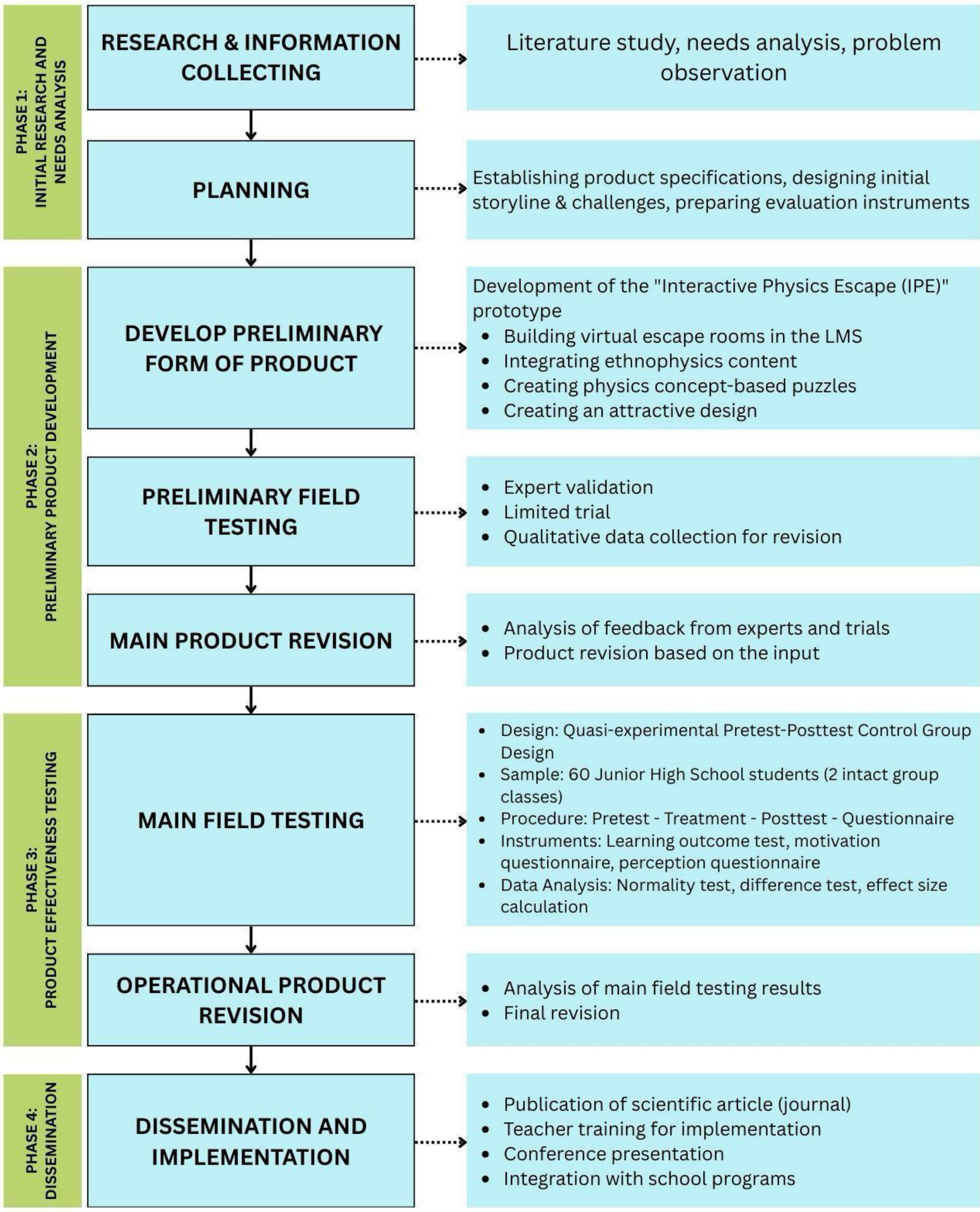

Figure 1. Borg & Gall method (1983)

The subjects of this research were class VIII students at a private junior high school in Indonesia. The research involved two classes that had been formed (intact groups), namely the experimental class and the control class, each with 30 students. The experimental class is a class that takes part in learning using Interactive Physics Escape media based on a Learning Management System (LMS) with an ethnophysical approach, while the control class is a class that receives Direct Instruction learning without interactive media. The selection of participants was carried out using a purposive sampling technique with an intact group. This technique is commonly used in educational research because classes in schools have been formed administratively, making it difficult to randomize individuals (Fraenkel, Wallen, & Hyun, 2019; Creswell & Guetterman, 2021).

This research uses two main instruments. First, a learning outcomes test in a pretest-posttest format which measures mastery of the concepts of vibration, waves and sound. The items were designed based on the revised Bloom's taxonomy (C1–C4) and the junior high school curriculum. This instrument has gone through a validity test using the Aiken index with a value of 0.95, which shows a very high level of agreement between 3 experts (expert judgment) regarding the suitability of the question items with the indicators being measured. In addition, the reliability test using Cronbach's alpha produced a value of 0.94, which indicates a very high level of measurement reliability (Aiken, 1985; Anderson & Krathwohl, 2001). Second, a media perception questionnaire with a five-point Likert scale was designed to assess media from a user's perspective (user-centered evaluation). The questionnaire has been tested for construct validity through confirmatory factor analysis and has high reliability in all dimensions, with a Cronbach's alpha of 0.94, which reflects the very adequate stability and consistency of respondents' responses. Data from the two instruments was then analyzed descriptively to assess the feasibility, practicality and effectiveness of learning media (Sugiyono, 2019). Meanwhile, to interpret the feasibility, practicality, effectiveness and motivation scores obtained from the questionnaire (Table 2).

Table 2. Interpretation of the average score of the motivation scale

Score Range	Category	Interpretation
1.00 – 1.79	Very Low	Motivation is very weak
1.80 – 2.59	Low	Motivation is not good
2.60 – 3.39	Moderate	Motivation is quite good
3.40 – 4.19	High	Good motivation
4.20 – 5.00	Very High	Motivation is very high

Statistical analysis in this study used two approaches. For within-group comparisons, the Wilcoxon signed-rank test (Table 3) was directly applied to examine whether there was a significant improvement in learning outcomes from pretest to posttest in both the experimental and control classes. For between-group comparisons, the Mann-Whitney U test was used to test the superiority of the media over Direct Instruction. The combination of these tests provides evidence that the media is effective in improving learning outcomes within groups and is comparatively more effective between groups.

