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[Review Article]

STUDENT ENGAGEMENT TRENDS IN PHYSICS EDUCATION: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Traditional physics instruction often struggles to connect abstract formulas with real-world phenomena, reducing student engagement. This review maps current research trends and evaluates how innovative instructional models influence engagement across educational levels. Following PRISMA, 104 Scopus records (2016–2025) were screened, and studies were retained only if they were full-text empirical articles that measured at least one engagement dimension (behavioural, cognitive, or affective) within a physics learning context, yielding 23 articles. Methodological quality was appraised using the Mixed Methods Appraisal Tool, and thematic relations were mapped with VOSviewer. The findings show that innovative models foster multidimensional engagement through personalised, interactive, and culturally situated experiences, raising motivation and learner autonomy, although technical and pedagogical barriers persist. Effective physics instruction therefore requires synergy between advanced technology, culturally responsive contexts, and supportive learning environments. Strengthening teachers' pedagogical-technological competence should be prioritised alongside technology adoption.

Keywords: Student Engagement, Physics Education, Systematic Literature Review.

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1. INTRODUCTION

Physics education plays a fundamental role in developing scientific understanding and preparing students to interpret natural phenomena through evidence-based reasoning. However, physics remains one of the disciplines that presents persistent pedagogical challenges because many concepts involve abstract representations, invisible mechanisms, and complex mathematical formalism that are difficult to connect with students' everyday experiences. Topics such as electricity, magnetism, mechanics, and energy frequently generate conceptual difficulties, reduced motivation, and limited participation when learning environments fail to provide meaningful connections between scientific concepts and students' lived contexts (Ayasrah et al., 2024; Wijaya, 2025; Liani et al., 2020). These challenges indicate that improving physics learning requires not only the delivery of scientific content but also the development of learning experiences capable of fostering sustained student engagement.

Student engagement has increasingly become a central construct in educational research because it represents a critical pathway connecting learning experiences with meaningful educational outcomes (Pianta et al., 2012). Engagement is not limited to students' physical participation in classroom activities but represents a multidimensional construct involving behavioural, cognitive, affective, and social dimensions (Fredricks et al., 2016). Behavioural engagement reflects students' participation, persistence, and involvement in learning activities; cognitive engagement refers to psychological investment, strategic learning processes, and willingness to apply mental effort; affective engagement concerns students' interest, emotional responses, and sense of belonging; while social engagement highlights interaction and collaboration with teachers and peers (Fredricks et al., 2016; Pianta et al., 2012). Therefore, understanding how instructional approaches influence different dimensions of engagement is essential for developing physics learning environments that are meaningful, inclusive, and sustainable.

Various instructional innovations have been developed to address the challenge of enhancing student engagement in physics education. Technology-supported approaches, including artificial intelligence (AI), virtual reality (VR), augmented reality (AR), computer simulations, and digital learning platforms, have been increasingly explored because they provide interactive representations of abstract physical phenomena and opportunities for personalised learning experiences (Lieb & Goel, 2024; Masopust et al., 2025; Robledo-Rella & Toh, 2024). Similarly, active learning approaches such as project-based learning, flipped learning, gamification, and inquiry-based learning have been reported to encourage students' participation, cognitive involvement, and conceptual understanding (Agustini et al., 2022; Richter & Kickmeier-Rust, 2025; Wang et al., 2025). However, the effectiveness of these approaches may vary depending on the learning context, physics topic, implementation design, and engagement dimension being targeted.

Beyond technological and active-learning interventions, culturally responsive approaches such as ethnophysics have emerged as an important perspective in physics education. Ethnophysics integrates scientific concepts with local cultural practices and indigenous knowledge, enabling students to interpret physics principles through familiar experiences and meaningful contexts (Jufrida et al., 2025; Sunarti et al., 2025). Unlike technology-based interventions that primarily enhance interaction through digital representation, ethnophysics strengthens engagement by increasing students' perceived relevance, cultural connection, and emotional attachment toward physics learning. Through contextualised investigation and collaborative exploration of local phenomena, ethnophysics may support affective engagement by developing students' interest, sense of value, and belonging, while simultaneously promoting social engagement through communication, peer collaboration, and shared knowledge construction (Jufrida et al., 2025; Sunarti et al., 2025). Thus, ethnophysics provides a complementary pathway for addressing engagement dimensions that cannot be fully explained through technological innovation alone.

