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The effect of digital board–assisted outdoor learning on students' critical thinking and learning interest: a quasi-experimental study

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Abstract

Many junior high school students still exhibit a low level of critical thinking ability and a limited interest in learning physics, particularly in abstract topics such as work and simple machines. This study aims to determine the effect of outdoor learning assisted by a digital board on students' critical thinking ability and learning interest in the topic of work and simple machines among junior high school students. The research employed a quasi-experimental method with a pre-test–post-test control group design. The subjects consisted of 66 junior high school students divided into experimental and control classes (33 students each), selected using a cluster random sampling technique from the eighth-grade population at SMP Negeri 2 Kedungbanteng, Banyumas. The observation results showed a 31% increase in student learning activity after the implementation of outdoor learning. The t-test results indicated a significant difference in critical thinking ability (Sig. $0.008 < 0.05$) and learning interest (Sig. $0.000 < 0.05$) between both classes. These findings demonstrate that outdoor learning, assisted by a digital board, is effective in improving students' critical thinking abilities and learning interest. This implies that integrating digital tools into outdoor learning environments can enhance student engagement and higher-order thinking, offering educators an innovative approach to promote active and meaningful learning in physics education.

Keywords: Critical Thinking, Digital Board, Learning interest, Outdoor Learning

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I. Introduction

Education enhances the quality of human resources. One of the growing challenges in Indonesia's education system is the generally low academic achievement of students, particularly in the sciences, including physics. The findings from international studies, such as PISA 2018, suggest that Indonesian students, in general, compare favorably with students from lower-tier countries, ranking 74th out of 79 countries in terms of scientific literacy [1]. Other studies, such as the TIMSS, suggest that Indonesian students lack advanced thinking skills and even advanced scientific problem-solving [2]. Even within the country, the results of the 2019 National Science Examination showed poor achievement, particularly in understanding concepts and applying scientific reasoning. This suggests that students have been taught science in a manner that prevents teachers from striking a balance between critical thinking and problem-solving. The results of such assessments indicate that the time students spend in school attending science lessons is largely dominated by traditional teaching methods, where the teacher controls the focus and students are not encouraged to take responsibility for their own learning.

The urgency of this research lies in the need to address students' low critical thinking ability and lack of interest in physics learning, which can hinder their conceptual understanding and problem-solving competence. Therefore, it is crucial to develop innovative learning models that engage students actively and relate physics concepts to real-life experiences. In reality, critical thinking skills are essential in learning physics, as well as in any other field of science, as they enable students to assess data, form conclusions, and apply logical steps to problem-solving [3]–[5]. Additionally, the psychological factor of learning interest affects the levels of success achieved in learning. Low interest levels in physics are a sign of low motivation and disinterest in the learning process [6]. In the field of educational psychology, extensive research has shown that learning is essential for fostering motivation, persistence, and ultimately, success in one’s studies [7]–[9]. This suggests that learning is structured in an engaging and connected way, linking to real-world applications, which can enhance students' motivation while also supporting their cognitive success [10]. This current research contributes to the field of physics education by providing empirical evidence on the effectiveness of outdoor learning, facilitated by a digital board, in enhancing students' critical thinking abilities and interest in learning.

Meaningful and contextual approaches used in learning should also be paired with those that are enjoyable in order to address the issue at hand. Prior research characterises constructivist and learner-centred designs as approaches that promote active learning through inquiry, collaboration, and reflection within authentic learning contexts. For example, Maglinte and Coronica [11] demonstrated that a constructivist e-learning module in General Biology fosters learner-centred and collaborative reflection and experiential learning, resulting in improved problem solving, critical thinking, and creativity. In the same manner, Hernández and González [12] showed that instructional models focused on the learner and incorporate creative learning processes that promote vigorous engagement, fostering active, meaningful learning.