Table 3. Wilcoxon signed-rank test and mann-whitney u categories

p-value	Improvement Category
$p < 0.01$	Very Significant
$0.01 \le p < 0.05$	Significant
$p \ge 0.05$	Not Significant

Data analysis was continued by calculating N-Gain to determine the magnitude of the relative increase in student learning outcomes. Although the significance test shows whether the increase or difference is statistically significant, N-Gain provides information on how much improvement occurred. Thus, N-Gain complements the interpretation of results by providing a practical picture of the effectiveness of a given intervention (Table 4).

$$N - Gain = \frac{posttest - pretest}{maximum\ score - pretest}$$

Table 4. N-gain interpretation categories (Hake, 1998)

N-Gain Value	Improvement Category	Interpretation
< 0.3	Low	Increasing learning outcomes is less than optimal
0.3 – 0.7	Moderate	Moderate increase in learning outcomes
> 0.7	High	The improvement in learning outcomes is very good

Apart from N-Gain, the Rank-Biserial Correlation measure was also calculated to complete the interpretation of the results, especially in comparing the average difference between the experimental and control groups in standard deviation units (Kerby, D. S. (2014). Rank-Biserial Correlation provides a practical picture of the magnitude of the effect of treatment as a group so that it can provide a more comprehensive understanding of the real impact of the intervention provided (Table 5).

Table 5. Interpretation of effect size (Rank-Biserial Correlation)

Type of Effect Size	Value Range	Category	Reference
Rank-Biserial Correlation	< 0.30 0.30 - 0.50 >0.50	Small Medium Large	Kerby, D. S. (2014)

Thus, all research procedures starting from media development design, experimental design, data collection, to analysis techniques have been designed to comprehensively answer the three research questions. Next, the results of data analysis will be explained and discussed sequentially according to the research objectives.

RESULTS AND DISCUSSION

Results

Media Interactive Physics Escape

Before presenting research results, it is important to understand the design of the media being tested. This media is a game created in an LMS, consisting of four levels that integrate physics concepts (vibrations, waves, sounds) with the Indonesian cultural context through an ethnophysical approach (Figure 2 and Figure 3). Each level is designed as an "Interactive Physics Escape" which requires students to complete missions based on interactive activities such as drag and drop, virtual lab, TTS, and digital gamelan exploration. Students must enter the correct code to proceed to the next level. This can create gamified and contextual learning dynamics. This structure is designed to increase student involvement and link physics with local wisdom, where the display and interactive game flowchart are presented in Figure 2, Figure 3, and Table 6.

