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# Foundation for the Development of a Digital Game-Assisted Problem-Based Learning Model for Mechanics Physics: A Student Needs Analysis Study

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**Abstract**

Physics learning, particularly abstract Mechanics concepts, often poses significant challenges for students. This preliminary research aims to identify specific challenges and student needs as a robust empirical foundation for the development of an innovative learning model. The study adopted a quantitative descriptive survey method, utilizing a validated structured questionnaire. Participants were 170 eleventh-grade students from two reference state high schools in North Lampung, Indonesia. Data were analyzed using descriptive statistics. Perceptual survey results indicated that the topic "Motion on an Inclined Plane" (M=3.58) was perceived as the most difficult, with the main hindering factors being "concepts are too abstract" (62.0%) and "too many formulas to memorize" (56.0%). Conversely, students showed very high interest in educational games (M=4.78) and interactive simulations (M=4.54). A nuanced gender analysis revealed that male students tended to show slightly higher interest and self-confidence in technology, while female students reported a greater appreciation for collaborative learning. Collectively, these findings conclude a strong student demand for the adoption of more visual and interactive learning methods. This provides a compelling pedagogical and empirical justification for the development of a Digital Game-Assisted Problem-Based Learning Model (PBL-GD). The implementation of this model must therefore consider an inclusive design to bridge the expectations and learning needs of all students, including gender-specific preferences.

**Keywords:** needs analysis, physics learning, mechanics, educational games, problem-based learning

## 1. Introduction

Physics, as a fundamental science, is often considered a challenging subject for students at the upper secondary level (Zulkiffli et al., 2024). Among its various topics, Mechanics serves as a core pillar, introducing essential concepts such as force, motion, and energy. A strong mastery of Mechanics is not only crucial for understanding advanced Physics topics but also for developing analytical thinking and problem-solving skills (Docktor & Mestre, 2014) However, various studies consistently report that students encounter significant difficulties in comprehending abstract and mathematical Mechanics concepts (Betari et al., 2021; Zou, 2020). These learning difficulties stem from a variety of factors, ranging from the abstract nature of the concepts demanding a high level of spatial visualization (Savinainen et al., 2013; Stieff et al., 2018), to learning approaches overly focused on mathematical manipulation without deep conceptual understanding (Phage, 2017; Wooten et al., 2018), and conventional methods that often fail to create an active and engaging learning environment (Hope et al., 2023).

To overcome these challenges, innovation in pedagogical approaches is imperative. The advancement of digital technology offers substantial opportunities to transform Physics instruction (Murtaza et al., 2022). One promising approach is Game-Based Learning (GBL), where educational games present Physics concepts through interactive simulations, allowing students to experiment in safe and engaging virtual environments (Klopfer & Squire, 2008; Papanastasiou et al., 2017). Supported by meta-analyses demonstrating its effectiveness in improving cognitive learning outcomes (Murtaza et al., 2022), GBL has been shown to increase engagement and motivation through elements of challenge, narrative, and instant feedback (Hussein et al., 2019; Ortiz et al., 2016). Simultaneously, to ensure deep conceptual understanding, a robust pedagogical framework such as Problem-Based Learning (PBL) is essential. PBL trains students to learn through authentic problem-solving, encouraging critical thinking, collaboration, and the

application of theoretical concepts, thereby making learning more meaningful (Loyens et al., 2023).

While previous research has extensively identified student difficulties in Mechanics (Nuriyah et al., 2018) and explored the potential of GBL separately (Cheng et al., 2015),critical intersections remain unexplored. Crucially, few studies have examined how specific game mechanics align with the distinct 'Physics Identity' of male and female students, particularly in the context of abstract Mechanics. Furthermore, comprehensive studies specifically mapping the needs of Indonesian students to inform the integrated design of Problem-Based Learning with Digital Games remain limited. Consequently, the majority of existing GBL studies tend to focus on *effectiveness* without a preceding in-depth *needs analysis*, while conventional PBL studies seldom fully leverage the interactive potential of digital games for abstract concept visualization. This gap is precisely what this study aims to address. Given that the design of effective learning interventions must be founded on accurate field-based needs analysis (Al-Samarraie & Saeed, 2018; Murtaza et al., 2022), this preliminary research serves as a crucial first step. To fulfill these needs, this study specifically aims to: (1) identify the Mechanics topics perceived as most difficult by students; (2) identify the primary factors hindering students in Physics learning; and (3) analyze students' perceptions and levels of interest in the application of problem-based learning models integrated with educational games.

