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INTEGRATING STEM AND INTERACTIVE SIMULATIONS I NTO TEACHING THE "OSCILLATIONS" TOPIC: PERCEPTIONS, CHALLENGES, AND POTENTIAL IN UPPER SECONDARY PHYSICS

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Abstract

This study investigates high school students' learning interest in the Grade 11 Physics "Oscillations" topic and examines teachers' perceptions of integrating STEM education and simulation software to enhance engagement. A questionnaire with Likert-scale items and open-ended questions was administered in Dong Thap province to 164 students (126 Grade 11 and 38 Grade 12). Also, 23 experienced Physics teachers supplemented the collected data. Quantitative data were analyzed using descriptive statistics, while qualitative responses were analyzed to identify recurring themes. Results indicate that many students perceive oscillations as abstract, difficult to visualize, and weakly connected to real-life contexts, and teachers report that instruction still largely relies on lecture-based approaches. Both teachers and students expressed positive attitudes toward STEM-oriented learning activities and simulation tools (e.g., PhET) for improving conceptual visualization, learning motivation, and learner autonomy, consistent with constructivist and self-determination perspectives. However, a clear gap persists between positive perceptions and actual implementation of active learning (e.g., projects, model-making), primarily due to limitations in facilities (78.26% of teachers) and preparation time (56.52%). The survey findings contribute to supporting the development of feasible STEM-integrated and simulation-supported lessons for teaching "Oscillations" at the upper secondary level.

Keywords: *Current situation, grade 11 Physics, learning interest, oscillations, simulation software, STEM.*

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TÍCH HỢP STEM VÀ MÔ PHỎNG TƯƠNG TÁC TRONG DẠY HỌC CHỦ ĐỀ 'DAO ĐỘNG': NHẬN THỨC, THÁCH THỨC VÀ TIỀM NĂNG TRONG MÔN VẬT LÝ TRUNG HỌC PHỔ THÔNG

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Tóm tắt

Nghiên cứu này khảo sát hứng thú học tập của học sinh trung học phổ thông đối với chủ đề "Dao động" trong Vật lý lớp 11 và xem xét nhận thức của giáo viên về việc tích hợp giáo dục STEM và phần mềm mô phỏng nhằm tăng cường mức độ tham gia học tập. Bảng hỏi kết hợp các mục theo thang Likert và câu hỏi mở được triển khai tại tỉnh Đồng Tháp cho 164 học sinh (126 học sinh lớp 11 và 38 học sinh lớp 12) và 23 giáo viên Vật lý có kinh nghiệm, đồng thời bổ sung phỏng vấn. Dữ liệu định lượng được phân tích bằng thống kê mô tả, còn phản hồi định tính được phân tích để xác định các chủ đề lặp lại. Kết quả cho thấy nhiều học sinh nhìn nhận chủ đề dao động là trừu tượng, khó hình dung và ít gắn kết với bối cảnh thực tiễn, đồng thời việc giảng dạy của giáo viên vẫn chủ yếu dựa trên thuyết trình. Cả học sinh và giáo viên đều bày tỏ thái độ tích cực đối với các hoạt động học tập định hướng STEM và công cụ mô phỏng (ví dụ, PhET) trong việc cải thiện trực quan hóa khái niệm, động lực học tập và tính tự chủ của người học, phù hợp với các quan điểm kiến tạo và tự quyết. Tuy nhiên, vẫn tồn tại khoảng cách rõ rệt giữa nhận thức tích cực của giáo viên về dạy học STEM và mức độ triển khai thực tế các hình thức học tập tích cực (ví dụ, dự án, chế tạo mô hình), chủ yếu do hạn chế về cơ sở vật chất (78,26% giáo viên) và thời gian chuẩn bị (56,52%). Các kết quả khảo sát thu được góp phần hỗ trợ cho việc xây dựng các bài học tích hợp STEM có tính khả thi và hỗ trợ mô phỏng khi dạy học chủ đề dao động ở bậc trung học phổ thông.

Từ khóa: *Dao động, hứng thú học tập, phần mềm mô phỏng, STEM, thực trạng, Vật lí 11.*

1. Introduction

Physics is a foundational subject in general education, contributing to students' scientific thinking, logical reasoning, and problem-solving capacity (Ministry of Education and Training, 2018). In the Grade 11 curriculum, "Oscillations" as a core topic supports subsequent learning in mechanical waves and electromagnetic oscillations and is closely related to everyday phenomena such as pendulum motion and vibrations. However, students often perceive this topic as abstract and mathematically demanding, which can reduce their understanding, engagement, and overall learning outcomes.