Although numerous studies have investigated strategies for improving student engagement in physics education, the existing evidence remains fragmented. Previous reviews and research syntheses in physics education have predominantly focused on learning achievement, conceptual understanding, technology implementation, or general pedagogical trends rather than examining student engagement as the primary analytical construct. Most empirical studies have investigated individual interventions, such as AI-assisted learning, VR/AR, gamification, e-learning, flipped learning, or project-based learning, within specific educational settings, making it difficult to determine how different instructional models correspond with particular engagement dimensions (Laumann et al., 2025; Masopust et al., 2025; Richter & Kickmeier-Rust, 2025; Robledo-Rella & Toh, 2024; Wang et al., 2025). Furthermore, engagement is frequently treated as a secondary outcome alongside achievement, motivation, or conceptual understanding rather than being systematically analysed through its behavioural, cognitive, affective, and social components (Agustini et al., 2022; Pranata, 2024; Wang et al., 2025).

This fragmented evidence creates several unresolved gaps in the literature. First, a conceptual gap exists because limited synthesis has examined how different instructional models influence specific dimensions of student engagement in physics education. Second, a methodological gap remains because previous studies employ diverse instruments and research designs, making the strength and reliability of evidence difficult to compare. Third, a contextual gap exists because findings generated from technologically advanced learning environments may not necessarily represent diverse educational settings where infrastructure, teaching practices, and cultural contexts differ. Consequently, a systematic synthesis that integrates instructional models, physics topics, engagement dimensions, measurement approaches, and methodological quality is required.

The need for such a systematic literature review has become increasingly urgent in the current educational landscape. Following the COVID-19 pandemic, physics education has experienced rapid expansion of digitally mediated learning environments, accelerating research on AI, VR/AR, gamification, and online instructional platforms (Jufrida et al., 2025; Lieb & Goel, 2024; Masopust et al., 2025; Thi Ngoc Anh et al., 2025). However, technological development has progressed faster than the accumulation of robust evidence regarding how these innovations influence different forms of student engagement. Without a comprehensive quality-appraised synthesis, educational decisions may be influenced more by technological novelty than by evidence-based understanding of effective pedagogical mechanisms. Moreover, because engagement is highly dependent on educational context, findings from specific settings cannot automatically be transferred without systematic evaluation (Fredricks et al., 2016).

Therefore, the Systematic Literature Review (SLR) approach is appropriate for addressing these challenges because it provides a transparent, reproducible, and evidence-based method for identifying, evaluating, and synthesising existing research findings. Through systematic identification, screening, methodological appraisal, and thematic synthesis, an SLR can provide a comprehensive understanding of research development while revealing methodological strengths, limitations, and future research directions.

Based on the identified problems and research gaps, this study aims to systematically analyse trends and characteristics of research on student engagement in physics education from 2016 to 2025. Specifically, this review investigates the publication trends, instructional models, research subjects, physics topics, engagement dimensions, measurement approaches, and methodological quality of existing empirical studies. The synthesis generated from this review is expected to provide evidence-based insights for developing physics learning approaches that are more interactive, contextually relevant, and capable of strengthening students' behavioural, cognitive, affective, and social engagement.

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2. METHOD

This study employs a systematic literature review (SLR) methodology to evaluate and synthesize scholarly research regarding student engagement in physics education. To ensure the findings are transparent, reproducible, and free from reporting bias, the investigation adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021). The selection process involves a rigorous progression through identification, screening, and eligibility assessment, ultimately leading to the inclusion of relevant studies. By following the PRISMA protocol, the research effectively maps the current academic landscape and provides an objective analysis of the literature (Rethlefsen et al., 2021). As a secondary source study, the data consists exclusively of peer-reviewed articles indexed in the Scopus database, meaning no direct field observations or primary data collection were performed. A visual representation of the study's selection criteria and flow is provided here.

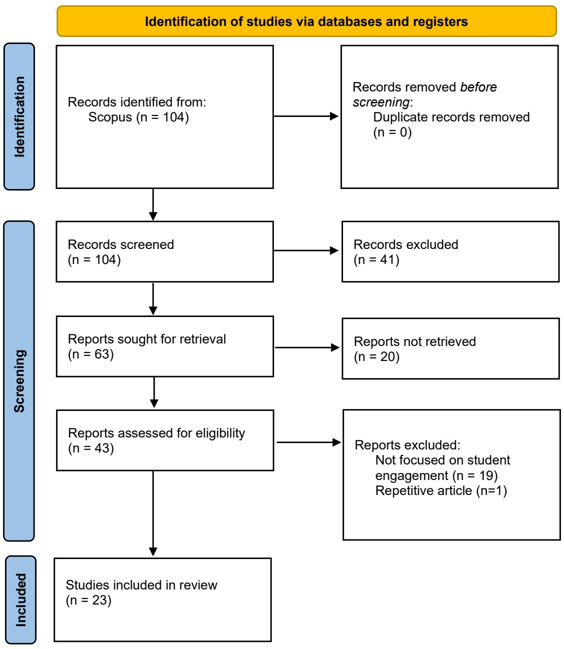

Figure 1. Prism Flow Chart.