## 2. Method

This study employed a quantitative approach with a descriptive survey design to collect initial data, serving as an empirical foundation for the design of learning interventions (Creswell, 2010). Participants in this study were 170 eleventh-grade students from two reference state high schools in North Lampung, Indonesia. The sample comprised 99 male students (58.2%) and 71 female students (41.8%). Participants were selected using purposive sampling. These schools were chosen based on several criteria: their status as reference schools in the district, a diverse student background, and the availability of adequate ICT facilities. These factors made them suitable for this preliminary study. However, it is important to acknowledge that the characteristics of reference schools such as students typically possessing above-average academic abilities and generally having more adequate access to technology might influence the observed profiles of student interest and technological self-efficacy. Therefore, while these findings offer valuable insights for similar contexts, their generalizability to non-reference schools, which may have different ICT access and student demographics, should be approached with caution. Furthermore, all participating students had already completed the Physics curriculum on Mechanics. The data collection procedure involved distributing a structured questionnaire to all eligible participants.

The primary instrument used in this study was a questionnaire whose quality was ensured through a series of procedures. Before use, the instrument was validated by two physics education experts to guarantee its content validity, ensuring that the questionnaire items were relevant and representative of the intended constructs. Subsequently, a pilot test was conducted on 20 students (outside the main sample), and the reliability analysis for the Likert scale section yielded a Cronbach's Alpha value of 0.89, indicating excellent internal consistency (Tavakol et al., 2011). The instrument was designed to capture data from three domains: perception of the difficulty level of Mechanics topics (a 5-point rating scale, where 1=Very Easy, 2=Easy, 3=Quite Difficult, 4=Difficult, 5=Very Difficult), identification of learning hindering factors (a multiple-response format, where students could select all relevant options), and perception of innovative learning (4 items on a 5-point Likert scale). All data collected from the 170 respondents were then analyzed using descriptive statistics, including the calculation of mean scores, frequency, and percentage. For the interpretation of topic difficulty categorization, mean scores of 1.00-2.49 were categorized as "Easy," 2.50-3.49 as "Quite Difficult," and 3.50-5.00 as "Difficult."

## 3. Results

This section presents the main findings obtained from the analysis of survey data from 170 students. The presentation of results is organized into three key areas to address the research objectives: (1) students' perception of difficulty levels regarding essential topics in Mechanics, (2) identification of the main factors perceived as hindering the learning process, and (3) analysis of students' perceptions and levels of interest in innovative learning solutions. Each sub-section will present general findings, which are then further elaborated with a comparative analysis by gender to provide a more comprehensive understanding.

### *3.1 Students' Difficulty Level on Mechanics Material*

The collective analysis of students' perceptions revealed a clear hierarchy of difficulties in Mechanics, where topics demanding strong spatial visualization and vector analysis skills presented the main challenges. These findings are supported by quantitative data showing "Motion on an Inclined Plane" as the topic perceived to be the most difficult with a mean score (M=3.58, "Difficult" category), followed by "Static & Kinetic Friction Force" (M=3.06, "Quite Difficult" category). Both topics were consistently reported as challenging by students, suggesting that the process of force decomposition is a fundamental conceptual barrier. Full details of the difficulty ratings for each topic are presented in Table 1.

Table 1. Difficulty Level of Mechanics Topics in General

| No | Material Topics | Mean (M) | Difficulty Category |
|---|---|---|---|
| 1 | Motion on the Inclined Plane | 3.58 | Difficult |
| 2 | Static & Kinetic Friction Force | 3.06 | Difficult |
| 3 | Newton's Law (∑F=ma) | 2.74 | Quite Difficult |
| 4 | Free-Object Diagram | 2.54 | Quite Difficult |

To deepen the study of material difficulty, further analysis was conducted by grouping the perceptions of male and female students. Figure 1 presents a comparison of difficulty level perceptions between male and female students. Visually, the graph highlights a consistent pattern: across all four topics tested, female students generally reported slightly higher levels of difficulty than male students. This perceptual difference was most observable in the topic "Motion on the Inclined Plane," where the mean score for female students (M=3.71) showed a discernible difference compared to male students (M=3.28).

