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STUDENT'S LEARNING INTEREST IN PBL WITH POWER OF TWO AND GAMES ON VECTOR MATERIALS

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Abstract:
There is an issue with students' learning interest in physics, especially with abstract topics like vectors, where students are often passive participants with little to no engagement. This study aims to analyze how problem-based learning, the power of two strategy, and interactive game media influence students' learning interest in the class X physics subject at SMA Negeri 7 Malang. This research utilizes a descriptive qualitative case study methodology and involved 9 students who were selected based on their level of engagement in the class. Data were collected through classroom observations, semi-structured interviews, and documentation based on three dimensions (affective, cognitive, and behaviour), and were analyzed using triangulation and interactive data analysis techniques. The findings indicate that the PBL-PoT model assisted by interactive games contributes to the development of students' learning interest, particularly in the affective and behavioral dimensions. Learning interest emerges from the interaction between involvement, enthusiasm, understanding, and collaboration. However, students with low initial ability require additional support, including reinforcement of prerequisite concepts, heterogeneous grouping, and gradual scaffolding. This study has several limitations, including a single school context, limited participants, short implementation time, and no measurement of initial interest or learning outcomes. Future research is recommended to involve broader participant groups, apply longer implementation periods, and examine the relationship between interest dimensions and student learning outcomes.

Keywords: learning interest, Problem-Based Learning, Power of Two, interactive games.

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INTRODUCTION

Physics is an essential part of the natural sciences and uses explanations based on an understanding of concepts along with mathematics to describe different natural phenomena. Learning physics can be very difficult due to the abstract concepts and symbolic language. Learning physics also requires a lot of logical-mathematical reasoning (Husna & Kurniawan, 2022). From the research done there is low engagement and students' motivation is also low during physics classroom learning, especially when the teacher exposes the learning materials with a lot of memorization and teacher-

centered explanations (Martawijaya et al., 2023; Swandi et al., 2021). This leads students to be passive during the lesson, easily distracted, and not very interested in the learning activities.

Interest in learning plays a crucial role in shaping student participation and academic success. Interest is defined as a psychological tendency characterized by focused attention, positive feelings, and sustained involvement in learning activities (Hartono et al., 2021). It develops through meaningful learning experiences rather than being an innate trait (Okyranida et al., 2021). Empirical evidence indicates that low learning interest is reflected in behaviors such as lack of participation, minimal collaboration, and superficial engagement with learning tasks (Ritonga et al., 2025). To enhance students' learning interest, teachers should implement engaging and varied instructional approaches supported by innovative visual, audio, and digital media, continuously provide motivation and pedagogical innovation to present physics as an accessible and meaningful subject (Sofna et al., 2023) . Therefore, enhancing students' learning interest requires instructional approaches that actively involve students cognitively, socially, and emotionally.

Problem-Based Learning (PBL) has been widely recognized as an approach that promotes contextual understanding and active knowledge construction (Kurniawan et al., 2023). Through real-world problem scenarios, students engage in inquiry, discussion, and solution design (Mann et al., 2021). PBL has also been proven to increase students' motivation, involvement, and interest in learning, because students feel more involved in the learning process, which ultimately has an impact on improving their learning outcomes (Munawaroh et al., 2022; Nicholus et al., 2023; Velly, 2021). Nevertheless, previous findings indicate that some students still struggle to participate optimally in group discussions, particularly when collaborative structures are not clearly defined (Pujiyanti et al., 2021). Several pedagogical approaches have been proposed to address these challenges. Problem-Based Learning (PBL), which situates learning in real-world problems, has been widely investigated and shown to foster deeper understanding and active involvement in various physics topics. For example, studies on PBL implementation in high school physics contexts reported increases in students' engagement and interest, with measurable improvements in both attitudes and learning activities after instructional intervention (Utami et al., 2024). Using the Problem Based Learning model can improve the activity and learning outcomes of students by 15.67% for temperature and heat subject matter (Muhidin & Suparman, 2025). This limitation proposes the developing of peer interaction techniques that can be integrated to improve the interaction.