The Scopus database was prioritized for the literature search due to its comprehensive collection of high-quality, peer-reviewed journals specifically focused on physics education. The steps in conducting research with the SLR method are as follows: The first step is to search forarticles on Scopus using the main keywords about the student engagement in physics education. The search terms used were "Student Engagement" or "behavorial engagement" or "cognitive engagement" or "affective engagement" and "physics education" or "physics learning". Thesearch queries used are as follows: TITLE-ABS-KEY ("student engagement" OR "behavioral engagement" OR "cognitive engagement" OR "affective engagement") AND TITLE-ABS-KEY ("physics education" OR "physics learning") AND PUBYEAR > 2016 AND PUBYEAR < 2026.

There were 104 articles identified from the Scopus database based on the predetermined search keywords. All retrieved articles were systematically examined through keyword suitability, titles, and abstracts to ensure their relevance to the research focus, namely student engagement in physics education. During the initial screening stage, articles that were not journal articles, unavailable in full-text format, unrelated to physics education, or did not investigate student engagement outcomes were excluded, resulting in 63 articles remaining for further assessment.

The screening process was subsequently conducted through a full-text review by evaluating the extent to which each study explicitly addressed student engagement dimensions, including behavioural, cognitive, and affective engagement, within physics learning contexts. Articles that did not directly measure student engagement outcomes, did not examine relevant instructional interventions, or presented repetitive findings without additional contributions were excluded. After the full-text eligibility assessment, 23 articles met the inclusion criteria and were considered eligible for methodological quality appraisal.

To enhance methodological rigor and reduce potential selection bias, the screening and eligibility assessment processes were performed independently by two researchers. The level of agreement between researchers was evaluated using percentage agreement, while any discrepancies in article selection were resolved through discussion until a consensus was achieved. This procedure was implemented to improve the objectivity and reliability of the study selection process. Furthermore, the methodological quality of the included studies was assessed using adapted criteria from the Mixed Methods Appraisal Tool (MMAT) , covering aspects such as the clarity of research objectives, appropriateness of the methodological approach, validity of measurement instruments, transparency of analytical procedures, and consistency in reporting research findings. Each study was classified based on three quality categories: high, moderate, and low (Hong et al., 2018). Studies demonstrating high and moderate methodological quality were retained for the final synthesis, whereas studies with low methodological quality were excluded from further thematic analysis to ensure the credibility and robustness of the evidence generated from the SLR. After the full-text eligibility assessment, The final corpus therefore consisted of 23 studies that fulfilled both relevance and minimum methodological quality requirements. The relatively limited number of included studies reflects the specific nature of research focusing explicitly on student engagement as a primary construct within physics education during the 2016–2025 period.

To perform an initial network mapping of thematic relevance, the 23 selected articles were compiled in Excel, converted to CSV format, and subsequently processed using VOSviewer version 1.6.20