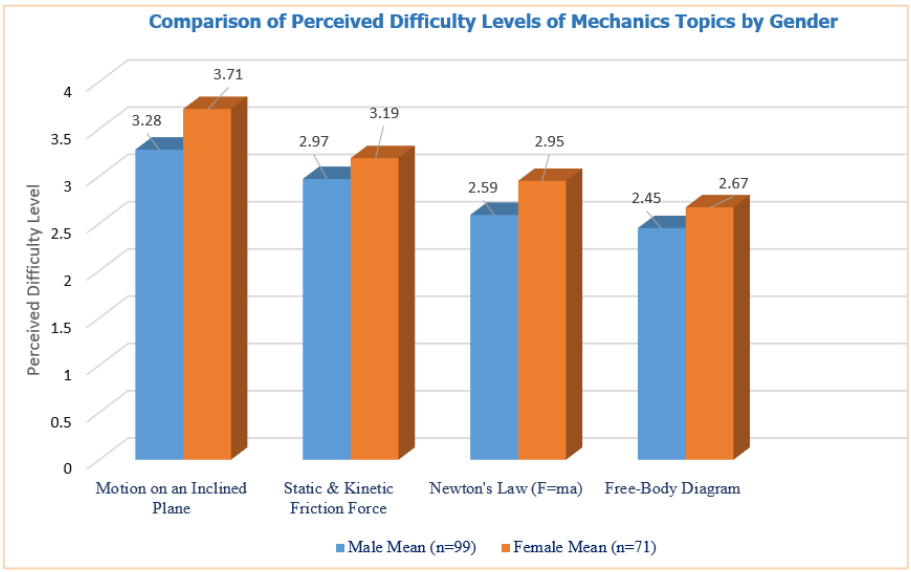



Figure 1. Perception of the difficulty level of Mechanics material by male and female students

*3.2 Factors Hindering Physics Learning*

This study also identified factors that hinder students in learning Physics. Based on the frequency analysis of the five provided options, intrinsic obstacles related to the material, such as abstract concepts and mathematical demands, were the dominant factors reported by students. Table 2 below presents the results of the questionnaire analysis from 170 students regarding factors hindering Physics learning.

Table 2. Factors Hindering Physics Learning

| No | Inhibition Factors | Frequency (f) | Percentage (%) |
|---|---|---|---|
| 1 | Concepts are too abstract and hard to imagine | 105 | 62.0% |
| 2 | Too many formulas to memorize | 95 | 56.0% |
| 3 | It's hard to connect theory to the real world | 65 | 38.0% |
| 4 | Lack of teaching aids or practicum | 51 | 30.0% |
| 5 | The way the teacher explains is less interesting | 17 | 10.0% |

To observe how perceptions of learning barriers vary between genders, Figure 2 presents a percentage comparison for each factor. The data revealed interesting differences in priorities: female students (47.6%) tended to report difficulties in 'connecting theory to the real world' more frequently than male students (31.0%). Conversely, male students (34.5%) more often highlighted 'lack of teaching aids or practicums' as a main obstacle compared to female students (23.8%).

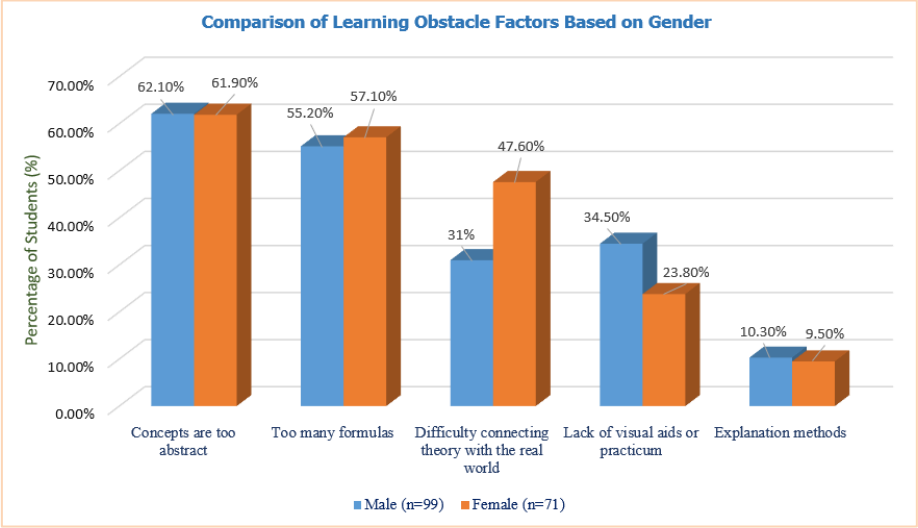



Figure 2. Factors hindering Mechanics learning according to male and female students