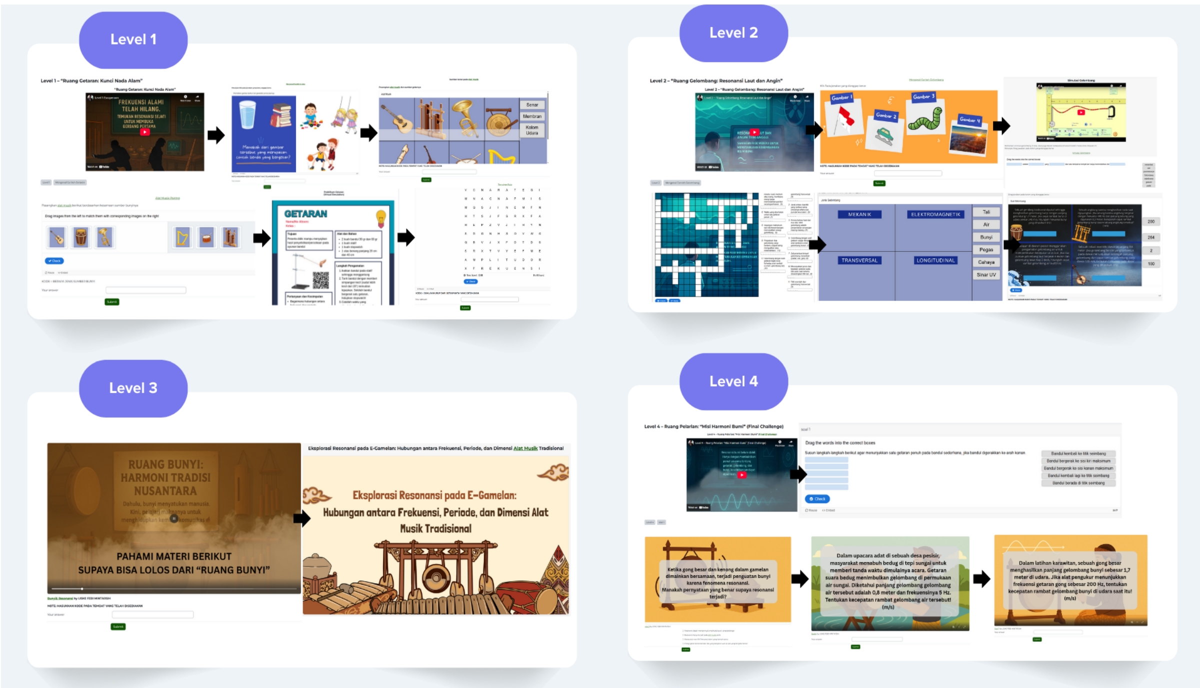

Figure 2. Interactive physics escape

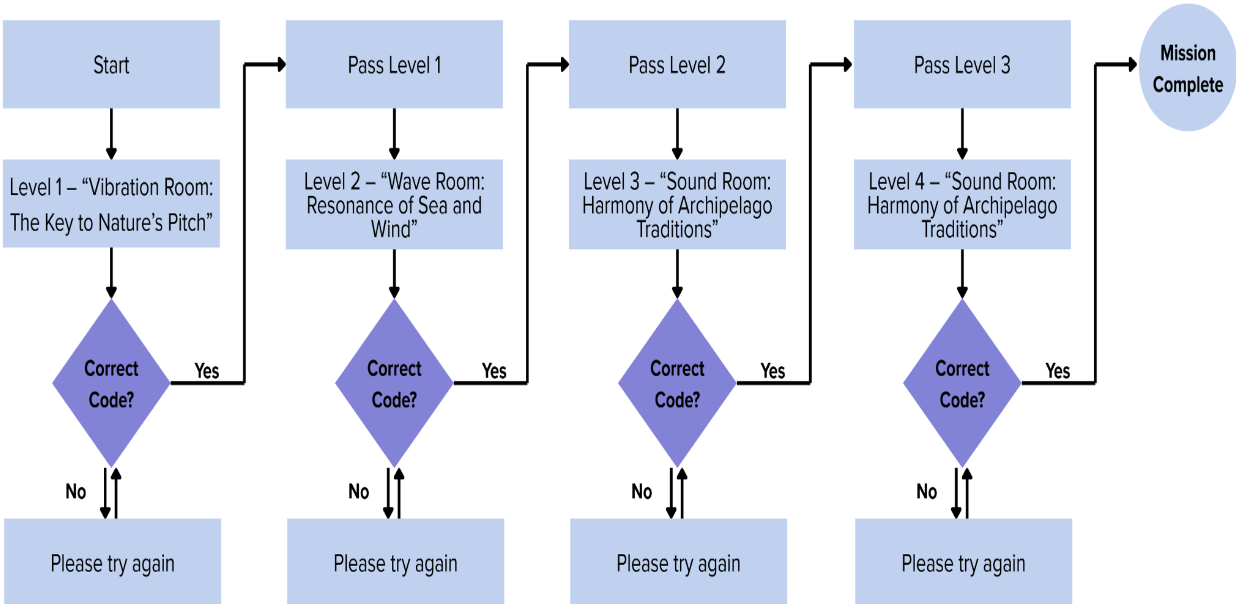

Figure 3. Interactive physics escape flowchart

This research involved 30 students who used LMS-based Interactive Physics Escape media and ethnophysics on the topics of vibrations, waves and sound. Data were collected through closed and open questionnaires to assess students' perceptions of learning motivation, feasibility, practicality and media effectiveness. Analysis was carried out descriptively quantitatively based on average scores and qualitative analysis of students' open answers.

Table 6. Interactive Physics Escape media questionnaire data based on LMS and ethnophysics

Code	Statement	Mean	SD	Category
	Feasibility			
A01	The integration of traditional musical instruments makes learning meaningful.	3.39	0.78	Moderate
A02	Examples are relevant to everyday life.	3.57	0.79	High
A03	Explanations of traditional musical instruments are easy to understand.	3.46	0.88	High
A04	The material is in accordance with the curriculum.	3.57	0.88	High
A05	The relationship between physics and local culture is well explained.	3.46	0.88	High
A06	Proud to introduce Indonesian culture.	3.46	0.79	High
	Practicality			
B01	The LMS display is attractive and easy to navigate.	3.29	0.83	Moderate
B02	Interactive features work well.	3.64	0.68	High
B03	Media is easily accessible.	3.86	0.74	High
B04	Instructions for use are clear.	3.79	0.83	High
B05	Visual design supports understanding.	3.75	0.74	High
B06	Feedback from the system helps learning.	3.86	0.83	High
B07	Can be used independently without a teacher.	3.54	0.79	High
B08	Activities in the LMS strengthen understanding of concepts.	3.32	0.90	Moderate
	Effectiveness			
C01	This media makes me learn actively and independently.	3.46	0.73	High
C02	The Escape Room concept makes learning more interesting.	3.64	0.95	High
C03	Challenges encourage critical thinking.	3.64	0.73	High
C04	Motivated to complete each level.	3.64	0.73	High
C05	Helps understand physics concepts better.	3.32	0.72	Moderate
C06	Can work together/discuss in solving challenges.	3.93	0.65	High
C07	The material is presented clearly and easy to understand.	3.32	0.84	Moderate
C08	Media makes you more interested in studying physics.	3.39	0.88	Moderate
C09	Study time is more fun.	3.71	0.76	High
C10	Want to try similar media for other topics.	3.50	0.96	High

a. Media Eligibility

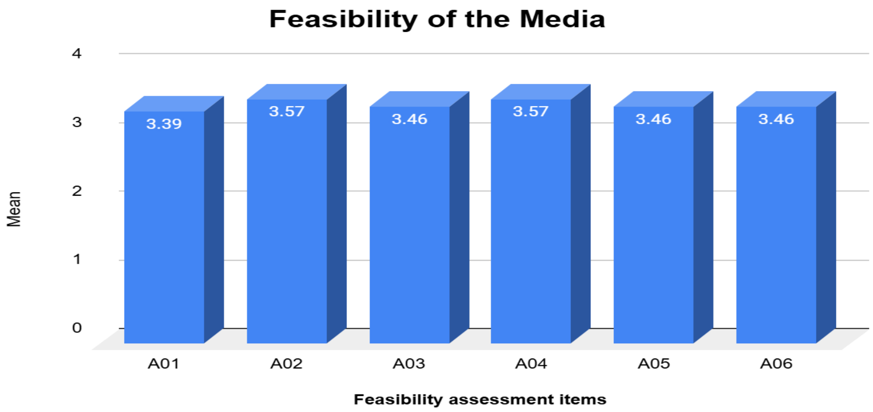

Figure 4. Average score for the feasibility aspect of learning media

Based on data on the feasibility of the Interactive Physics Escape media, it can be interpreted that the LMS-based ethnophysics approach has been very well received by students in terms of curriculum suitability, contextual relevance, and clarity of delivery of cultural material. Five of the six appropriateness indicators are in the High category (average score ≥ 3.40), with two statements receiving the highest scores, namely "Material is appropriate to the curriculum" (M = 3.57) and "Examples are relevant to everyday life" (M = 3.57). This shows that the integration of local culture through musical instruments does not interfere with academic suitability, but rather strengthens the relevance of physics learning in students' real lives. As seen in Figure 4, drag and drop activities that connect musical instruments with types of sound sources provide concrete and contextual learning experiences. In addition, the high score for the statement "Proud of introducing Indonesian culture" (M = 3.46) indicates that this media not only functions as a learning tool, but also plays a role in strengthening students' cultural identity and national pride.