An example of a cooperative solution designed to mitigate the documented obstacles is the Power of Two, which utilizes structured discussions in pairs to facilitate and deepen operations in understanding and improving accountability (Khaidir et al., 2019). The Power of Two learning model positively and significantly contributed to the elevation of student interests and the outcomes of learning. Working in pairs allows more intensive interaction and reduces social loafing compared to larger groups. In addition to instructional models, the integration of interactive learning media is also essential (Bai et al., 2020). Game-based learning has been shown to increase motivation and emotional engagement through challenge, feedback, and competition elements (Khoiruddin & Iskandar, 2024). Learning using games can increase learning motivation by 17% (Donuata et al., 2019) and shows a significant relationship with student engagement (Ambikapathy et al., 2024). The application makes students not only feel very motivated, but also fairly valued (Kurniati et al., 2021). Digital platforms such as Wordwall can be accessed through a browser and offers a variety of features that support concept reinforcement and active participation, which allows game-based learning activities (Agustin et al., 2024; Juan et al., 2025). Wordwall are useful as a learning resource, media, and fun assessment tool for students (Lestari, 2021). The applications contain images, audio, animations, and interactive games to engage students (Hidayaty et al., 2022).

Although previous studies have demonstrated the effectiveness of PBL, cooperative learning strategies, and game-based learning separately, but most research in physics education primarily on cognitive outcomes rather than affective dimensions such as learning interest. Problem-based learning (PBL) makes students feel more involved in the learning process and can increase their interest in physics learning (Nicholus et al., 2023). However, empirical findings indicate that some students still experience difficulties in participating optimally in group discussions (Pujiyanti et al., 2021), suggesting the need for more structured cooperative mechanisms, such as Power of Two strategy. Game-based activities utilizing interactive cooperative techniques tend to positively affect motivation in students

(Tran, 2019), especially in relation to actively engaging learning activities. However, there tends to be a scarcity of data to support the analysis of structural integration of interactive cooperative learning in particular classroom contexts. In teaching abstract topics of physics, such as vectors, there is a need for a sustained level of interest to engage the learner. In addition, a sustained level of interest to learn physics is required, along with quality representation of physics concepts, to engage the learner. There is a noted shortage of literature supporting the integration of active learning peer collaboration techniques with the multiple interactive instructional frameworks.

While some studies focus on separate instructional components, such as either PBL or gamification, there is a dearth of research to support teaching the physics of a game-based interactive cooperative learning approach that elicits peer collaboration. In particular, there is a deficiency of research in teaching abstract concepts to students learning the physics of game-based scenarios that elicits active collaboration and learner interest in the game. There is also a noted lack of interest to learn the game, sustain the level of interest to learn, and represent concepts needed to convey a game to sustain interest that would otherwise reduce the need to learn the game of physics interactive in collaborative game scenarios.

Thus, a case study is conducted in a grade X class at SMA Negeri 7 Malang, intending to explore the physics learning process that employs the PBL model combined with the Power of Two strategy and interactive game media. The study aims to analyze students' learning interest in vector material by examining how the integration of these approaches shapes multiple dimensions of interest, including attention, enjoyment, involvement, and effort. Through an in-depth exploration of this particular classroom context, the research is expected to provide empirical insight into the interplay of cognitive, social, and emotional mechanisms in fostering multidimensional learning interest.

RESEARCH METHOD

Research Design

This research employed a descriptive qualitative approach with a case study design. The qualitative approach was used to explore students' learning interest in depth within a natural classroom setting without manipulating variables. According to Creswell (2016), qualitative research focuses on interpreting the meanings that individuals or groups construct in relation to social phenomena. For a case study, as explained by Sinaga (2025) highlights that this approach involves an intensive and in-depth examination of a particular event while preserving its natural context without any manipulation. This study obtain a comprehensive understanding of students' experiences and responses toward the implementation of the learning model through direct observation, semi-structured interviews, and documentation, so that learning phenomena can be studied in real contexts (Muhtadi, 2025). In this study, qualitative data served as the primary and sole source of analysis, focusing on rich, descriptive insights obtained from participants.

Research Target/Subject

This research was conducted at SMA Negeri 7 Malang, which was selected because the researcher was conducting teaching assistance using the PBL model, aided by the power of two and interactive games, in grade 10. The school environment was cooperative for research activities. The research was conducted from October to November 2025. The subjects were grade 10 students, selected from three classes with similar initial abilities. The selection of students from each class was carried out through a purposive sampling technique using their degree of participation in class activities, which was classified into three categories: highly active, moderately active, and less active. This classification was made using observation as the data collection instrument in the classroom before the actual data collection process. From the three classes, a total of 9 participants were selected. The target was to achieve representation in various classroom contexts and different levels of participation.