*3.3 Students' Perception of Innovative Learning*

The final part of this study explored students' perceptions of innovative learning solutions. Four statements were presented using a 5-point Likert scale, and the results indicated a very positive response. This suggests a strong readiness and desire from students to adopt more modern learning methods. Full details of students' perceptions of innovative learning are presented in Table 3 below.

Table 3. Students' Perception of Innovative Learning

| **No** | Statement | Mean (M) | Interpretation |
|---|---|---|---|
| 1. | I am interested if learning Physics uses educational games. | 4.78 | Very High |
| 2. | I am confident in using new applications/software on my computer or cellphone. | 4.66 | Very High |
| 3. | I would understand Physics better if it was explained with interactive simulations. | 4.54 | Very High |
| 4. | Group study (collaboration) helped me understand the material better. | 4.16 | High |

A detailed comparison by gender regarding innovative learning perceptions is presented in Figure 3. The data revealed that male students reported somewhat higher mean scores on most technology-centric items. The most notable differences were observed in 'Interest in using educational games' (Male M=4.97 vs. Female M=4.52) and 'Confident in using new applications/software' (Male M=4.83 vs. Female M=4.43). A smaller gap was seen in 'Understanding interactive simulations' (Male M=4.59 vs. Female M=4.48). Interestingly, this trend reversed for the collaborative item, 'Aided by group learning,' where female students (M=4.24) reported a slightly higher mean score than male students (M=4.10).

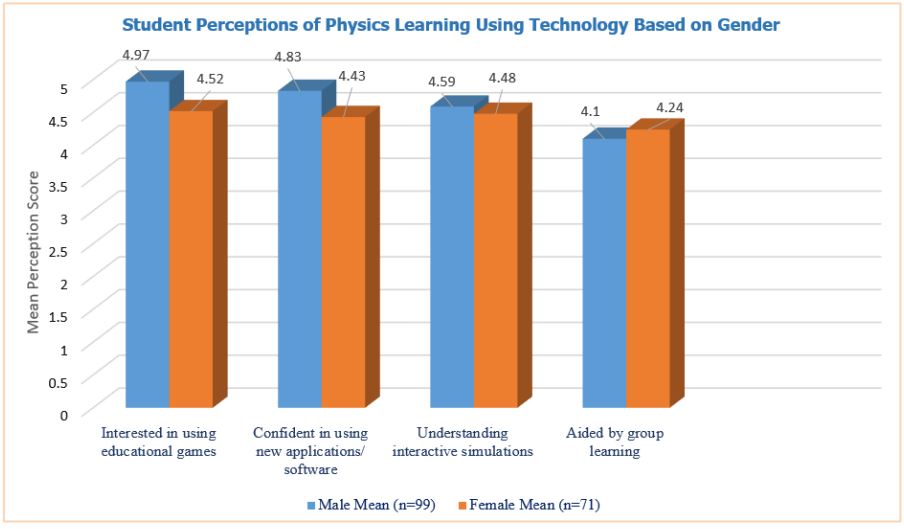



Figure 3. Comparison of Innovative Learning Perceptions by Gender

## 4. Discussion

The findings of this study offer deep, interrelated insights that form a coherent argument, providing a strong justification for the development of innovative learning models. The discussion of these key findings is organized into several sub-chapters to explore each aspect in more depth.

### *4.1 Conceptual Challenges and Cognitive Overload in Mechanics*

The identification of "Motion on an Inclined Plane" and "Frictional Force" as the most arduous topics (Table 1) corroborates established literature (Docktor & Mestre, 2014; Savinainen et al., 2013). However, this study highlights that the core difficulty extends beyond theoretical understanding. It lies in the simultaneous demand for abstract reasoning and spatial visualization. Students must not only grasp Newton's Laws but also perform vector decomposition on a tilted axis, a complex process that significantly spikes intrinsic cognitive load (Sweller, 2019). Critically, the gender disaggregation in Figure 1 adds a new layer of insight: female students reported a notably higher difficulty level (M=3.71) compared to their male counterparts (M=3.28). This disparity suggests that conventional, formula-centric teaching lacks the necessary support. As validated by recent research (Koskinen et al., 2023; Yang et al., 2024), interactive virtual visualizations and game-based scaffolds are particularly effective in enhancing students' spatial abilities and reducing cognitive gaps. Therefore, our findings explicitly validate the urgency for interactive simulations, serving not merely as engagement tools but as essential cognitive bridges to help students, particularly females, visualize these abstract forces concretely.