Drawing upon these educational principles, the strategic use of outdoor learning can serve as a valuable tool. This model focuses on fostering student engagement with the environment beyond the confines of the classroom, thereby promoting genuine experiential learning. This practice aligns with the cornerstone tenets of constructivist learning theory, which posits that knowledge can only be acquired through active engagement with the environment and subsequent reflective interactions [13]. Also, outdoor learning is a perfect illustration of Kolb's theory of experiential learning, which emphasises that learning is most valuable when it is initiated through a practical experience and followed by a reflective, thoughtful process of that experience [14]. Moreover, the literature in science education emphasises that when combined with collaboration, project-based learning, and outdoor activities, learners' 21st-century skills, particularly critical thinking, creativity, and scientific communication, are significantly enhanced.

The effectiveness of this approach has been documented by a number of authors. Crismono [15] is one of the authors who studied outdoor-based learning and found that it enhanced students’ mathematical critical thinking skills. Damayanti and Mundilarto [16] found that students' attitudes and conceptual understanding of science improved with project-based outdoor learning. While these studies are valuable, most have failed to incorporate digital technology, which is a primary concern for 21st-century education. In this case, digital collaborative tools can be beneficial. For instance, digital boards (i.e., Padlet) can be used to present and visualise data collaboratively, capture field activities, and integrate them with data-centric scientific exploration.

Several studies conducted in Indonesia have shown that outdoor learning offers meaningful benefits across various educational contexts. Prasetya et al. [17] found that outdoor learning in social studies classes enhanced students’ integrity, motivation, and engagement by providing concrete learning experiences that made lessons more enjoyable and contextual. However, the study also noted practical challenges such as high costs, time constraints, and teachers’ limited experience in managing outdoor activities. Similarly, Siswoyo et al. [18] highlighted that outdoor learning in environmental education produced positive outcomes when supported by systematic management involving curriculum analysis, planning, implementation, and evaluation. Their findings suggested that effective outdoor learning requires balanced coordination between classroom and field activities. In addition, Meyer et al. [19] reported that outdoor learning combined with environmental technology significantly improved children's learning outcomes and engagement in English learning activities in Patti Village, Moa, Southwest Maluku. These local findings emphasise that outdoor learning can effectively enhance students' motivation and understanding when contextualised to Indonesian settings, although its implementation still demands adequate planning, resources, and teacher readiness.

While many studies alone have supported either outdoor learning or the use of digital media, few have integrated both approaches in the context of teaching physics, specifically the topic of work and simple machines. This lack of research underscores the need to explore how outdoor learning, augmented with a digital board teaching approach, can improve students' critical thinking skills and learning interest. With that, this study intends to fill this gap by examining the outdoor learning paired with a digital board teaching approach as a novel instructional framework for junior high school students. One of the promising tools for integrating outdoor learning is Padlet, which offers high interactivity, appealing visuals, and real-time integration of digital learning resources [20]. In particular, Padlet enhances collaboration and visual documentation, which is ideal for outdoor classroom settings. This makes it particularly well-suited for capturing fieldwork and enabling students to process digital data in real-time analytically.

Constructivist and experiential learning theories are closely related to outdoor learning because they support the idea that learning occurs as an active construction of knowledge through direct experience, student reflections on that experience, and student interactions with their environment. As a result of the outdoor setting offering a true context to which students may apply theoretical concepts to actual, observable data, students will develop a deeper conceptual understanding from constructivist perspectives. In addition, experiential learning theory provides further support for this through its emphasis on hands-on experiences that allow learners to participate in observation, experimentation, and reflective processes, all of which contribute to the development of critical thinking skills and long-term interest in learning.

Although there has been considerable research supporting the effectiveness of using outdoor learning and digital media separately, relatively little research has combined these two methods of learning within the teaching of physics (specifically, in the topic of work and simple machines). Thus, there is a need to evaluate how combining experiential learning through outdoor activities with interactive digital tools can lead to a richer and more meaningful learning experience. Consequently, the objective of this study was to investigate the impact of integrating outdoor learning with a digital board on the critical thinking abilities and learning interests of junior high school physics students; thus, providing empirical evidence for the practical implementation of constructivist and experiential learning principles in junior high school physics education.