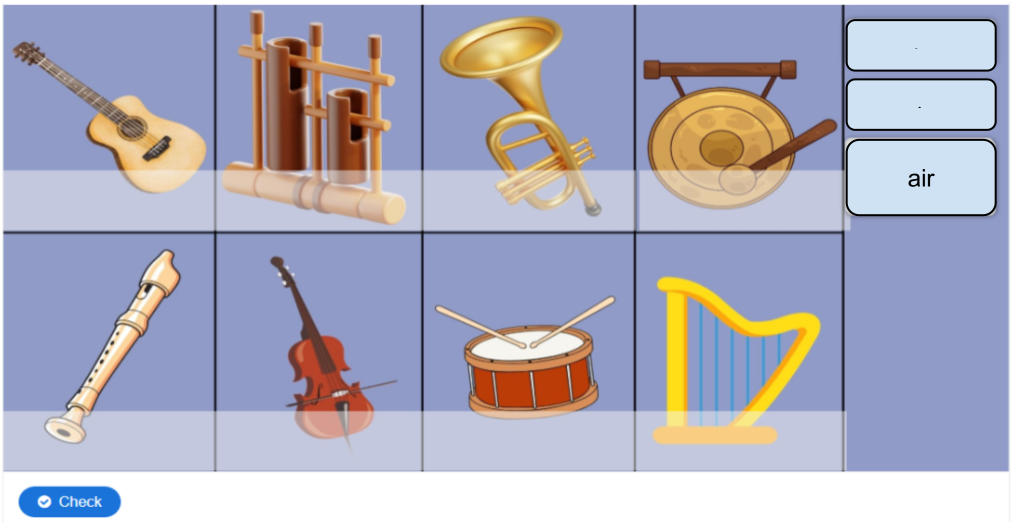

Figure 5. Drag and drop activity in Interactive Physics Escape

However, there is one indicator that is in the Medium category, namely "Integration of traditional musical instruments makes learning meaningful" (M = 3.39). These scores suggest that although students appreciated the cultural elements inserted, some students may need further assistance to fully relate abstract physics concepts to the cultural context presented. Although the drag and drop mechanism (Figure 5) has helped visualize the relationship between musical instruments and physics concepts, some students may still need a more in-depth explanation of the underlying physics principles. Thus, although in general the media is considered appropriate and effective in conveying ethnophysics-based content, there is still room for improvement, especially in terms of deepening conceptual explanations and scaffolding so that cultural integration is not only interesting, but also cognitively meaningful and deepens students' understanding of physics.

b. Media Practicality

Based on media practicality data (Figure 6), it shows that this platform really supports independent learning. The indicators "Media is easily accessible" and "System feedback aids learning" (M = 3.86) received the highest scores. This indicates that the media can be easily operated by students and that the system's responsiveness significantly facilitates their learning process. These findings reinforce the characteristics of the LMS-based approach, which focuses on practical media and active interaction.

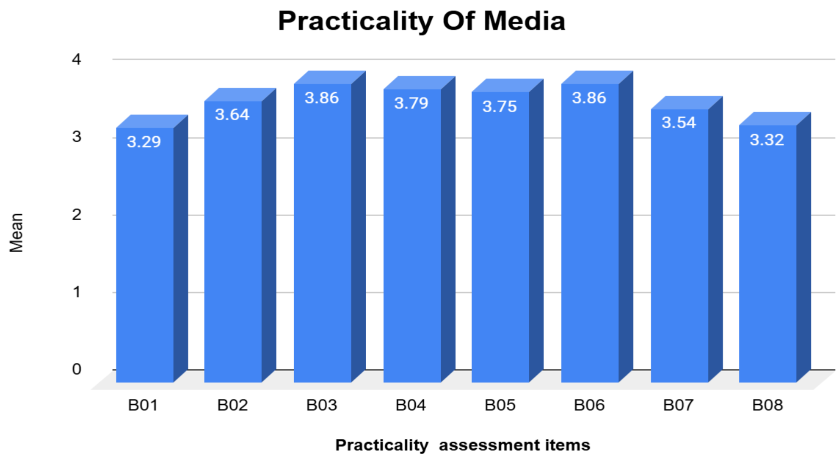

Figure 6. Average score for the practical aspect of learning media

Additionally, high scores were found for the indicators "Clear instructions for use" (M = 3.79) and "Visual design supports understanding" (M = 3.75). Figure 7A shows how the TTS in the LMS is designed with concise instructions, an organized layout, and clear presentation of material vocabulary. This design allows students' attention to be directed to the learning content without being distracted by navigation issues.

Relatively lower scores were obtained for two indicators: "The LMS display is attractive and easy to navigate" (M = 3.29) and "Activities in the LMS strengthen conceptual understanding" (M = 3.32). Important insights are seen in Figure 7B, which displays the crossword puzzle after completing the activity. Students' success in completing the task has not been fully followed by conceptual reinforcement due to the static display and the lack of interactive visualizations. One example is the lack of additional explanations regarding the relationship between terms and physics concepts after students have answered correctly. As an LMS-based medium, Interactive Physics Escape has generally met the practicality aspect. However, opportunities for development remain open through the integration of animation, the automatic presentation of contextual explanations, and the provision of links to further material to enhance visual appeal and deepen conceptual understanding in a more interactive manner.

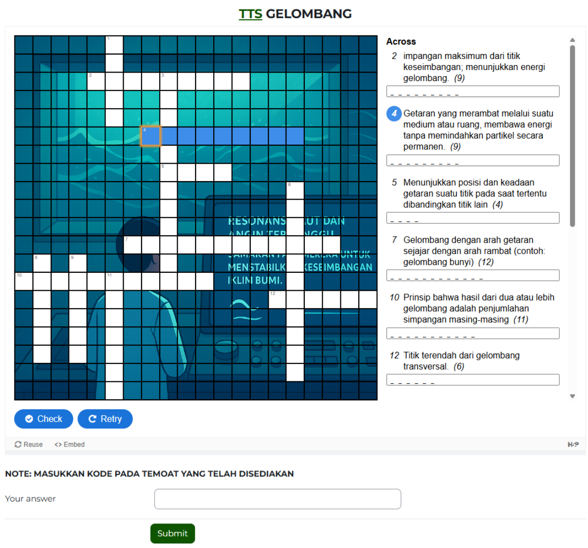

Figure 7A. TTS display with clues and empty grid

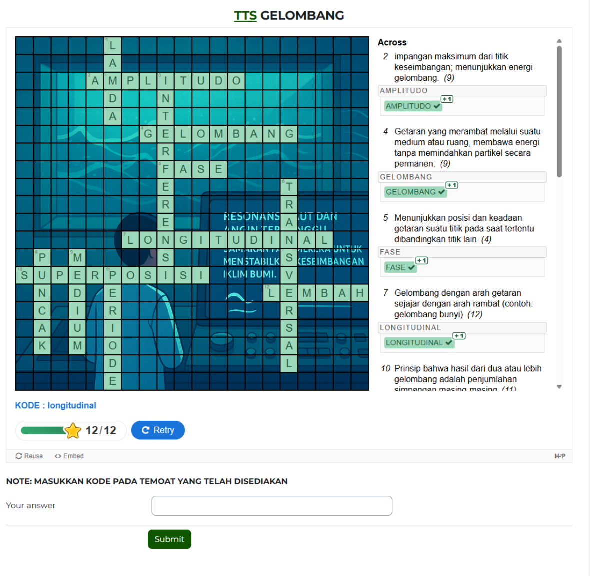

Figure 7B. The TTS display after filling in, with highlights on the answers

c. Media Effectiveness

Based on media effectiveness data, it shows that the ethnophysics-based gamification approach is successful in creating an interesting and collaborative learning environment. The bar graph displays the highest peak in the indicator "Can collaborate/discuss in solving challenges" (M = 3.93), which visually confirms the power of media in facilitating social learning. This peak did not occur by chance but was supported by project-based activities such as Resonance Exploration in E-Gamelan (Figure 8 and Figure 9). In this activity, students in groups select instruments, measure frequencies with Phyphox, and discuss comparisons of the empirical data that students obtained with existing literature.