### *4.2 Intrinsic and Extrinsic Barriers in Learning*

The dominance of "too abstract concepts" (62.0%) and "too many formulas to memorize" (56.0%) as primary hindering factors (Table 2) confirms a fundamental problem in Physics education (Uwamahoro et al., 2021). These two factors are interconnected: when students struggle to grasp abstract concepts, they often resort to a compensatory strategy of memorizing formulas (rote learning) without deep understanding. This phenomenon suggests that meaningful learning has not been fully achieved (Grove & Bretz, 2012). Interestingly, the gender disaggregation in Figure 2 reveals a critical distinction. While male students (34.5%) tended to perceive the 'lack of teaching aids' as a significant barrier, female students (47.6%) more frequently reported difficulties 'connecting theory to the real world.' This finding aligns with the seminal work of Hazari et al. (2010), who reported that female students' physics identity is significantly correlated with real-world contextual connections, whereas male students often focus more on technical mastery. This comparison suggests that the learning barrier for female students is not merely the complexity of the material, but the lack of narrative relevance. Therefore, to be inclusive, the proposed PBL model must integrate strong real-world scenarios to cater to female students' preferences, while simultaneously offering virtual manipulation tools to satisfy male students' technical interests.

### *4.3 Student Readiness and Interest in Learning Innovation: A Gender Review*

The most significant finding of this study is the very high enthusiasm among students for innovative learning methods (Table 3). Their strong interest in educational games (M=4.78) and interactive simulations (M=4.54) clearly indicates a demand for learning approaches that are more engaging and relevant to their digital world. However, a gender-based review in Figure 3 revealed discernible differences. Male students reported higher levels of self-confidence in using new applications or software (M=4.83) compared to female students (M=4.43). Similarly, interest in educational games showed male students (M=4.97) exhibiting near-maximum enthusiasm compared to female students (M=4.52).

These differences, often referred to as a gender digital divide in the context of self-confidence and interest, have been reported in various studies (Broos & Roe, 2006; Mumporeze & Prieler, 2017). This does not necessarily imply lower technical abilities in female students but rather may be rooted in socio-cultural factors and prior experiences. Some studies suggest that differences in technology self-efficacy are often influenced by gender stereotypes and the types of digital activities engaged in outside of school. It is crucial to emphasize that despite the observed score differences, the average perception of female students remained within the "High" to "Very High" categories. This indicates that interest in learning innovation is universal and not limited to one gender. These findings, in fact, underscore the urgency for designing an inclusive Digital Game-Assisted Problem-Based Learning model. A successful design should effectively bridge these differences, for example, by providing adequate technical scaffolding, choosing narrative and game mechanics that appeal to diverse interests (not solely competition-oriented), and emphasizing collaborative aspects to build confidence and engagement for all students.

### *4.4 Bridge to Solutions: Conceptual Sketch of the Proposed PBL-GD Model*

Stemming from the findings that students face conceptual difficulties with abstract material but demonstrate high interest in technology, the proposed learning model sketch is designed to bridge these two aspects. This model integrates the Problem-Based Learning (PBL) framework with Digital Games as the primary medium to visualize concepts and trigger the inquiry process. The justification for the PBL framework is not only supported by students' positive perception of group study (M=4.16) but is more critically rooted in the study's primary findings: the fact that 'concepts are too abstract' (62.0%) and 'it's hard to connect theory to the real world' (38.0%) were dominant learning barriers provides a strong pedagogical rationale

for using PBL, a framework specifically designed to bridge this theory-practice gap through authentic problem-solving.