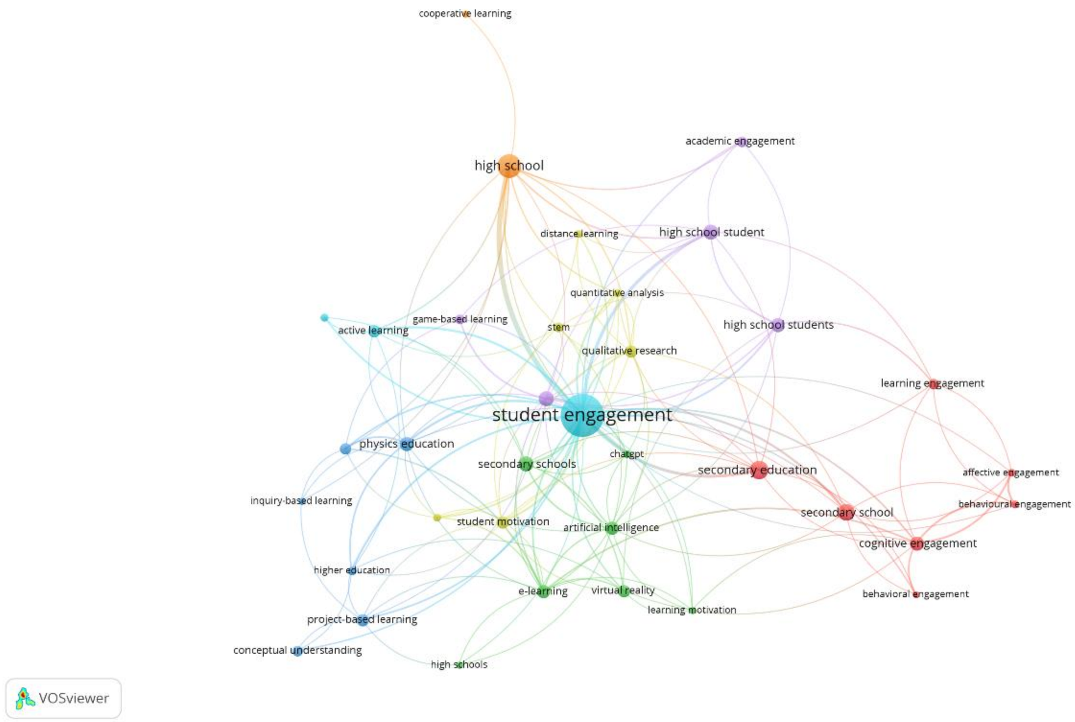

Figure 2. Initial Network Visualization.

The resulting visualization in Figure 2 reveals a complex pattern of associations surrounding student engagement in physics education. The bibliometric analysis suggests that research in this field is intricately linked with various pedagogical and technological domains, including inquiry-based learning, student motivation, and conceptual understanding. Furthermore, the map highlights a significant trend toward integrating modern technologies, such as artificial intelligence and virtual reality within both secondary and high school.

3. RESULT AND DISCUSSION

Based on the data obtained on articles on student engagement, each aspect will then be analyzed by looking at the number of article publications from

2016 to 2025, the methods and topics, and the results of each research paper on student engagement. Using some of these analyses, the researchers will lead discussions on the implementation of student engagement in physics education, intervention strategies designed to enhance engagement, and measured outcomes across behavioral, cognitive, and affective domains. The research findings, based on the year of publication of articles on student engagement in learning physics, are presented in Figure 3 as follows.

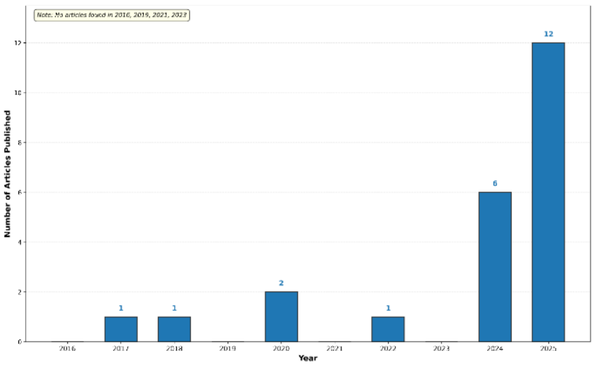

Figure 3. Article distribution 2016-2025.

The volume of published articles reflects the frequency of research conducted within a specific timeframe. According to the data in Figure 3, there was no distinct pattern of fluctuation in publication numbers over the years. However, the graph highlights a notable surge in publications starting in 2024 compared to previous periods. This upward trend in literature regarding student engagement suggests a significant growing interest among researchers to explore this topic more extensively.

Increasing the volume of research focused on student engagement leads to a more favorable impact on the growth of the educational system. This argument stems from the principle that the fundamental objective of any academic inquiry is the enhancement of educational quality and practice (Coburn & Penuel, 2016) Specifically, research contributes to pedagogical improvement by: (1) providing validated evidence that educators can apply in the classroom; (2) serving as a rigorous foundation for policy-making at institutional and national levels; and (3) reshaping teachers' conceptual approaches to instruction.

According to Fredricks et al. (2016) extensive research has identified specific strategies that educators can implement to boost student engagement throughout the learning process. Student engagement reaches an optimal level when the implemented learning model provides tasks that are diverse, challenging, engaging, and personally meaningful to the students (Fredricks et al., 2016). The learning models applied to enhance student engagement are presented in Table 1. These models, which are capable of improving student engagement as shown in Table 1, are classified into 12 categories based on the characteristics of students' learning experiences, learning context, problem-solving approaches, outcome orientation, and the technology involved in increasing student engagement. The classification of learning models is shown in Table 2. The results of a literature review from various studies show that project based learning and game-based learning are learning models that are often used to improve student engagement.

Table 1. Learning Models That Can Improve Student Engagement.