II. Methods

Research Design

This study applied a quantitative approach and quasi-experimental design in the form of a pretest-posttest control group design. A quasi-experimental design was chosen because it allows for the comparison of treatment effects between groups in real classroom settings where random assignment of participants is not feasible [21]. This design is appropriate for educational research conducted in school environments, as class groupings are predetermined by school administration and cannot be reorganised purely for research purposes. This approach enabled the assessment of the learning outcomes of the experimental group, which received outdoor learning with the aid of a digital board, and the control group, which was taught using the direct teaching method. The learning materials focused on work and simple machines for eighth-grade junior high school students.

Setting and Participants

The research was conducted at SMP Negeri 2 Kedungbanteng, Banyumas Regency, during the even semester of the 2022/2023 academic year. The sampling process used a cluster-random sampling technique because selecting individual students was not feasible within the school's administrative structure. The procedure began by identifying all eighth-grade classes as sampling clusters. Two classes were then randomly selected by drawing lots to ensure that each had an equal chance of being chosen. The first selected class was assigned to the experimental group, which received outdoor learning supported by a digital board.

In contrast, the second was assigned to the control group and taught using the direct teaching method. There were 33 students in both the experimental and control groups. The sample size was determined based on the existing class distribution in the school, as class restructuring was not feasible within the natural school setting. Although the sample size was relatively small, it met the practical and logistical constraints typical of quasi-experimental research in educational contexts, where intact classes are used as samples [22].

Instruments

This study was conducted using three instruments: (1) a critical thinking skills test, (2) a learning interest questionnaire, and (3) an observation sheet aimed at monitoring learner learning activities throughout the learning processes. The critical thinking skills test in physics, focusing on the topic of work and simple machines, was adapted from Irianti and Prasetyo [23] and has been validated (INFT MNSQ). The five items showed adequate fit, with values ranging from 0.77 to 1.33 and positive point-biserial correlations. The learning interest questionnaire, adapted from Taligansing [24], contained 28 items, each with a validity index greater than 0.05.

The student observation sheet was constructed with several assessment components that focused primarily on the students' learning activities and engagement. A total of 10 components were used as criteria for monitoring and assessing student engagement. These skills included designing experiments, asking appropriate questions or identifying problems, posing testable hypotheses, conducting experiments or collecting data, analysing the data, and defending the conclusions drawn from the analyses. For the observation sheet, an Aiken's V value greater than 0.5 indicated that all items were valid.

Regarding instrument reliability, the critical thinking skills test had a reliability of 0.56, which exceeds the lower bound of 0.5, indicating that all five items are reliable. Although the coefficient is modest, it is still considered acceptable for exploratory educational research and classroom-based studies involving cognitive constructs with small item numbers [25]. Meanwhile, the learning interest questionnaire achieved a Cronbach's Alpha of 0.890, surpassing the minimum threshold of 0.700, and is therefore considered reliable.

Research Procedure

Padlet was used as an aid for the outdoor learning process, which was conducted over four 40-minute sessions. The learning experiences were designed to integrate digital collaboration tools with active participation in outdoor activities, in line with constructivist and experiential learning theories.

Session 1. Before beginning the outdoor learning activities, students took a pre-test to assess their prior knowledge of the subject matter. The teacher then divided the students into small groups, explained the steps of the outdoor learning process, and guided them in setting up individual Padlet accounts as an example of a digital learning tool. To prepare for the following sessions, the teacher also shared a link containing introductory information related to the topic that would be explored.

Session 2. In this session, students engaged in outdoor learning on the topic of *work*, using a student worksheet as a guide. Working collaboratively in teams, they answered questions and solved problems from the worksheet. After completing their tasks, each team discussed their observations and uploaded their group's results to Padlet.