Prior research has reported a decline in students' interest in Physics, frequently associated with lecture-centered instruction and limited opportunities for experiential learning and real-world connections (Osborne et al., 2003; Potvin & Hasni, 2014; Steidtmann, 2023). For oscillations in particular, students commonly struggle with key concepts such as simple harmonic motion, phase, frequency, and energy relationships, especially when learning resources provide insufficient visualization and interaction. These challenges suggest a need for instructional approaches that better support conceptual understanding and learning motivation.

STEM education has been widely promoted as an approach that integrates Science, Technology, Engineering, and Mathematics to address authentic problems while fostering creativity, collaboration, and the ability to apply interdisciplinary knowledge (Bybee, 2013). In Physics teaching, STEM-oriented tasks can engage learners through designing and constructing models or products that make abstract concepts more tangible. At the same time, simulation software (e.g., PhET, Crocodile Physics, Algodoo) supports visualization, hypothesis testing, and flexible parameter manipulation, enabling students to actively construct knowledge through interactive exploration (Wieman et al., 2008).

While numerous studies have examined STEM education and simulation tools in Physics instruction (Agyei, 2021; Dominguez et al., 2023; Quach et al., 2023; Nguyen et al., 2024), existing work has largely emphasized lesson design or instructional effectiveness. Little attention has been given to documenting students' learning interest at the level of specific curriculum topics and to examining the feasibility of combining STEM learning tasks with simulation tools for teaching those topics. The Grade 11 "Oscillations" topic is both conceptually demanding and rich in real-world applications-empirical evidence on students' engagement and the practicality of implementing a combined STEM and simulation approach, but it remains limited particularly in the local context.

Consequently, this study aims to (i) assess the current status of students' learning interest in the Grade 11 Physics topic "Oscillations" and (ii) explore students' and teachers' perceptions of the potential and feasibility of integrating STEM-oriented activities and simulation software to enhance engagement. The study addresses the following research questions:

(1) What is the current status of students' learning interest in the topic "Oscillations", and what are the reported practices of using STEM-oriented activities and simulation software in teaching this topic in high schools?

(*2) What are teachers' and students' perceptions of how STEM-oriented activities and simulation software influence learning interest in "Oscillations"?*

(*3) What barriers and enabling conditions affect implementation, and what recommendations can support feasible integration to enhance learning interest?*

2. Theoretical Overview and Research History

2.1. Theories of learning interest and motivation

2.1.1. Learning interest: concept and role

Learning interest is a psychological construct reflecting learners' positive orientation toward learning and is closely associated with engagement, commonly reflected in enjoyment, attention, active participation, persistence, and a tendency to re-engage with learning tasks (Nguyen, 2007). Leontiev (1978) describes interest as a selective attitude toward an object based on its personal significance and emotional attractiveness. In school contexts, interest is shaped by both learner-related factors (e.g., needs and prior experience) and instructional factors, especially content characteristics, teaching methods, real-life relevance, and learning supports such as technology and visualization (Osborne et al., 2003).

In this study, learning interest in "Oscillations" is operationalized via five indicators (Q1.1-Q1.5: in-class interest, self-initiated learning beyond class time, participation, enjoyment of problem solving, and application orientation), while three items (Q1.6-Q1.8: perceived difficulty, pressure from formulas/calculations, and perceived lack of understanding) are treated as barriers that may hinder interest. Accordingly, STEM-oriented tasks and interactive simulations are considered instructional supports that may strengthen interest indicators and mitigate these barriers.

2.1.2. Motivation foundations: Constructivism and SDT

Social Constructivism posits that learners actively construct knowledge through social interaction and the use of mediating tools in meaningful contexts; learning is strengthened when teachers and peers provide scaffolding within the Zone of Proximal Development (Vygotsky, 1978; Kim, 2001). For "Oscillations," STEM-oriented tasks (e.g., design-and-build models, context-based problem solving) and simulation-based exploration can serve as mediating tools that make abstract relationships observable and discussable, thereby supporting participation (Q1.3) and problem-solving engagement (Q1.4). Self-Determination Theory (SDT) explains sustained motivation via satisfaction of the three basic psychological needs: competence, autonomy, and relatedness (Deci & Ryan, 1985; Ryan & Deci, 2000). In this study's context, simulation tools can support competence by enabling parameter manipulation and immediate feedback, potentially reducing perceived difficulty (Q1.6) and improving understanding (Q1.8). STEM-oriented tasks can support autonomy through learner choice, planning, and iterative design (Q1.2), while collaborative learning can support relatedness (Q1.3). Combined, these theories provide a rationale for using STEM-oriented tasks and simulations to enhance learning interest (Q1.1-Q1.5) and mitigate barriers (Q1.6-Q1.8) in learning "Oscillations."