No.	Authors (Year)	Model of Teaching	Frequency
1	Laumann et al. (2025); Wang et al. (2025) Jufrida et al. (2025); Sunarti et al. (2025)	Project-Based Learning (PjBL)	4
2	Richter & Kickmeier-Rust (2025); Pranata (2024); Thi Ngoc Anh, et al. (2025); Ermakan, et al. (2024)	Gamification & Game-Based Learning	4
3	Lieb & Goel (2024) Robledo-Rella & Toh (2024); Jufrida et al. (2025)	Artificial Intelligence (AI) & Chatbots	3
4	Haris et al. (2024); Agustini et al. (2022)	Flipped Learning Models	2

No.	Authors (Year)	Model of Teaching	Frequency
5	Peer & Kapon (2025); Kapon, Schvartzer, & Peer (2021)	Maker-Based Inquiry	2
6	Ayasrah et al. (2024); Masopust et al. (2025)	Computer Simulations & Augmenterd/Virtual Reality (AR/VR)	2
7	Sunarti et al. (2025); Jufrida et al. (2025)	Ethnophysics/Ethnoscience	2
8	Musengimana et al. (2025); Robledo-Rella & Toh (2024)	Problem-Solving & Active Learning Support	2
9	Stanley et al. (2017); Tuveri & Steri (2025)	Hands-On & Laboratory Activities	2
10	Wijaya (2025) Gregorcic et al. (2018)	Interactive & Multi-Sensory Technology	2
11	Laumann et al. (2025); Liani et al. (2020)	E-Learning Platforms	2
12	Leshko et al. (2025)	Historical Principle Implementation	1

Table 2. Classification Learning Model.

No	Classification	Model of Teaching
1	Project-Based Learning (PjBL)	• `Project-Based Learning with E-Learning Courses • Project-Based Learning (University Level) • AI-Driven Project Based Learning with Ethnoscience • Project-Based Learning with Ethnoscience
2	Gamification & Game-Based Learning	• Gamification with Knowledge Space Theory • Physics Education Technology (PhET) as Game-Based Learning • Gamified Mobile Learning (Quizalize) • Gamification with Kahoot! Platform
3	Artificial Intelligence (AI) & Chatbots	• LLM-as-tutor Chatbot (NewtBot) • Artificial Intelligence for Active Learning Support • AI-Driven Ethnoscience
4	Flipped Learning Models	• Knowledge-Based Flipped Classroom Model • Quantum Flipped Learning Model
5	Maker Based Inquiry	• Maker-Based Inquiry • Engineering Maker-Based Inquiry
6	Computer Simulations & Augmented/Virtual Reality (AR/VR)	• Computer Simulations • Virtual and Augmented Reality
7	Ethnoscience / Ethnophysics	• Ethnophysics with Problem-Based Learning • AI-Driven Project Based Learning with Ethnoscience
8	Problem-Solving & Active Learning Support	• Problem-Solving Strategies Training • Active Learning Support with AI
9	Hands-On & Laboratory Activities	• Lab Notebooks in Electronics Lab • Hands-On Activity
10	Interactive & Multi-Sensory Technology	• Multi-Sensory Media Innovations

No	Classification	Model of Teaching
		• Interactive Whiteboard Technology
11	E-Learning Platforms	• E-Learning Courses with Project-Based Learning • Communication Platform (WhatsApp) in E-Learning
12	Historical Principle Implementation	• Historicism Principle Learning

Based on the data presented in Table 1, there is a clear trend in the selection of learning models among researchers to enhance student engagement. Gamification models have emerged as one of the most prominent approaches, with research indicating that the use of gamification in e-learning environments has expanded rapidly since 2014, particularly as a response to the educational challenges posed by COVID-19 (Ermakan et al., 2024). Furthermore, Project-Based Learning (PjBL) continues to dominate as an effective pedagogical strategy for improving both student engagement and learning outcomes (Wang et al., 2025).

Interactive technological models, such as virtual reality, augmented reality, and AI-based chatbots, have also shown a significant increase, reflecting the digital transformation within physics education (Masopust et al., 2025). Additionally, there is a growing trend regarding the integration of culture-based approaches and ethnophysics, which demonstrates an effort to make physics learning more contextually relevant to students' personal experiences (Sunarti et al., 2025). Notably, the work of Sunarti et al. (2025) and Jufrida et al. (2025) exemplifies a multi-model intervention strategy by successfully integrating Project-Based Learning (PjBL) with ethnophysics. Overall, the modern physics education landscape is characterized by a shift from traditional passive learning toward approaches that are more interactive, meaningful, locally wisdom-oriented, and technology-driven.

According to (Pianta et al., 2012), student engagement is far more profound than mere physical presence or passive compliance, serving instead as a vital "gateway" to meaningful learning outcomes. Fredricks et al. (2016) argue that viewing engagement solely through the lens of behavioral participation, which involves academic involvement, persistence, and adherence to school rules overlooks the critical internal motivations and cognitive strategies that determine long-term learning quality. Consequently, student engagement is defined as a multidimensional construct comprising behavioral engagement, cognitive engagement involving psychological investment and self-regulated learning, and affective or emotional engagement, which encompasses a student’s sense of belonging and reactions toward teachers and peers (Fredricks et al., 2016). Furthermore, recent perspectives highlight social engagement as a crucial additional dimension, emphasizing the quality of social interactions and collaboration among students as essential components for understanding engagement within the school environment (Fredricks et al., 2016; Pianta et al., 2012).