Session 3. The third session focused on the topic of simple machines. Similar to the previous session, students participated in outdoor learning using the student worksheet as a guide, collaborated to solve problems, and discussed their findings. As part of their group discussions, students used Padlet to share photos, videos, and reflections on their learning experiences.

Session 4. The final session served as a review and consolidation of the learning from Sessions 2 and 3. Students presented their individual results to the class, completed practice assignments, and engaged in further discussions via Padlet. At the end of this session, they also took a post-test to measure their learning progress.

At the conclusion of each meeting, the teacher provided feedback on students' work, assigned follow-up tasks through Padlet, and allocated time for reflection and prayer, led by one of the students.

Data Collection

The data were gathered through the use of tests (pre-test and post-test), questionnaires, and observations. Students' critical thinking skills on the topic of work and simple machines were assessed before and after the learning period. Students' interest in learning physics was gathered through questionnaires that were given before and after the learning process. On the other hand, data on the students' learning activities in the course of the three learning sessions were collected using the students' activity observation sheets.

Data Analysis

The collected data on students' critical thinking skills and learning interests were analysed using a set of statistical tests. Some preliminary tests were done to ascribe a certain type of statistical to the data, and as such, normality and homogeneity tests were done, with a decision threshold of $p > 0.05$, indicative of the data being normally distributed and homogeneous. For the tests described above, if the assumptions were met, an independent-samples t-test was conducted to determine whether the experimental and control groups differed significantly. The t-test was conducted at a 5% significance level ($\alpha = 0.05$). All the tests and statistical analyses were processed on SPSS version 26. In the meantime, observation data on student activities were evaluated with a descriptive analytic methodology.

Ethical Statement

This study has adhered to the principles of ethical research. Participation was fully voluntary, and students were debriefed on the aims and processes of the study prior to their involvement. Consent was acquired verbally, and participants were informed of their right to confidentiality concerning personal details, which would only be used in the study. Additionally, students were made aware of their right to withdraw from the study at any point in the process, academically or personally, without any repercussions.

III. Results and discussion

Results

Descriptive Statistics

Table 1 presents the results of students' critical thinking abilities and learning interests in the experimental and control classes. Regarding critical thinking ability, the experimental class showed an increase in the mean score, from 43.76 on the pre-test to 80.24 on the post-test, resulting in an N-gain of 0.66, indicating moderate to high improvement. On the other hand, the control class's mean score on the pre-test was 44.12, and the post-test score was 75.03, resulting in an N-gain of 0.56. This indicates that both groups showed improvement. However, the greater increase in scores suggests that the experimental class benefited more from the learning, as outdoor activities combined with a digital board provided higher classroom engagement compared to the traditional methods used in the control class.

Table 1. Critical thinking and learning interest scores

Parameter	Value (Mean)	
	Experimental Class (N=33)	Control Class (N=33)
Critical Thinking Ability		
Pre-test	43.76	44.12
Post-test	80.24	75.03
N-Gain	0.66	0.56
Learning Interest		
Pre-test	62.53	63.87
Post-test	86.86	82.19
N-Gain	0.65	0.50

Regarding learning interest, the experimental class showed greater improvement, with a pre-test score of 62.53 and a post-test score of 86.86, resulting in an N-gain of 0.65, indicating moderate to high growth. In contrast, the control class had an N-gain of 0.50, with pre- and post-test scores of 63.87 and 82.19, respectively. This shows that students who learned using outdoor digital media garnered more interest in the subject of study compared to those who were taught using the traditional method.

Effect of Outdoor Learning Assisted by a Digital Board on Students' Critical Thinking Ability

The prerequisite tests were conducted before hypothesis testing to ensure that the data met parametric assumptions. The significance values of the normality test (Shapiro–Wilk) and homogeneity test (Levene's Test) are presented in Table 2. The significance values of the Shapiro–Wilk test for both the experimental class ($p = 0.124$) and the control class ($p = 0.112$) are greater than 0.05, indicating that the data in both groups are normally distributed. Additionally, the Levene's Test significance value is 0.438 (> 0.05), showing that the variances between the two groups are homogeneous. Therefore, a t-test was conducted to address the research question regarding the effect of outdoor learning assisted by a digital board on students' critical thinking ability.