As an illustration of its implementation, digital games will be utilized as a problem trigger at the beginning of the learning cycle. Students will be exposed to virtual scenarios relevant to the most difficult identified topics, for example, adjusting the glide angle and friction force to launch an object onto a target or identifying forces on various inclined plane scenarios. In this scenario, the game not only demands problem-solving but also visualizes the real-time decomposition of force vectors, a process that is a major conceptual obstacle. The game can also provide instant feedback on the accuracy of force analysis and object trajectories. The syntax of the PBL-GD model can proceed as follows:

1. Student Orientation to the Problem (Game Trigger): The teacher introduces a challenging game scenario (e.g., "How can you make the sled reach point X at the end of an inclined plane with specific friction?"). The game allows students to engage in initial experimentation and directly experience the problem's complexity.
2. Organizing Students for Learning (Group Formation & Initial Discussion): Students in small groups discuss the problem presented by the game, formulate questions, and identify what they already know and what they need to learn. Collaborative features within the game (if available) or structured group discussions can facilitate this.
3. Guiding Individual and Group Investigation (Game Exploration & Data Gathering): Students utilize the game as a tool for investigation: varying parameters (angle, coefficient of friction, mass), observing the outcomes, and collecting both visual and numerical data. The game functions as a virtual laboratory, enabling empirical exploration of abstract concepts. The teacher provides technical and differentiated scaffolding during this phase, which is particularly important for students less confident with technology (especially females, based on our findings).
4. Developing and Presenting Artifacts (Analysis & Presentation): Based on the data and experiences from the game, students analyze their findings, formulate solutions, develop mathematical models (if relevant), and present them to the class. Critical discussion about the results obtained from game simulations and their connection to physics theory becomes the focus.
5. Analyzing and Evaluating the Problem-Solving Process (Reflection): Students and the teacher reflect on the learning process, the effectiveness of the solutions, and the conceptual understanding built, including how the game experience aided in visualizing abstract concepts.

This emphasis on collaborative aspects aligns with students' positive perceptions of group learning (M=4.16) and is designed to build confidence and engagement for all students, regardless of their initial comfort level with technology. Thus, the model transforms abstract difficulties into interactive challenges that can be explored visually and collaboratively, simultaneously bridging the gap between theory and practice.

*4.5 Implications, Limitations, and Suggestions*

Practically, these findings have direct implications for high school Physics educators to begin integrating digital tools such as simulations and educational games into classroom learning. For curriculum developers and policymakers, these results underscore the importance of designing inclusive interventions, considering the nuanced differences in perceptions of difficulties and learning preferences between male and female students. This can lead to the development of more specific material guidelines or teacher training programs.

However, this study has limitations that need to be acknowledged. The primary limitation lies in the sample, which was restricted to two reference state high schools. The characteristics of reference schools, such as the selection of students with above-average academic capabilities and potentially more adequate access to technology, may have influenced the findings. Specifically, these factors might have contributed to the exceptionally high mean scores for interest in educational games (M=4.78) and confidence in using new software (M=4.66). Therefore, the readiness level and technology self-efficacy of students in non-reference schools, which may have different ICT access and student demographics, might show different profiles. Furthermore, as a descriptive survey study, the findings regarding gender differences are perceptual and based on students' self-reports; the study did not employ inferential statistical tests to establish the statistical significance of these observed differences. The self-report nature of the instrument also has limitations in capturing actual behavior or objective levels of conceptual understanding.

Stemming from these findings and limitations, further research is recommended to focus on the model design and development phase. The top priority is to realize the Digital Game-Assisted Problem-Based Learning Model (PBL-GD) through a Design-Based Research (DBR) approach or the ADDIE model. This includes:

1. Prototype Design and Development: Creating specific Physics Mechanics educational game prototypes, integrated PBL learning modules, and comprehensive teacher guides.
2. Comprehensive Validation: Conducting validation by physics education experts, media/technology experts, and game design experts to ensure the pedagogical, content, and technical validity of the game prototypes and learning tools.

3. Small-Scale Trial (Pilot Study): Implementing an initial trial with a smaller student sample to evaluate usability, engagement, and gather iterative feedback for design refinement.
4. Development of Evaluation Instruments: Designing and validating more comprehensive instruments, not only for perceptions but also for objectively measuring cognitive learning outcomes (conceptual understanding) and affective outcomes (motivation, self-efficacy).

These steps are prerequisites before moving on to subsequent research, specifically quasi-experimental studies to empirically test the model's effectiveness on a more representative scale, including comparing results across different school types.

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**Data sharing statement**

No additional data are available.

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