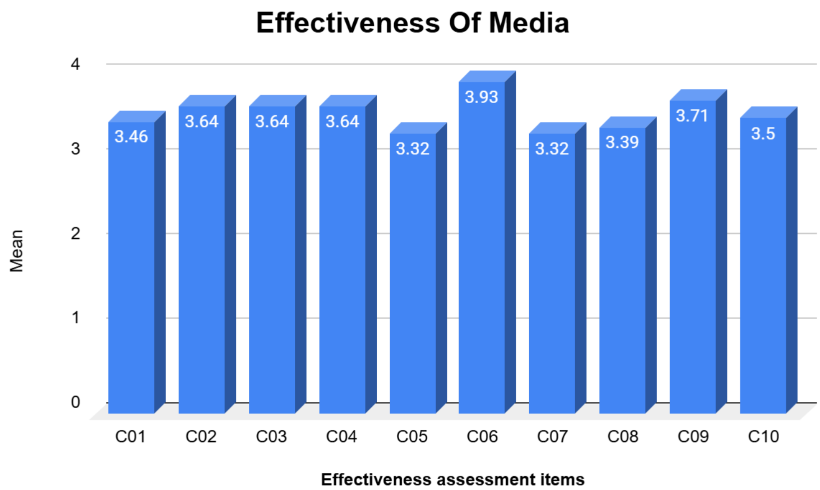

Figure 8. Average score for the effectiveness of learning media

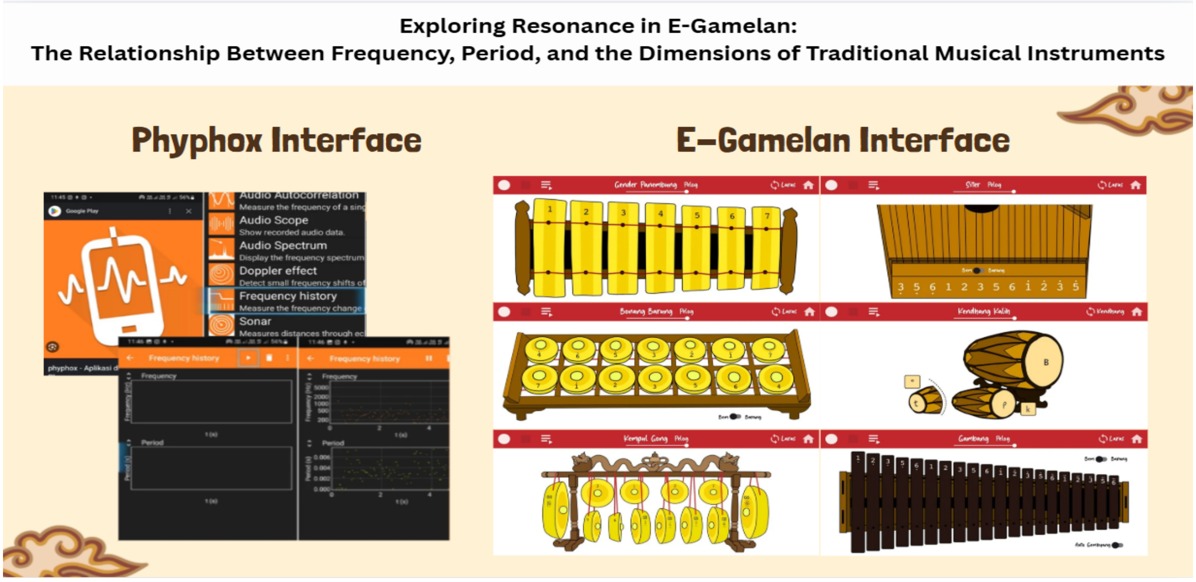

Figure 9. Project-based activities: Exploration of Resonance in E-Gamelan

In addition, three indicators related to attractiveness and challenge "Escape Room concept makes learning more interesting" (M = 3.64), "Challenges encourage critical thinking" (M = 3.64), and "Motivated to complete each level" (M = 3.64) are consistently in the high zone reflecting the success of gamification. E-Gamelan activities contribute to learning by presenting authentic, inquiry-based challenges: students not only solve puzzles, but also become young researchers who test the relationship between the dimensions of traditional musical instruments (such as the length of the saron or the diameter of the drum) and the frequency of the sound proxduced. The visual cultural context strengthens the emotional attachment reflected in the high score of "Study time is more enjoyable" (M = 3.71).

However, the graph also shows valleys in the indicators "Helps understand physics concepts better" (M = 3.32) and "Material is presented clearly and is easy to understand" (M = 3.32). This is where E-Gamelan activities provide a critical explanation: although exploration activities are in-depth and contextual, the transition from practical measurements (frequency, period) to abstract conceptual understanding (mathematical relationships, physical factors of materials and temperature) requires more explicit scaffolding. In other words, the medium has been successful in "pulling students in" through highly motivated ethnophysics and gamification, but more structured guidance is needed to "dive deeper" into conceptual understanding.

Overall, the integration of activities such as E-Gamelan Exploration with a systematic flow from cultural observation, measurement, data analysis, to literature comparison not only explains why the media is effective at increasing motivation and collaboration, but also where the opportunities are to improve conceptual understanding. These findings are in full alignment with the title of the research which emphasizes an LMS-based ethnophysical approach to improve learning outcomes and motivation.

The Impact of Media on Learning Motivation

Learning motivation data is measured using a 1-5 Likert scale filled in by students and supported by participant observation during the learning process.