Table 2. Results of prerequisite tests on students' critical thinking ability

Class	Shapiro-Wilk Sig.	Levene's Test Sig.
Experimental	0.124	0.438
Control	0.112	0.438

Table 3 shows that the Sig. (2-tailed) the value from the t-test is 0.008, which is lower than the significance level of 0.05. This indicates that there is a significant difference in critical thinking ability between the outdoor learning class and the control class.

Table 3. Results of the t-test for critical thinking ability

Parameter		Levene's for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
N-Gain	Equal variances assumed	0.608	0.438	2.733	64	0.008
	Equal variances not assumed			2.733	63.799	0.008

Effect of Outdoor Learning Assisted by a Digital Board on Students' Learning Interest

Table 4 shows the results of the normality and homogeneity tests for students' learning interest data. The significance values of the Shapiro–Wilk test for both the experimental class ($p = 0.131$) and the control class ($p = 0.118$) are greater than 0.05, indicating that the data in both groups are normally distributed. However, the significance value of Levene's Test is 0.006, which is less than 0.05. This means that the data do not meet the assumption of homogeneity, indicating that the variances between the two groups are not equal.

Table 4. Results of prerequisite tests on students' learning interest

Class	Shapiro-Wilk Sig.	Levene's Test Sig.
Experimental	0.131	0.006
Control	0.118	0.006

Although the data on students' learning interests are not homogeneous, the t-test can still be conducted by interpreting the Sig. (2-tailed) value from the equal variances not assumed parameter. Based on Table 5, the Sig. (2-tailed) value obtained from the t-test (equal variances not assumed) is 0.000, which is smaller than the significance level of 0.05. This indicates a significant difference in students' learning interest between the outdoor learning class and the control class.

Table 5. Results of the t-test for learning interest

Parameter		Levene's for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
N-Gain	Equal variances assumed	8.167	0.006	4.916	64	0.000
	Equal variances not assumed			4.916	50.444	0.000

Effect of Outdoor Learning Assisted by a Digital Board on Students' Activity

Over the course of three learning sessions, the learning activities of students were documented, and these activities were recorded for subsequent sessions. The illustration in Figure 1 shows the comparative results. Each group demonstrated an increase in student engagement levels. However, the experimental class engagement levels showed an increase of 31.00% in the last session and 26.75% for the control class. This demonstrates the effectiveness of the outdoor learning approach in creating a more stimulating learning atmosphere that fostered student enthusiasm.

The study shows that student activities improved progressively from session to session, including the final session. These activities encompassed visual, oral, listening, writing, and motor components. Attention to the learning material was used to assess the visual component. Students' participation in asking questions, providing answers, and expressing opinions contributed to the oral component. Compliance with instructional activities served as evidence of listening skills. Finally, contributions to worksheets, notes, and written tasks related to experiential learning were used to evaluate the writing component. Meanwhile, motor activity was evaluated based on students' participation in group experiments and the accuracy of their experimental procedures.

Students' learning behaviours were influenced positively due to being in an open outdoor learning space, as they were able to engage actively with the environment and learn from it, instead of passively receiving knowledge from a teacher or other source. The opportunity for exploration, discussion and interaction with their surroundings in an outdoor setting also seemed to foster students' natural curiosity about their world and provide them with a greater sense of control over their own learning, thus students were demonstrating positive changes in their learning behaviors (i.e., more interactive, communicative and reflective) due to the support of real-world experiences and digital opportunities available to them while participating in an outdoor learning experience.