There were three classes with five students each, labeled A1-A3, B1-B3, and C1-C3. Three teacher-researchers were chosen because they experience the learning environment and the behavior phenomena within the classroom. The arrangement of students with these codes presents the opportunity to create a structured environment around the learning process system to yield a complete case study and bridge the gap towards describing the identified phenomena of vector learning using the PBL model with the Power of Two and Games.

Research Procedure

The study procedure consisted of five stages: preparation, instrument development and validation, learning implementation, data collection, and data analysis. In the preparation stage, the researcher developed instructional materials, including a Problem-Based Learning (PBL) module integrated with the Power of Two strategy and interactive game media, designed student worksheets (LKPD) and learning scenarios, and coordinated with the physics teacher to ensure alignment with classroom conditions. As part of instrument development and validation, the researcher constructed the interview protocol and the observation sheets and subsequently had them validated by experts to confirm the content validity regarding learning interest dimensions, and later, the tools were piloted with a small sample of students. During the implementation stage, learning activities were conducted using PBL initiated by contextual problems, followed by structured pair discussions through the Power of Two strategy and reinforced with interactive game-based activities on vector material, with the teacher and researcher acting as facilitators. Data were collected through classroom observations to capture students' learning interest and engagement, semi-structured interviews with selected participants to explore their experiences and perceptions, and documentation including field notes and photographs to support data interpretation. In the data analysis stage, qualitative analysis was conducted by organizing and interpreting data from observations, interviews, and documentation, while triangulation was applied to enhance the credibility of the findings.

Instruments, and Data Collection Techniques

Data were collected using three instruments: observations, semi-structured interviews, and documentation, which collected specifically focused on three dimensions, such as affective, cognitive, and behavioral (Wong & Liem, 2022), 1) the affective dimension refers to students' activating emotional responses with varying degrees of pleasantness; 2) the behavioral dimension represents students' intentional exertion of effort; and 3) the cognitive dimension involves students' concentration and task-relevant thinking processes. Observations were conducted using observation sheets to capture students' learning interest as it emerged during the learning process, as well as to document the implementation of the instructional strategy. The semi-structured interviews were guided by an interview protocol consisting of interrelated questions to explore students' experiences and perceptions of their learning interest during the implementation, as presented in Table 1. Documentation, including photographs and field notes, was used as supplementary evidence to support data interpretation and enhance the credibility of the research findings.

Table 1. Semi-structured interviews

No.	Questions
1	How did you feel during the explanation and discussion phases of the lesson?
2	How did the interactive games change your learning experience?
3	Was there any part of the lesson that made you more curious or interested? Why?
4	Did you feel more concentrated and focused than in previous lessons? Why?
5	What did you spend the most time doing in the lesson? (e.g., doing the discussion, answering the questions, playing the game)
6	Would you like to have more lessons that use this exact model? Why?
7	How would you describe the experience of working with the people in your class during the discussion phase?
8	Which part of the lesson was more useful for you in terms of learning: the discussion with your classmates or the explanation provided by the teacher? Why?

The researchers designed the interview and observation instruments and then validated them by seeking expert opinions on their construction and relevance to the dimensions of learning interest. Before commencing data collection, a trial was conducted to assess the clarity of the items among a number of students. The interview items that tested the students' perceptions on the lessons were reworded to remove ambiguous terms such as "feel about" and "experience." Students were urged to give their perception on the phase of the lesson, be it during the explanation, the discussion and other lesson activities, and while engaging in the interactive games. As for the comparative terms "more than" and "more focused," the reference was provided and stated to be the previous lessons. For the phase of the lesson called "forms of involvement" the term was changed to "what did you do during the lesson"

to become jargon free and precise instructive terms. The researchers intended to have the interview items focused on results that are unambiguous in nature and clear in the data construct. Besides, other questions were added to capture students' perceptions of the current lesson, contextualized in comparative frameworks.