2.2. Theoretical basis of STEM-oriented tasks and simulation software (concise)

2.2.1. Definitions

STEM education can be defined as an interdisciplinary approach that integrates Science, Technology, Engineering, and Mathematics to address authentic problems by applying knowledge and skills across domains (Tsupros et al., 2009). In school practice, STEM is commonly implemented through design/project-oriented tasks that require learners to plan, test, and refine solutions, thereby enhancing practical relevance and higher-order thinking (Honey et al., 2014). Simulation software refers to computer-based applications that represent processes or phenomena in a virtual environment, enabling users to manipulate variables and observe outcomes. In Physics education, interactive simulations (e.g., PhET) are used to visualize abstract concepts, support inquiry, and allow safe, flexible experimentation.

2.2.2. Rationale for integration to enhance learning interest

Integrating STEM-oriented tasks with simulation software is theoretically consistent

with Social Constructivism and Self-Determination Theory (SDT) and provides a rationale for enhancing learning interest in "Oscillations." From an SDT perspective, STEM tasks can support autonomy through learner choice in planning and design, while simulations support competence by providing immediate feedback when students vary parameters (e.g., mass, amplitude, frequency) and observe changes in motion; together, these conditions are expected to strengthen motivation and persistence (Ryan & Deci, 2000; Wieman & Perkins, 2005). Integration also increases perceived relevance by linking oscillations to practical contexts (e.g., vibration control, musical instruments), while simulations make time-varying quantities and relationships easier to interpret, reducing the sense of abstraction (Zacharia & Olympiou, 2011). From a constructivist view, collaborative STEM work and simulation-based inquiry promote discussion, scaffolding, and shared meaning-making, thereby supporting relatedness and knowledge construction in a conceptually difficult topic (Vygotsky, 1978; Pang et al., 2024). Accordingly, the integrated use of STEM-oriented tasks and interactive simulations is expected to increase students' reported interest and engagement (in-class interest, participation, self-initiated learning, problem-solving enjoyment, and application orientation) and to mitigate common barriers such as perceived difficulty, pressure, and lack of understanding in learning oscillations.

2.3. Literature review

2.3.1. Learning interest in Physics and "Oscillations"

Prior studies suggest that the abstract and conceptually demanding nature of Physics can contribute to reduced student interest (Duit & Treagust, 2012). For oscillations, research has documented students' difficulties in conceptualizing key ideas such as phase and frequency, which are challenging to visualize without appropriate representations (Beichner, 1994). In Vietnam, studies examining high school students' interest in Physics have also reported generally low levels of interest, often attributed to limited real-life relevance in lesson content and the prevalence of transmission-based instruction that constrains student activeness (Hai, 2023; Ngo, 2024).

2.3.2. STEM and simulation in Physics teaching

Addressing these challenges, STEM-oriented tasks and simulation software have been increasingly discussed in Physics education. STEM approaches, commonly implemented through design/project-oriented activities, are reported to support active learning and learner engagement (Honey et al., 2014). Empirical work has noted improvements in students' interest when participating in STEM activities (Chiu et al., 2015). Interactive simulations, particularly PhET, have been widely reported to support conceptual learning by enabling visualization and inquiry through parameter manipulation (Wieman & Perkins, 2008). In Vietnam, technology-supported teaching (e.g., using Desmos for oscillations- and waves-related concepts) has been reported to increase students' learning interest compared to traditional approaches (Phong, 2024).

2.3.3. Research gaps

While the potential of of STEM-oriented tasks and simulations, two gaps remain relevant to Grade 11 "Oscillations" topic.

(i) Existing Vietnamese studies on learning interest in Physics often address the subject broadly, while topic-specific evidence on students' learning interest in "Oscillations"- a highly abstract topic with distinctive conceptual demands-remains limited.

(ii) While STEM and simulations have been studied individually, empirical evidence about the feasibility of integrating both approaches for teaching "Oscillations," including

stakeholder perceptions and practical barriers to implementation in high schools, is still insufficient.

To address these gaps, this study surveys the current state of students' learning interest in "Oscillations" and explores teachers' and students' perceptions of the feasibility and potential of integrating STEM-oriented tasks and simulation software in teaching this topic.