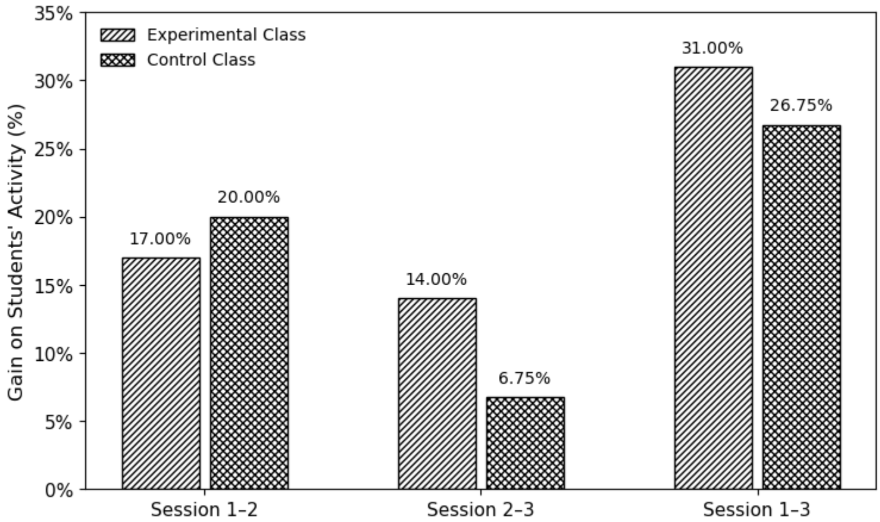

Figure 1. Observation of student activities in the experimental and control classes

Overview of Digital Boards

In the learning process, students were encouraged to think critically, as shown in Figure 2. Students were guided to formulate questions with their groups related to work, simple machines in general, and the principles of simple machines in the human skeleton and muscles. In the same aspect, students were also asked to formulate problem statements, as shown in Figure 3. In both activities, the aspect of focusing questions through critical thinking skills was achieved.

Figure 2. Example of questions on the aspect of focusing questions in critical thinking skills on the digital board platform

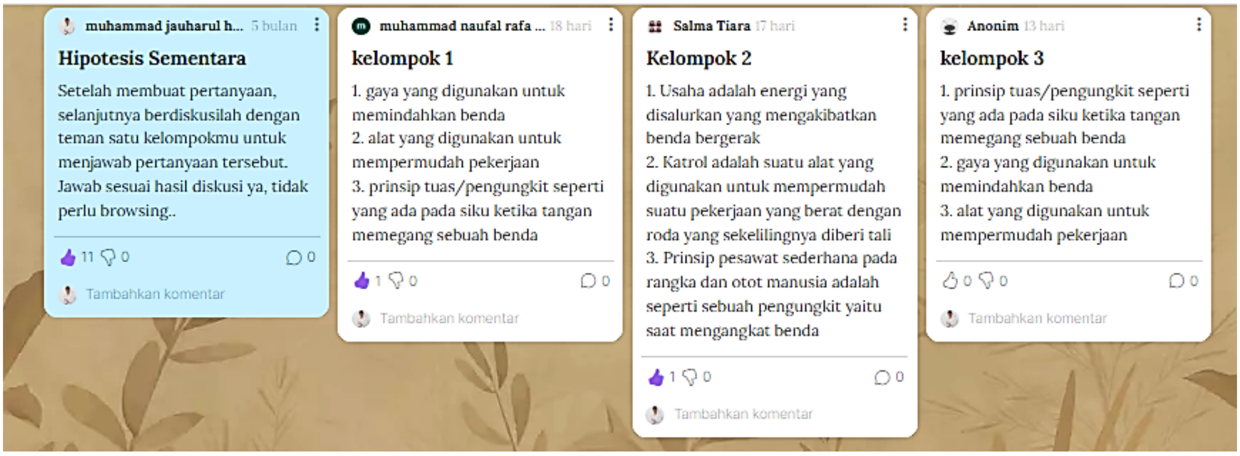

Figure 3. Example of problem statements created by students to stimulate critical thinking skills on the digital board platform

In Figure 4, students were assigned a task to practice moving a heavy object (a bucket filled with water) as an example of the topic work. This activity demonstrated that the aspects of decision-making and action, as well as information gathering within the domain of critical thinking skills, were achieved.