Data analysis technique

Data analysis was conducted in three stages: data condensation, data presentation, and drawing conclusions based on the interactive model of Miles et al., (2018). First, during the data condensation stage, interviews were transcribed verbatim and analyzed using open coding techniques. Researchers identified meaningful statements related to students' learning interests and labeled them with initial codes. These initial codes were then grouped into broader categories that aligned with three predetermined indicators of learning interest: affective, cognitive, and behavioral (Aditya & Imami, 2024). Second, during the data presentation stage, the condensed data were presented narratively, categorized into thematic tables and supported by representative student quotes to illustrate each indicator. Third, the conclusion-drawing stage was conducted inductively by interpreting the meaning of the data and connecting it to students' cognitive, social, and emotional mechanisms.

Data analysis was carried out continuously to produce accurate findings that reflect the actual conditions. Data validity was maintained through the application of source and technique triangulation (Sinaga, 2025). Triangulation was conducted by combining the results of observations, interviews, and documentation to obtain a comprehensive understanding of student behavior, interaction patterns, and learning motivation. Through this approach, the collected data became more valid and reliable, and was able to represent the real situation comprehensively, especially in explaining the emergence and dynamics of each aspect of learning interest influenced by the integrated PBL model Power of Two with the help of interactive games.

RESULTS AND DISCUSSION

The data from nine students were interpreted in three steps. First, open coding was the process for identifying as many as 42 open codes, including “interactive learning is interesting,” “games increase motivation,” “conceptual confusion,” “discussion aids understanding,” and “limited engagement to doing exercises.” Second, axial coding was the process for classifying the open codes to fewer abstract codes, as in three main codes comprised of: Affective (motivation, positive emotions, and interest in the model), Cognitive (understanding, focus, curiosity, and, confusion), and Behavioral (active/limited engagement, effective/ineffective collaboration, and model preference). Third and final, coding was the process of combining the three main codes to describe students interest levels in high, moderate, and low based on the consistency of patterns in the model.

Mapping Variations in Learning Interest Based on Dimensions

Information from observations, interviews, and documents showed notable diversity among students' interest in learning about vector topics with the use of the PBL-PoT model with interactive gaming. The three dimensions of learning interest, duch as affective, cognitive, and behavioral, illustrate how students become engaged in learning activities. The following sections present findings based on these three indicators, summarized in Tables 2.

Table 2a. Mapping of Student Interest in First Class

Indicator	A1	A2	A3
Affective	Enthusiastic, interactive, not boring	Quite enthusiastic due to challenging questions	Discussion makes it relaxed, although lacking understanding
Cognitive	Understands, focused, curious due to challenges & practice	Moderately understands, focused, curious due to complete media	Lacks understanding (missed material), focused because material is difficult, interested in new material

Behavioral	Active (answers, joins challenge, independent), effective collaboration, wants this model	Limited (still confused), effective collaboration, wants this model	Independent, sufficient collaboration (sharing info) but less focused, wants this model

Table 2b. Mapping of Student Interest in Second Class

Indicator	B1	B2	B3
Affective	Very fun, enjoyable, understands	Enjoyable, not boring, initially confused but turns out simple	Fun BUT does not understand (stuck)
Cognitive	Understands, focused (sits in front & wants to know), curious about real-life application	Moderately understands, focused when doing exercises, NOT curious	Does NOT understand (confused about sin cos), low focus, NOT curious
Behavioral	Active (discusses, takes notes, answers questions), enjoyable collaboration, wants this model	Limited (only does exercises), enjoyable collaboration, wants this model	Limited, collaboration NOT effective (both confused), does NOT want this model (prefers textbook)

Table 2c. Mapping of Student Interest in Third Class

Indicator	C1	C2	C3
Affective	Very helped, very understands, game is good	Very fun, easy to understand, game helps memory	Fun because the game is interactive, BUT confused (teacher too fast)
Cognitive	Very understands, focused (interesting material), curious about the use of vectors	Moderately understands, focus NOT stable (disturbed by friends), curious about how to calculate	Lacks understanding (teacher's speed), low focus, NOT curious
Behavioral	Active (does board exercises, group practice), effective collaboration, wants this model	Limited (answers teacher's questions), enjoyable & helpful collaboration, wants this model	Limited (answers teacher's questions), collaboration NOT effective (both equally do not understand), wants this model (because the game is fun)

1. Affective Dimension: Game as a Trigger for Positive Emotions

Based on Tables 2a-2c, the majority of students (A1, A2, B1, B2, C1, C2) showed positive affective responses to the PBL-PoT model assisted by interactive games. They stated that learning felt "alive," "not boring," and "more enthusiastic." A1 expressed, *"Vector material becomes easier to understand because not only looking at PPT, but also practicing and doing exercises at the same time"* (Interview, 2026). Observations confirmed the presence of enthusiasm during learning activities (Observation, 2026).