To provide a comprehensive overview of the analyzed literature, the selected studies were categorized based on the types of instruments used and the targeted dimensions of student engagement. The distribution of this data collection is systematically presented in Table 3 below.

Table 3. Data Collection.

No.	Dimensions of Student Engagement	Data Collection Instruments	Source Articles (Authors)
1	Behavioral Engagement	Student Engagement in School Questionnaire (SESQ); Classroom Observations; Digital Questionnaires; Quizalize Analytics (Attempts, Time Spent); Lab Notebooks Analysis; User Experience Questionnere; Peer Interaction Observation; Social Presence Scale; Collaborative Learning Rubrics.	Wijaya (2025); Stanley et al. (2017); Pranata (2024); Tuveri & Steri (2025); Lieb & Goel (2024); Jufrida et al. (2025); Ayasrah et al. (2024);
2	Emotional / Affective Engagement	Likert Scale-based Questionnaires; Semi-structured Interviews; Perception Questionnaires; Academic Emotions Questionnaire, Survey Method	Sunarti et al. (2025); Richter & Kickmeier-Rust (2025); Robledo-Rella & Toh (2024); Gregorgic et al. (2018); Ermakan, et al. (2024); Leshko et al. (2025)
3	Cognitive Engagement	Deep Learning Subscale; Problem-Solving Tests; Cognitive Skills Rubrics; Motivated Strategies for Learning Questionnaire (MSLQ); Conceptual Test	Wang et al. (2025); Peer & Kapon (2025); Agustini (2022); Masopust et al. (2025)
4	Multi-Dimensional Engagement	20-item Student Engagement Survey (Fredricks et al. adaptation); Multiple Observations from T0 to T5; Comprehensive Survey Instruments; Student Engagement Scale (SES-4DS); Reformed Teaching Observation Protocol (RTOP); Discourse analysis interview	Thi Ngoc Anh et al. (2025); Laumann et al. (2025); Haris et al. (2024); Liani et al. (2020); Musengimana et al. (2025); Kapon et al. (2021)

Based on the classification in Table 3, the reviewed studies measure student engagement through several distinct dimensions, including behavioral engagement (participation and task completion), emotional or affective engagement (interest and attitudes), and cognitive engagement (self-regulation and deep learning strategies). Furthermore, some research incorporates agency engagement, reflecting student autonomy, and social engagement, which focuses on collaboration and peer interaction (Liani et al., 2020; Thi Ngoc Anh et al., 2025).

In general, these studies employ a combination of quantitative and qualitative approaches. Quantitative instruments include questionnaires using Likert scales mostly utilizing 5-point or 6-point Likert scales analytics tracking, and pre-post test measurements (Haris et al., 2024; Lieb & Goel, 2024; Ermakan, et. al, 2024) Qualitative instruments encompass classroom observations, semi-structured interviews, and artifact analysis, such as lab notebooks and project evaluations (Stanley et al., 2017; Wang et al., 2025). Most of the questionnaires used demonstrate high reliability, with Cronbach's alpha values ranging from 0.70 to 0.92. This indicates strong internal consistency for measuring the construct of student engagement (Agustini et al., 2022; Liani et al., 2020).

The empowerment of student engagement was aimed at students. Based on information regarding data collection, a mixed-methods design constituted the most frequently utilized approach by researchers. This indicates that, in general, these studies sought to provide a more comprehensive understanding of the research problem and to determine which approaches are most effective in enhancing student engagement. In conducting research, It required research subjects to test their hypotheses. Based on Figure 4, the most widely selected research subjects were senior high school students, followed consecutively by students in higher education, junior high school, and elementary school.

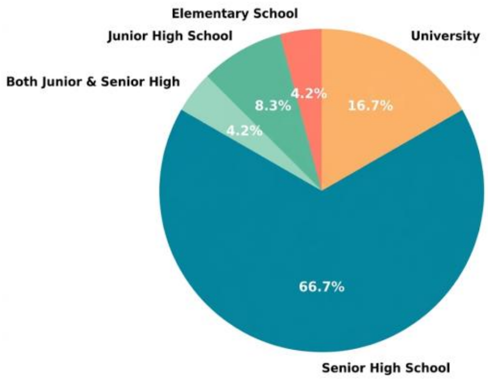

Figure. 4 Distribution of Articles by Research Subject.