Figure 4. Student activities related to critical thinking skills in the aspects of decision-making, action, and information gathering on the digital board platform

Discussion

Analysis of the pre-test and post-test scores for the assessment of critical thinking showed that the outdoor learning class achieved an average N-gain of 0.66, while the control class had an average N-gain of 0.56. Both values fall within the moderate range. An N-gain of 0.66 in the outdoor learning class indicates a notable improvement in students' understanding after instruction. The control class also showed improvement, with an N-gain of 0.56, though not as pronounced. The fact that both N-gain values are in the moderate range suggests that the learning gains were meaningful for both groups, reflecting comparable growth in understanding for the outdoor learning and control classes.

An increase in students' critical thinking ability post learning can be seen in both the outdoor learning and control groups. This finding aligns with Crismono [15], who states that outdoor learning approaches have a positive impact on students' mathematical critical thinking skills. Similarly, Oktaviriani and Jadmiko [26] observed that incorporating a problem-based learning model with outdoor studies enhanced critical thinking skills in social studies for fourth-grade students.

Cognitive Development Theory posits that using outdoor learning approaches in science, which incorporate the environment, can enhance students' higher-order thinking skills. In this approach, teachers design learning activities connected to real-life situations, encouraging students to think both critically and creatively when solving problems. Engagement in contextual activities such as observation, exploration, and interaction with the environment allows students to acquire comprehensive and meaningful learning experiences. Therefore, integrating contextual learning materials through outdoor learning can support the development of higher-order thinking skills, particularly critical and creative thinking, in mathematics.

Digital learning tools like Padlet.com can significantly aid in utilising outdoor learning. In their study, Rathakrishnan et al. [27] found that students who used backchannel communication with Padlet scored higher on levels of macro-critical thinking than those who did not. Their study validated the use of online backchannel communication as an effective tool for enhancing students' critical thinking. In the context of outdoor learning, Padlet.com is one of several tools that can streamline the organisation of learning materials, student assignments, and discussions. Resources such as photographs, videos, and articles related to the current math topic can be linked to students' immediate surroundings. Students can also be encouraged to share their ideas and findings and collaborate on more complex outdoor learning tasks, further supporting their learning goals.

Additionally, based on the analysis of pre-test and post-test mean scores for learning interest, the outdoor learning class achieved an average N-gain of 0.65, while the control group had an N-gain of 0.50. Both scores fall within the moderate range. An N-gain of 0.65 in the outdoor learning class indicates a substantial increase in students' learning interest following instruction. In contrast, the control group also showed improvement, but to a lesser extent. These results suggest that both instructional approaches positively influenced students' learning interest, with outdoor learning proving to be more effective.

According to Supardi et al. [28], students' levels of learning interest vary; some demonstrate strong engagement, while others tend to be passive. For this reason, teachers need to be aware of students' learning interests to design instruction that promotes positive learning outcomes. Teaching involves more than delivering content; it encompasses guiding, training, and supporting learners through the learning process. Clearly, interest is a key factor that influences the level of support students receive and motivates them toward higher achievement.

In this study, there was a constant rise in the level of student participation between the first and the last sessions of the study. Learning activities include the participation of every individual, resulting in positive transformation through social and environmental engagement. Learning activities include the acquisition of knowledge through observation, experience, self-study, inquiry, and initiative. This shows that every student has to take part in the learning process to accomplish significant results.

In comparison to using only direct instruction, there was an increased amount of improvement in both critical thinking and interest in learning when using the digital board for outdoor learning. The results from this study support the idea of constructivism, where the physical environment of learning assists students in creating knowledge by interacting with the world around them. Students were able to create connections between prior knowledge and the new experiences they had while working together, inquiring, and discussing their findings in the outdoors, all key components of constructivist learning.