Malone (1981) states that elements of challenge (from card challenges) and curiosity (through hands-on practice) in games can arouse students' intrinsic motivation. In line with this, the integration of game elements not only increases intrinsic and extrinsic motivation but also creates a more enjoyable and positively competitive learning environment (Gaurina et al., 2025). This finding aligns with research showing that game-based learning increases students' affective engagement and classroom enthusiasm, particularly when digital media are integrated into structured instructional models (Angraini et al.,

2023). Furthermore, other research shows that gamification effectively increases affective engagement, characterized by increased attention, learning satisfaction, and a sense of connection to learning activities (Li et al., 2024).

On the other hand, the cases of B3 and C3 reveal an important anomaly. B3 admitted, *"FUN!!! but honestly, I don't understand at all (stuck);"* while C3 only liked the game without any indication of understanding the material. The teacher said that the students "easily lost focus and were unable to follow the learning flow completely" (Field Notes, 2026). This demonstrates that positive affect can occur without the presence of cognitive affect. According to S. Hidi & Renninger (2006), students such as B3 and C3 are at the triggered situational interest stage (they are interested due to the game), but have not yet developed to the maintained situational interest, and certainly not to the individual interest stage as they lack conceptual understanding. This means that the game is useful to elicit positive affect, but it is not enough to build understanding without the help of scaffolding the prerequisite concepts.

2. Cognitive Dimension: The Gap Between Enjoyment and Understanding

From a cognitive standpoint, we observe a polarization among students' cognitive responses, mirroring the data illustrated within Tables 2a-2c. The first group (A1, B1, C1) canalized strong comprehension, stakeholder-anchored, and teased, relentless focus. A1 expressed curiosity and stated, “Curiosity came, because the questions demanded things. I wanted the correct answers. A developing practicum simulated curiosity within experimentation because I was matching the vector to the statements” (Interview, 2026). B1 demonstrated curiosity about "its application in real life". The teacher described, “This group consistently maintained attention, even while the provided tasks transformed, demonstrating self-control while learning” (Field Notes, 2026).

The second group (B3, C3, and to a lesser extent A3) demonstrated deep conceptual confusion. B3 candidly offers, “What’s the concept? I still don’t get. What are we looking for? How are Sin and Cos used? Why is it this example? How can it work? Sin and Cos, what sort of calculations are conducted?” (Interview, 2026). So C2. The teacher's notes confirmed “when engaged in discussions, the students remained confused, as they were solely fixated on completing the given tasks” (Field Notes, 2026).

The initial cognitive readiness of students is of critical importance to the efficacy of Problem-Based Learning (PBL). The investigation process cannot be followed optimally if students have not mastered the underlying concepts, for example, the fundaments of trigonometry, such as sin and cos (Belland et al., 2009). It has also been argued that the ability of PBL is a function of the students’ ability to comprehend the basic concepts that have been applied within the process of problem-solving (Jihadillah, 2025). In contrast, the instances of A3 and C2 (moderate interest) indicate that their affective responses (i.e., enjoyment, absence of boredom) and cognitive engagement do not reflect a direct, or clear relationship. This supports the argument of Zainuddin et al., (2020) that although gamification is geared towards increasing motivational engagement, is not sufficient for ensuring a comprehensive or deep understanding of concepts. Within the framework of S. Hidi & Renninger (2006), such students are within the transition from the triggered situational interest and sustained situational interest, indicating that their interest is still a function of the external conditions (games, challenges) and has not crystallized into a deeper interest.

3. Behavioral Dimension: Collaboration as a Key to Success

Applying a behavioral perspective, Tables 2a-2c indicate a considerable range in engagement. Students with effective collaboration (A1, B1, C1, C2) demonstrated active participation: A1 was involved in *"actively answering, joining the challenge competition, and understanding independently from the learning outcomes"*; C1 worked on *"board exercises and group practice creating vector directions"*. As one student stated, “*I understand vectors better because my partner explains them step by ste*p”, while another mentioned, “*Discussion makes me less confused because I can ask directly*” (Interview, 2026). The teacher noted their *"activeness in discussions, asking questions, and involvement in problem-solving"* (Observation, 2026).