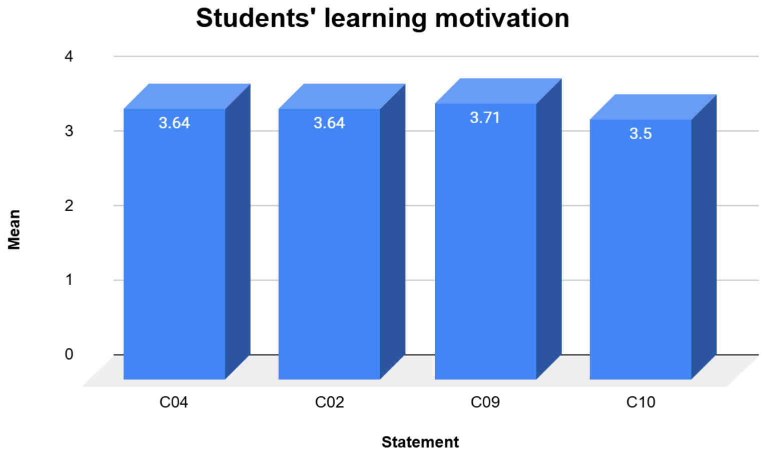

Figure 10. Average score of student learning motivation

Based on quantitative and qualitative data, Interactive Physics Escape media has a strong and multidimensional impact on student learning motivation (Figure 10). Quantitatively, indicators that directly reflect motivation achieve consistently high scores. Students felt motivated to complete each level (M=3.64), thought the Interactive Physics Escape concept made learning more interesting (M=3.64), felt that learning time was more enjoyable (M=3.71), and even had the desire to try similar media on other topics (M=3.50). These scores demonstrate that gamification successfully creates an intrinsically motivating learning environment, with integrated elements of challenge, achievement and fun.

Qualitative data from student responses deepens and gives color to the numbers. Many students provided positive testimonials by writing about their experiences, for example, "exciting" and "enjoyable." These student statements indicate that the integration of gamification and ethnophysics learning can be a learning experience that increases students' learning motivation. The increase in students' intrinsic motivation to learn is proportional to the increase in students' understanding in learning the material of waves and sound. Students' enthusiasm in completing each challenge is not a burden, but rather a learning activity that stimulates healthy competition. This indicates high student interest in participating in learning (M = 3.50) and similar methods can be applied to this learning material. These student responses indicate that the learning method that has been implemented is a solution to increase students' understanding and intrinsic motivation.

On the other hand, a small number of students stated that sometimes they were bored and confused if it was not explained. From this feedback, it can be concluded that high levels of motivation need to be maintained through clear instructions and adequate scaffolding. Challenges and excitement must be balanced with structured guidance to avoid a decrease in motivation due to confusion.

Overall, the Interactive Physics Escape media succeeded in increasing students' learning motivation through an ethnophysics-based gamification approach. This motivation is not only momentary but also shows the potential to develop into a more sustainable interest, as seen in students' desire to explore other topics with a similar approach. These findings are in line with the research objectives which emphasize increasing motivation as one of the key outcomes from implementing this innovative media.

The Influence of Media on Cognitive Learning Outcomes

In this section there is a presentation of quantitative analysis data, namely the influence of learning media on cognitive learning outcomes.

a. Initial Equality Test

Table 7. Independent samples t-test of initial equality

	t	df	p
Value	1.775	57	0.081

The results of the Independent Samples T-Test (Table 7) on the pretest data show a t value of 1.775 with a degree of freedom (df) of 58 and a significance value (p) of 0.081, which is greater than 0.05. These findings indicate that there is no statistically significant difference between the average pretest scores of students in grades VIII-4 and VIII-5. In other words, before being given treatment in the form of using LMS-based Interactive Physics Escape media with an ethnophysical approach, both groups had relatively equal or balanced initial abilities. These results show that the initial conditions of the two classes can be considered homogeneous in terms of basic academic abilities in Vibration, Waves and Sound material.

b. Test of Improved Learning Outcomes of Experimental Class Students

Table 8. Descriptive analysis of pretest posttest experimental class

	N	Mean	SD	SE	Coefficient of Variation
Pretest	30	12.37	3.178	0.580	0.257
Posttest	30	18.30	3.261	0.595	0.178

The results of the descriptive analysis for class VIII-4 (experimental class) showed a clear increase in learning outcomes after implementing the treatment (Table 8). The average posttest score was 18.30 higher than the pretest average of 12.37, which means that there was an increase in the overall score after students took part in learning using LMS-based Interactive Physics Escape media with an ethnophysical approach.

Table 9. Wilcoxon signed-rank test for experimental class

Measure 1	Measure 2	W	z	p	Rank-Biserial Correlation	SE Rank-Biserial Correlation
Pretest	Posttest	0.000	-4.782	< .0001	0.257	0.206

The results of the normality test for class VIII-4 (experimental class) show that the significance value (p) is 0.003, which is smaller than the critical limit of 0.05. This means that the data is not normally distributed, so the basic assumptions for using parametric tests are not met, so the Wilcoxon Signed-Rank test is carried out (Table 9). The results of the Wilcoxon Signed-Rank Test for class VIII-4 (experimental class) show that the significance value is $p < 0.001$, which means there is a very significant difference between the pretest and posttest scores. These findings show that the treatment given, namely learning using LMS-based Interactive Physics Escape with an ethnophysical approach, has a significant effect on improving student learning outcomes. Apart from that, the

Rank-Biserial Correlation value of -1,000 shows a very strong effect, even close to a perfect effect. The negative sign on the coefficient does not indicate a bad direction of influence, but only reflects the direction of data comparison. Thus, these results can be interpreted to mean that the application of innovative learning media has a very strong and positive impact on improving the learning outcomes of experimental class students.

c. Test of Improved Learning Outcomes of Control Class Students

The results of descriptive analysis (Table 10) for class VIII-5 (control class) show that the average posttest score is 15.90 higher than the pretest average of 11.07, which means there is an increase in student learning outcomes after the learning process takes place. However, the standard deviation (SD) on the posttest is greater than the pretest, indicating that the distribution of student learning outcomes is more diverse. In other words, even though there was an increase in the average score, not all students experienced an increase in learning outcomes after direct instruction was carried out.