Based on Figure 4, research dominantly focuses on secondary and higher education, which is highly consistent with current finding patterns. Across the analyzed articles, studies centered on Senior High School (17 articles) and Higher Education (4 articles) for more than 70% of the total sample. This indicates a significant priority toward education levels that are complex and require substantial pedagogical innovation (Sunarti et al., 2025; Wang et al., 2025). These findings support the argument that student engagement research is more prominent at the secondary and higher education levels due to the urgent need to address academic complexity (Agustini et al., 2022; Haris et al., 2024; Kapon et al., 2021; Wang et al., 2025) and evaluate the effectiveness of digital innovations in supporting student learning autonomy (Jufrida et al., 2025; Lieb & Goel, 2024; Masopust et al., 2025; Robledo-Rella & Toh, 2024; Sunarti et al., 2025; Thi Ngoc Anh et al., 2025; Wijaya, 2025).

This study also classifies various physics topics used to enhance student engagement. Topics such as Electricity, Magnetism, Motion, Work, and Energy are the most frequently discussed subjects in research related to improving student involvement. Following these, topics like Cosmology, Astronomy, Waves, Optics, Thermodynamics, and Fluids are addressed to a lesser extent. The variety of physics topics in this study aligns with the specific characteristics of the learning models implemented, with some studies integrating multiple concepts simultaneously to provide a more holistic understanding. The classification of physics subject matter is shown in Table 4.

Table 4. Classification Based on Physics Subject Matter (Topic).

No.	Subject Matter (Topic)	Authors (Year)	Frequency
1	Electricity and Magnetism	Ermakan et al. (2024); Kapon et al. (2021); Haris et al. (2024); Lieb & Goel (2024); Liani et al. (2020); Musengimana et al. (2025); Wijaya (2025); Stanley et al. (2017)	8
2	Motion, Work, Energy, Power	Laumann et al. (2025); Thi Ngoc Anh et al. (2025); Sunarti et al. (2025), Richter & Kickmeier-Rust (2025); Peer et al. (2025), Pranata (2024), Masopust et al. (2025); Ayasrah et al. (2024)	8
3	Cosmology & Astronomy	Tuveri & Steri (2025); Gregorcic et al. (2018); Leshko et al. (2025)	3
4	Optics & Waves	Agustini et al. (2022), Wang et al. (2025)	2
5	Mechanic, Thermodynamic	Jufrida et al. (2025)	1
6	Linear momentum conservation, Fluids	Robledo-Rella & Toh (2024)	1

Based on Table 4. The topics of Electricity, Magnetism, Motion, Work, and Energy are frequently discussed in this study because these materials are highly abstract and cognitively demanding, making them difficult for students to visualize and relate to their daily lives without the help of specific technological interventions (Ayasrah et al., 2024; Liani et al., 2020; Richter & Kickmeier-Rust, 2025). Several previous studies have shown that traditional teacher-centered instruction and the lack of interactive learning media results in low students' engagement (Laumann et al., 2025; Sunarti et al., 2025; Wijaya, 2025). This disengagement is often rooted in students' inability to connect theoretical formulas with real-world phenomena, leading to decreased motivation and negative attitudes toward the subject (Ayasrah et al., 2024; Richter & Kickmeier-Rust, 2025). Understanding concepts is the basis for improving students' engagement as it acts as a cognitive bridge that allows students to participate more effectively in inquiry-based activities, such as gamified learning or ethnophysics-based projects, which in turn fosters deeper scientific literacy and problem-solving skills (Richter & Kickmeier-Rust, 2025; Sunarti et al., 2025).

Analysis of the reviewed literature indicates that the majority of pedagogical and technological interventions exert a significant positive impact across various dimensions of student engagement. Technology-based interventions, such as the use of computer simulations and multi-sensory media, have proven effective in enhancing students' positive attitudes and motivation (Ayasrah et al., 2024; Wijaya, 2025). Specifically, the integration of Physics Education Technology (PhET) simulations as a game-based learning tool has a positive effect on conceptual understanding and intrinsic motivation, particularly when addressing complex physics problems (Pranata, 2024). Similarly, the integration of Artificial Intelligence (AI) through chatbots (e.g., NewtBot) and AI-driven ethnoscience learning has demonstrated a capacity to personalize the learning experience, which in turn deepens psychological investment and cognitive engagement ((Jufrida et al., 2025; Lieb & Goel, 2024).

Active learning models, such as Quantum Flipped Learning and Project-Based Learning (PjBL), also show a strong positive influence. Agustini et al. (2022) found that the flipped learning model significantly increases the cognitive engagement necessary to achieve critical and creative thinking skills. In the context of higher education, PjBL has been shown to strengthen core competencies and cognitive skills through active participation in challenging design projects (Wang et al., 2025). Furthermore, gamification approaches incorporating competitive elements and scoring systems as implemented in platforms like Quizalize or competitive-themed educational games have been shown to increase task duration and students' active efforts in the classroom (Richter & Kickmeier-Rust, 2025; Thi Ngoc Anh et al., 2025).