Conversely, students with ineffective collaboration (B3, C3) experienced compounded confusion. B3 admitted, *"I always ask for help, but others are also confused"*; C3 stated that discussions were *"just ordinary because my desk partner also doesn't know"* (Interview, 2026). The teacher

observed that these students *"rarely participated in discussion dynamics and tended to withdraw"* (Field Notes, 2026).

Vygotsky's (1978) theory of social constructivism states that social interaction within the *zone of proximal development* (ZPD) can help students build understanding. When students collaborate with more capable peers, they can achieve levels of understanding they could not reach alone. Indicate that the Power of Two strategy functioned as peer scaffolding, supporting students' conceptual understanding (Moon et al., 2024) However, when both group members are below the ZPD (both equally do not understand), collaboration becomes dysfunctional. Slavin (2018) emphasizes that the success of collaboration in cooperative learning is strongly influenced by heterogeneous group composition. Research shows that PBL improves collaboration skills through group activities, with effectiveness influenced by appropriate student grouping, initial readiness, and level of engagement during the learning process, so that increased motivation and engagement do not occur evenly across all students (Dewi et al., 2024; Hidayati et al., 2024; Jothy et al., 2024).

Interestingly, despite limited engagement, the majority of students expressed a desire to use this model again. A1 wanted *"this learning method for the future so that students would be more active in answering"*; B2 admitted *"I want to because it's not boring, playing while learning"*; C1 liked *"learning with interactive games because it's very fun and we can learn in a relaxed way"* (Interview, 2026). The only contrasting sentiment came from B3, who stated, " I just want a textbook … I prefer reading." This statement suggests that positive emotional responses can sustain behavioral interest even in the absence of a complete cognitive grasp, and such a phenomenon in particular warrants consideration in game-based learning development.

Classification of Student Interest Levels: High, Moderate, Low

Based on triangulation of interview data, teacher observations, and field notes, students' learning interest in vector topics using the PBL-PoT model assisted by interactive games can be grouped into three levels, as shown in Table 3.

Table 3. Classification of Student Interest Levels

Interest Level	Student Initials	Number	Core Characteristics
High	A1, B1, C1	3	Consistently positive in affective, cognitive, and behavioral dimensions
Moderate	A2, A3, B2, C2	4	Positive in affective, but limited in cognitive or behavioral dimensions
Low	B3, C3	2	Positive affect (fun) but cognitively does not understand and collaboration is ineffective

High interest (A1, B1, C1) is characterized by consistency across all three dimensions. A1 stated, *"The learning is more alive, making me more enthusiastic about the practice part"*; B1 responded *"fun and enjoyable"*; C1 expressed curiosity about *"what its use will be later"* (Interview, 2026). The teacher noted that these students *"were able to maintain attention consistently even when activities changed"* (Observation, 2026). High interest is reflected in the alignment between positive feelings, conceptual understanding, and concrete actions in learning.

Moderate interest (A2, A3, B2, C2) shows positive but inconsistent responses. A2 admitted *"moderately understanding vector material"* and *"quite enthusiastic"*; however, C2 admitted *"sometimes I focus, sometimes I don't, because my desk partner is sometimes quiet, sometimes noisy"*; B2 even stated *"I don't know yet, because in my opinion the explanation is clear enough"*—showing a lack of cognitive drive to explore further (Interview, 2026). The teacher noted that *"students on average showed stable positive energy, but there was no apparent understanding of the material nor active participation in discussions"* (Field Notes, 2026). Nevertheless, they still expressed interest in using this model again, as expressed by A3: *"Yes, because it doesn't feel boring."*

Low interest (B3, C3) shows a misalignment between affective, cognitive, and behavioral dimensions. B3 said, *"FUN!!! but honestly, I don't understand at all (stuck)"*; C3 only said *"fun, because the game is interactive"* without any indication of material understanding (Interview, 2026). The teacher noted that *"these students easily lost focus and were unable to follow the learning flow completely"* (Field Notes, 2026). They didn't understand each other, so their collaboration wasn't

effective. Even in model preference, B3 firmly chose the conventional method: *"I just want a textbook... I prefer reading."*