Table 10. Descriptive analysis of control class pretest posttest

	N	Mean	SD	SE	Coefficient of Variation
Pretest	30	11.07	1.507	0.275	0.136
Posttest	30	15.90	3.188	0.582	0.200

Table 11. Wilcoxon Signed-Rank test for control class

Measure 1	Measure 2	W	z	p	Rank-Biserial Correlation	SE Rank-Biserial Correlation
Pretest	Posttest	7.000	-4.638	< .001	-0.970	0.206

Based on the results of the Wilcoxon Signed-Rank Test (Table 11) for the control class, namely the class that was not treated with Interactive Physics Escape media and only used direct instruction, a value of $p < .001$ and Rank-Biserial Correlation = -0.97 was obtained, which shows that there was a very significant increase in learning outcomes with a very strong effect even without innovative media intervention. These findings confirm that direct instruction methods remain effective in improving students' cognitive understanding. However, in the context of this research, the results of the control class actually function as a strong comparison to highlight the added value of the intervention provided: the superiority of the media does not only lie in improving learning outcomes, but in the results of the experimental class there is also increased motivation, collaborative involvement, and a contextual and enjoyable learning experience through the integration of ethnophysics, which cannot be achieved with direct instruction alone.

d. Test of Improved Learning Outcomes for Experimental and Control Classes

This research presents the results of tests of differences in learning outcomes (N-Gain) between the experimental class and the control class. This statistical test was carried out to determine whether there was a statistically significant difference in improving students' cognitive abilities between the group that used learning media and the group that used direct instruction. The findings from this test are the basis for concluding the influence of media on learning outcomes.

Table 12. Descriptive analysis of the experimental class posttest.

	Group	N	Mean	SD	SE	Coefficient of Correlation	Mean Rank	Sum Rank
Posttest	VIII-4	30	18.10	3.132	3.132	0.173	36.83	1068.0
	VIII-5	30	15.90	3.188	3.188	0.200	23.40	702.0

The results of the descriptive analysis (Table 12) showed that class VIII-4 (experimental class) had an average posttest score of 18.10, higher than class VIII-5 (control class) which obtained an average of 15.90. This indicates that in general, the learning outcomes of experimental class students are better after taking part in learning using LMS-based Interactive Physics Escape with an ethnophysical approach compared to students who study using direct instruction. Apart from that, the higher mean rank score in class VIII-4 (36.83 > 23.40) strengthens the finding that students in the experimental class have a tendency for higher posttest scores, so it can be concluded that the treatment given contributes positively to improving student learning outcomes.

Table 13. Independent samples t-test experimental class

	U	p	Rank-Biserial Correlation	SE Rank-Biserial Correlation
Posttest	633.0	.003	-0.455	0.150

The normality test results showed that the significance value was $p < 0.001$, which means the data was not normally distributed, so the Mann–Whitney U test was carried out. The results of the Mann–Whitney U test (Table 13) showed that the significance value $p = 0.003 < 0.05$, which means there was a significant difference between the posttest results of students in class VIII-4 (experiment) and class VIII-5 (control). These findings indicate that students who learn using LMS-based Interactive Physics Escape media with an ethnophysical approach obtain significantly higher learning outcomes compared to students who learn using direct instruction. The Rank-Biserial Correlation value of -0.455 indicates that the effect size is medium to strong, which means that the differences found are not only statistically significant, but also have considerable practical significance in improving learning outcomes. The negative sign on the correlation value only reflects the direction of ranking comparison between groups, where the first group has a higher score. Thus, it can be concluded that the innovative learning treatment given in class VIII-4 has a strong influence on improving student learning outcomes compared to direct instruction in class VIII-5.

Based on the data in the table and graph above, the comparison of N-Gain between the experimental and control classes confirms the added value of the media intervention being developed. The experimental class using Interactive Physics Escape achieved an N-Gain of 0.55 (Medium-Strong category), while the control class with direct instruction achieved an N-Gain of 0.38 (Medium category). This difference of 0.17 shows that the LMS-based ethnophysical approach is not only able to improve learning outcomes but also has a higher level of effectiveness than direct instruction. These findings are in line with the research aim of improving learning outcomes, while complementing previous quantitative evidence showing increased student motivation and engagement. Based on this, it can be concluded that the integration between Interactive Physics Escape, local cultural context, and LMS platform not only improves student learning outcomes, but can also increase students' intrinsic learning motivation in understanding wave and sound material. The implication is that an ethnophysical approach embodied in gamification-based interactive media has been proven to be an effective learning strategy academically and culturally.

Discussion

The Interactive Physics Escape media which was developed based on LMS and integrated ethnophysics is a feasible, practical and effective learning tool and significantly increases student motivation and learning outcomes on the topics of vibrations, waves and sounds. The following discussion interprets these key findings considering educational theory and previous research.

a. Feasibility: Suitability of Curriculum and Contextual Learning

High scores on curriculum suitability (M=3.57) and clarity of the relationship between physics and local culture (M=3.46) confirm the content validity and contextual relevance of the media from the user's perspective. The importance of understanding and implementing the curriculum as a basis for developing meaningful learning media, as stated by Sugiyono (2017), is reflected in the quality of the media used in this study. The concept of sound waves is understood by traditional musical instruments in drag-and-drop activities and e-gamelan exploration, allowing abstract physics concepts to be explained through a real-life cultural context. The integration of physics concepts and cultural contexts has been realized through the Interactive Physics Escape. Through this ethnophysical approach, students' understanding of difficult, abstract material can be enhanced (Parmin & Peniati, 2012).

Despite positive student responses, the moderate score for conceptual clarity (M=3.32) indicates that the delivery of the wave material needs to be strengthened in depth. Student responses emphasized the need for clear instructions before implementing the gamification. Without structured guidance, there is a possibility that students will focus solely on the game, without understanding the concepts of the wave material being studied. Based on this, several improvements are needed, namely implementing activities or initial explanations before implementing the gamification, either in the form of an introductory explanation of the material or explanations of the game instructions. Furthermore, reflection can also be conducted after the activity is carried out to maximize learning without reducing the fun element.

b. Practicality: High Level of Usability with Focus on Efficiency and User Satisfaction

The data obtained shows that Interactive Physics Escape is very practical to use, especially in terms of ease of access (M=3.86) and clarity of instructions (M=3.79). This indicates that the media has a high level of learnability, so that students can carry out gamification independently without requiring intensive guidance (Nielsen, 1994). The high score obtained in the feedback aspect (M=3.86) proves that the media can provide information that helps students carry out gamification-based learning activities, and the presence of clear feedback can reduce the possibility of student confusion (Hassenzahl & Tractinsky, 2006). Overall, the results of the data obtained indicate that the Interactive

Physics Escape media innovation has met the usability principles as formulated in international standards.