The synthesis of Tables 1, 3, and 4 indicates that the effectiveness of instructional models in enhancing student engagement depends on the alignment between pedagogical approaches, physics topics, and targeted engagement dimensions. Project-Based Learning (PjBL) emerged as one of the most frequently implemented models and demonstrated strong potential in promoting cognitive and multidimensional engagement, particularly in conceptually complex topics such as motion, energy, and mechanics. Through authentic problem-solving, collaboration, and knowledge construction, PjBL encourages students to apply scientific concepts and develop deeper understanding (Wang et al., 2025). Meanwhile, contextual approaches such as ethnophysics further strengthen affective and social engagement by connecting physics concepts with students' cultural experiences, increasing perceived relevance, interest, and collaborative learning opportunities (Jufrida et al., 2025; Sunarti et al., 2025).

For abstract topics such as electricity and magnetism, technology-supported approaches, including AI, simulations, and AR/VR, appear particularly valuable in supporting cognitive and affective engagement by providing visualisation, interaction, and personalised learning experiences (Lieb & Goel, 2024; Masopust et al., 2025). Gamification-based approaches primarily contribute to behavioural and affective engagement through increased participation, motivation, and immediate feedback mechanisms (Richter & Kickmeier-Rust, 2025). Overall, the reviewed studies suggest that cognitive engagement is one of the most consistently targeted dimensions in physics learning interventions, reflecting the importance of conceptual reasoning and problem-solving in physics education; however, behavioural, affective, and social dimensions remain essential components that collectively contribute to meaningful and sustainable engagement (Fredricks et al., 2016).

However, these findings also reveal that certain interventions yield sub-optimal impacts if they are not supported by adequate infrastructure and proper instructional design. Although the use of Interactive Whiteboards (IWB) offers potential for innovation, its positive impact is often hindered by deep-seated traditional teaching cultures; consequently, the tool is frequently used merely as a passive projector without meaningfully increasing student interaction (Gregorcic et al., 2018). Additionally, the transition to e-learning during the pandemic highlighted that while digital access may be available, students' affective engagement can decline manifesting as frustration if the assigned tasks lack utility value or real-life context (Laumann et al., 2025). Interestingly, some studies found that the choice of communication platform in (Whatsapp) magnetism learning does not significantly influence student engagement (Liani et al., 2020), suggesting that the platform itself is secondary to the quality of the instructional tasks.

Furthermore, external factors such as unstable internet connectivity remain major barriers that negate the positive effects of gamified platforms, particularly in resource-limited regions (Thi Ngoc Anh et al., 2025). These findings align with the argument by Fredricks et al. (2016) that engagement is highly context-dependent; without adequate environmental and technical support, even sophisticated interventions may fail to trigger behavioral or emotional engagement. Therefore, the effectiveness of interventions in physics education depends not only on technological sophistication but also on the teacher's ability to manage classroom interactions and integrate technology into meaningful disciplinary practices (Peer & Kapon, 2025; Pianta et al., 2012).

4. CONCLUSION

This literature review concludes that pedagogical and technological interventions in physics education play a pivotal role in enhancing multiple dimensions of student engagement. The integration of digital simulations (PhET), gamified mobile learning (Quizalize), and Artificial Intelligence (AI)-supported learning environments has demonstrated potential in strengthening behavioural, cognitive, and affective engagement by providing more interactive and meaningful representations of abstract physics concepts.

Furthermore, active learning approaches, including Project-Based Learning (PjBL) and Flipped Learning, contribute to deeper psychological investment, conceptual understanding, and critical thinking development among students. However, the findings also indicate that technology should not be considered a standalone solution. The effectiveness of technological interventions depends on appropriate pedagogical design, teacher competence, learning context, and supporting infrastructure. Therefore, meaningful student engagement in physics learning requires a balanced integration between technological innovation, pedagogical strategies, culturally responsive approaches, and supportive learning environments.

Despite these contributions, this review has several limitations that should be considered when interpreting the findings. First, the literature search was limited to the Scopus database as the sole bibliographic source, which may have resulted in the exclusion of relevant studies that were not indexed within the selected database. Second, the identification of studies was dependent on the predefined search terms related to “student engagement” and “physics education”, meaning that relevant studies using alternative terminology, such as learning involvement, learner participation, motivation, or science engagement, may not have been captured. Third, the final synthesis was based on a relatively focused corpus of 23 studies, reflecting the specific scope of research on student engagement in physics education but potentially limiting the generalisability of the conclusions across different educational contexts. Future systematic reviews are encouraged to expand the bibliographic coverage, develop broader search strategies, and consider quantitative meta-analytic approaches when sufficient comparable evidence becomes available.

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