This pattern indicates that interest is not a composite direct construct. Rather, it is the combination of the affective, cognitive, and behavioral components of interest, which is fundamentally multidimensional (Roundfield et al., 2018). High levels of student affective interest without cognitive interest are not typically addressed, and impact of the omni-scope of interest that exceeds measuring motivation or enjoyment, is often the primary focus of gamification. Even though students' interests do not only pay attention to affective aspects, but also cognitive and behavior. According to previous research, students'interest increase when students feel comfortable during learning, understand the learning objectives, and recognize the benefits of what they are studying (Harefa, 2023). Students with low interest remain trapped in the *triggered situational interest* phase and fail to progress to subsequent phases due to a lack of conceptual understanding support (S. E. Hidi & Renninge, 2026). Besides that, although students experienced enjoyment and active participation, their persistence in completing tasks varied individually. This finding aligns with previous research showing that gamification primarily strengthens motivation and engagement but may not equally influence all aspects of learning persistence (Nurhayati & Fathurrohman, 2025).

Learning interest can be shaped by the learning process, including instructional interventions. Interventions that integrate PBL models with gamification can significantly improve collaboration and learning engagement (Hanum et al., 2026), there by supporting the affective and behavioral dimensions of student interest. However, on the cognitive side, increased motivation and engagement are not always followed by improved conceptual understanding unless reinforced by mastery of basic concepts and appropriate collaboration (Gaurina et al., 2025; Jothy et al., 2024). The Power of Two strategy functioned as peer scaffolding, supporting students' conceptual understanding (Moon et al., 2024) but both group members are below the ZPD, collaboration becomes dysfunctional. Therefore, there is a need to integrate the model with appropriate pedagogy (Nurulaisyah et al., 2024). The key implication is that learning interventions should not only make students "happy" but also ensure that this enjoyment facilitates conceptual understanding.

The findings presented concern the critical reflections from the participants. Some participants need time to adapt, especially among those coming from a passive learning background. Some participants had trouble converting vectors to equations. This indicates, in spite of higher engagement, participants still face the challenge of comprehending the conceptual complexity of abstract material (Taqwa & Rahim, 2022). The results show that the integration of PBL, Power of two, and interactive games augments learning interest on multiple dimensions, and engagement cannot be sustained longer by affective measures. These results correlate to other studies that deal with the use of contextual learning to promote engagement (Kurniawan et al., 2023) and the use of gamification to boost motivation (Khoiruddin & Iskandar, 2024). This study further explains the role of structured pair learning that provides mediation between cognitive challenges and emotional learning engagement (Aisyah et al., 2025). Learning interest occurs not from a single instructional technique, but from the interaction of the affective, cognitive, and behavioral components.

CONCLUSION

The findings of the study further indicate that the PBL-PoT approach with the use of gamification has the potential to foster a learning environment that encourages students' motivation and engagement in the learning of physics in the affective and behavioral dimensions. Learning interest is created not from motivation only, but from the combination of extensive participation, motivation, enthusiasm, and understanding. The combination of PBL and gamification positively affects the participants' ability to collaborate as well as learning engagement. However, students with low initial ability require additional support in the form of reinforcing prerequisite concepts (such as basic trigonometry in vector topics), forming heterogeneous groups to optimize discussions through the ZPD mechanism, and providing gradual scaffolding to overcome conceptual confusion. Therefore, teachers may consider integrating contextual problems, structured peer discussion, and gamified activities in a balanced manner to stimulate multidimensional learning interest.

This study has several limitations. First, the research was conducted in a single school context with a limited number of participants, which restricts the generalizability of the findings. Second, the

qualitative case study design emphasizes depth of exploration rather than comparison with control groups, so conclusions are limited to describing patterns of learning interest development rather than measuring instructional effectiveness, and the focus only on interest dimensions without examining the relationship with learning outcomes. Third, the implementation was carried out within a relatively short time frame, which does not allow observation of long-term sustainability of students' learning interest. Also, the absence of initial interest measurement, and the focus only on interest dimensions without examining the relationship with learning outcomes

Future research is recommended to involve broader participant groups across different schools and educational levels, apply longer implementation periods, and incorporate comparative or mixed-method designs to examine the consistency and sustainability of learning interest development. Further investigation may also explore how each instructional component PBL, peer collaboration, and gamification individually examine the relationship between interest dimensions (affective, cognitive, behavioral) and student learning outcomes, and explore appropriate scaffolding strategies for students with low interest so that enjoyment of games can be transformed into complete conceptual understanding.

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