In an LMS-based online learning environment, the effectiveness of using Interactive Physics Escape is demonstrated by the findings of this study. In the context of e-learning, student engagement and the sustainability of the learning process are influenced by several important factors, namely ease of use, accessibility and system responsiveness. Support for independent learning at each learning speed can be seen from the high scores on indicators of accessibility and clarity of instructions, which are the main characteristics of e-learning systems. Previous research also explains that increasing learning independence, flexibility, and student engagement can be achieved through a well-designed e-learning environment, especially if it is supported by an intuitive interface and structured learning activities (Dhawan, 2020; Almaiah et al., 2020).

Based on qualitative data collection, several students stated that the Interactive Physics Escape media sometimes experienced response delays (lag), difficulties when entering answers, and media crashes. These technical problems can hinder the smooth learning process, while reducing the level of student activity and satisfaction in carrying out activities in gamification. This is in accordance with research literature stating that system stability is a significant determinant of the quality of the learning experience in the implementation of game-based learning (Boyle et al., 2016). Because most students use mobile phones in the LMS and data found indicating the need to optimize responsiveness on mobile phones, it is very important to strengthen the aspects of error prevention (error prevention) and improve stability in the next stage of development.

In general, Interactive Physics Escape is suitable for use as a self-learning tool integrated with an LMS. Practicality has been met, particularly in terms of ease of use. Achieving usability provides a strong foundation for the next stage of development, which focuses on technical improvements to ensure the system is more stable and optimized. In addition to technical improvements, the student user experience needs to be comprehensively considered during the development phase. Aesthetic aspects should be considered so that the media is not only easy to use but also captivating and enjoyable (Norman, 2004). In this way, a more meaningful, comfortable, and enjoyable learning experience can be provided through Interactive Physics Escape.

c. *Increasing Intrinsic Motivation through the Synergy of Gamification and Cultural Identity*

An engaging digital learning experience that supports students' intrinsic motivation is created through the integration of gamification elements using Interactive Physics Escape within an LMS-based e-learning environment. Students' learning motivation was successfully enhanced using Interactive Physics Escape media. This was demonstrated by the high average scores for the motivation to complete levels (M = 3.64) and enjoyment during the learning process (M = 3.71). In accordance with Self-Determination Theory, intrinsic motivation can grow when the needs for competence and relatedness are met (Ryan & Deci, 2000). The experience of success was facilitated through gradual challenges, immediate feedback, and a structured level system. This sense of accomplishment was further reinforced by the clear visualization of learning progress. Furthermore, the escape room format provided opportunities for independent thinking and finding one's own solutions. Thus, not only was motivation enhanced, but skills such as perseverance, problem-solving, and independent learning were also developed.

The data shows a high level of pride in Indonesian culture (M = 3.46). This indicates motivation stemming from an emotional dimension. Learning feels closer to students' lives due to the use of local cultural elements. Students' emotional engagement and enthusiasm for learning can be enhanced through a culturally responsive learning approach (Gay, 2018). The enjoyable learning experience is evident from student feedback stating that the media was engaging and engaging. Interest in utilizing similar media for other materials (M = 3.50) also indicates that the interest that arises is not fleeting. This means that this media has the potential to foster a more lasting interest in learning than merely a temporary interest during the activity (Hidi & Renninger, 2006).

The increase in motivation in this study was not solely caused by the attractive appearance of the game. Motivation is influenced by a combination of a structured game system and culturally contextualized learning materials. Through this combination, the learning experience can be felt to be more meaningful. In addition, the potential for increasing learning motivation can be achieved through the integration of ethnophysical and gamification approaches. With this strategy, students' internal motivational, emotional and cognitive aspects can be activated simultaneously.

d. *Encouraging Knowledge Construction through Collaboration and Improving Cognitive Learning Outcomes*

The effectiveness of Interactive Physics Escape can be identified through three main aspects: social collaboration, higher-order thinking engagement, and measurable improvement in learning outcomes. Support for group learning is demonstrated by the high collaborative problem-solving score (M = 3.93). In this process, understanding is built collaboratively through the exchange of ideas and clarification of concepts. Active communication, strategy sharing, and feedback between students are facilitated through group escape room activities, thus supporting individual skill development through team collaboration (Johnson & Johnson, 2009). The LMS-based e-learning environment also facilitates collaborative learning by enabling students to interact, discuss strategies, and solve problems collectively within the digital platform.

A significant improvement in learning outcomes was demonstrated through the Wilcoxon Signed-Rank Test ($p < 0.001$). Higher scores in the experimental group compared to the control group were also confirmed through the Mann-Whitney U Test ($p = 0.003$). The effect size ($r = -0.455$) indicates a moderate to strong effect, so the impact found cannot be considered a statistical coincidence.

The success of the Interactive Physics Escape media is supported by the integration of gamification and ethnophysics. Critical thinking and problem-solving exploration can be trained and facilitated through missions carried out gradually through gamification in the form of solving puzzles (M = 3.64), while concrete conceptual understanding is reinforced through cultural contexts such as traditional musical instruments. With meaningful learning, conceptual understanding can be improved (Bransford et al., 2000). Overall, motivation and challenges are presented in gamification, while understanding of the material and relevance is obtained through ethnophysics, resulting in interesting learning that can be understood by students in depth.

e. *Advanced Research*

Improvements in cognitive achievement, critical thinking skills, and student learning motivation were successfully achieved by Interactive Physics Escape. This success was made possible by the integrated blend of gamification elements and the local cultural context in the learning process. For the next development stage, improvements to the scaffolding aspect are needed to optimize learning support. Further research is recommended to determine the long-term impact on student knowledge retention. Furthermore, the consistency of the media's effectiveness needs to be tested through application to more diverse cultural backgrounds and student groups. This way, the media's potential to deliver more engaging, relevant, and meaningful science learning can be further strengthened.

CONCLUSION

Fundamental Finding: This study demonstrates that the LMS-based Interactive Physics Escape with an ethnophysics approach is feasible, practical, and effective in improving students' cognitive learning outcomes, motivation, critical thinking, and collaboration skills through the integration of gamification, LMS, and cultural context. **Implications:** The findings highlight both practical and theoretical contributions by providing an innovative model that integrates culture into science learning while strengthening the synergy between gamification, ethnoscience, and e-learning to support meaningful and holistic learning. **Limitations:** However, the study is limited to a single physics topic and educational level, with minor technical issues in LMS usability and potential class-specific dynamics affecting generalizability. **Future Research:** Future studies should expand the implementation across diverse materials, cultural contexts, and student groups, as well as explore long-term impacts and incorporate authentic assessments to better measure higher-order thinking skills.

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