Using the digital board also helped facilitate the construction of knowledge, as it provided a visual representation of abstract physics concepts and instant feedback on what the students did, allowing them to reflect on their own work and discuss their reflections with others. Additionally, using outdoor learning supported Kolb's experiential learning theory [29] as students were able to experience each part of the learning cycle: concrete experience (students experienced the simple machines and observed/experimented), reflective observation (students discussed their findings), abstractconceptualisationn (students connected their experiences to the physics principles), and active experimentation (students tested their ideas in real world contexts).

This cycle promotes critical thinking by encouraging students to apply, analyse, and evaluate information rather than just passively receiving it. The increase in interest in learning is due to the engagement with hands-on activities, which enhances students' intrinsic motivation and makes them believe that what they have learned is relevant to their everyday lives. The results of this study support the idea that outdoor learning combined with digital technologies represents both constructivism and experiential learning theory and assists in the development of both cognition and affect in junior high school physics education.

The research results have potential implications for physics instruction. Outdoor learning could be an example of one way to apply the topic of "work and simple machines." Students can collect and measure examples of how simple machines are used in real life, such as when they use a lever at the swings on the playground, when a pulley is used for the school flag pole or when an inclined plane is used for a ramp. When students see how theoretical formulas relate to observed events, they will understand how force and distance work together in everyday situations. The use of digital tools (such as Padlet) in the outdoors allows students to document information, post pictures and collaborate in analysing their results in real-time. This type of experience gives students concrete evidence of abstract concepts that support both critical thinking and conceptual understanding.

IV. Conclusions

This study sought to investigate how utilising an outdoor learning environment with a digital board impacts junior high school students' critical thinking skills and their interest in learning about junior high school physics. The data indicate that the experimental group had significantly greater N-gain scores (critical thinking = 0.66; interest in learning = 0.65) than the control group (critical thinking = 0.56; interest in learning = 0.50), both of which fell into the moderate category of N-gain scores. These results suggest that using an outdoor learning environment with digital tools can have a positive, statistically significant impact on enhancing students' critical thinking skills and learning interest. The inclusion of physical activity allowed students to connect abstract theoretical physics concepts to actual world examples. At the same time, the incorporation of a digital board enabled increased student interaction, cooperation, and engagement throughout the learning experience. Therefore, the objective of this research study was met as it demonstrated that integrating outdoor learning with digital assistance enhances student learning through creating a more effective and engaging learning environment that supports both cognitive and affective aspects of student learning. Theoretically, these findings strengthen the framework of constructivist and experiential learning theories, showing that digital-assisted outdoor learning can serve as an effective model for fostering active knowledge construction through direct experience and reflection. Practically, the study recommends that physics teachers adopt outdoor learning integrated with digital tools, such as interactive boards or online collaborative platforms, to bridge the gap between theory and practice. Implementing this model can make physics learning more engaging, contextual, and student-centred.

The study has some limitations. The first is that the study had a rather short experimental duration, and the second is that the number of subjects was relatively low (only two classes containing 33 students). The study's reliability, validity, and generalizability may be affected by these two factors. If an experimental period were extended, then one might expect a higher level of stability and additional insight into how students' development of their critical thinking skills and their interest in learning evolve. For this reason, future studies should include a larger group of students from various schools and extend the length of the instructional experience to at least several months or a whole semester. A study using a larger sample could test whether similar outcomes occur within various educational settings and across multiple subjects. It may also be helpful to explore the potential benefits of using other types of digital technologies in the outdoors, such as mobile-based learning apps or augmented reality, to determine which type of technology will be most beneficial in enhancing outdoor learning. Finally, using qualitative research methods, such as observing classrooms or interviewing students about their learning experiences and behaviours during outdoor digital-assisted instruction, can provide greater depth of information regarding students' experiences and changes in behaviour.

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