3. Data and Research Methods

This study used a survey design with a combination of closed-ended items (multiple-choice and Likert-scale questions) and open-ended questions. Participants included several high schools in Dong Thap province and included two groups: (i) 164 students (126 Grade 11 and 38 Grade 12) from multiple classes to enhance representativeness, and (ii) 23 experienced high school Physics teachers.

The student questionnaire examined (a) students' learning interest in the Grade 11 "Oscillations" topic and (b) their perceptions of the potential use of STEM-oriented tasks and simulation software in learning. The teacher questionnaire focused on current teaching practices for "Oscillations", students' commonly reported difficulties, and teachers' perceptions of the feasibility of integrating STEM-oriented tasks and simulation tools to enhance learning interest. In addition, interviews were conducted to clarify and elaborate on key survey findings.

Quantitative data derived from the Likert-scale items were processed and analyzed using SPSS software to compute descriptive statistics. Thereby, mean scores (M) were utilized to evaluate the perceived levels (ranging from low to high) of the investigated characteristics and instructional practices. Meanwhile, standard deviations (SD) were calculated to examine the variance and degree of differentiation among the respondents, indicating how much the individual participants' opinions varied from the average. Regarding the qualitative data obtained from the open-ended questionnaire sections and interview transcripts, thematic analysis was used to identify recurring themes, pedagogical patterns, and underlying explanatory factors.

4. Results and Discussion

4.1. Current state of students' learning interest in "Oscillations"

Table 1 shows that a moderate proportion of students reported being interested in learning "Oscillations" (Agree+Strongly agree = 56.10%, Q1.1), yet fewer reported self-initiated learning beyond class time (Agree+Strongly agree = 54.88%, Q1.2). This pattern suggests that students' interest may not consistently translate into sustained self-directed engagement. At the same time, perceived learning barriers were prevalent: 59.88% agreed/strongly agreed that the topic is difficult and discouraging (Q1.6), and 60.37% reported feeling pressured by formulas and calculation exercises (Q1.7). These results are consistent with prior literature describing oscillations as conceptually abstract and difficult to visualize (e.g., phase and frequency), which can hinder understanding and interest (Beichner, 1994; Duit & Treagust, 2012).

Descriptive statistics further supported these findings. Mean scores ranged from 3.10 to 3.98, indicating moderate levels of both learning interest and perceived challenges. The highest mean was observed for the perceived importance of learning oscillations (Q1.5: $M = 3.98$, $SD = 0.94$), while items related to learning difficulties received mean scores well above the scale midpoint (Q1.6–Q1.8: $M = 3.10$–3.16). Standard deviations ranged from 0.88 to 1.02, suggesting moderate variability and a relatively consistent pattern of responses among students.

Table 1. Students' interest level in the "Oscillations" topic

No.	Question	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
Q1.1	Students feel interested when learning lessons about oscillations (simple harmonic motion, spring pendulum, simple pendulum, etc.).	07 (4.27%)	07 (4.27%)	58 (35.37%)	57 (34.76%)	35 (21.34%)
Q1.2	Students actively seek additional information and materials about oscillations outside of the textbook/class time.	03 (1.83%)	07 (4.27%)	64 (39.02%)	62 (37.80%)	28 (17.07%)
Q1.3	Students like to ask questions and participate in discussions during lessons about oscillations.	03 (1.83%)	7 (4.27%)	74 (45.12%)	52 (31.71%)	28 (17.07%)
Q1.4	Students enjoy solving exercises or problems related to oscillations.	6 (3.66%)	3 (1.83%)	73 (44.51%)	50 (30.49%)	32 (19.51%)
Q1.5	Students desire to learn about the practical applications of oscillations in life (e.g., electronic devices, musical instruments, medicine, etc.).	5 (3.05%)	1 (0.61%)	41 (25.00%)	62 (37.80%)	55 (33.54%)
Q1.6	Students find the topic of oscillations difficult to understand and easily discouraging.	8 (4.88%)	25 (15.24%)	82 (50.00%)	33 (20.12%)	16 (9.76%)
Q1.7	Students feel pressured when learning the formulas and calculation exercises of the Oscillation topic.	12 (7.32%)	19 (11.59%)	81 (49.39%)	34 (20.73%)	18 (10.98%)
Q1.8	Students frequently fail to understand the lesson when studying the Oscillation topic.	9 (5.49%)	34 (20.73%)	69 (42.07%)	36 (21.95%)	16 (9.76%)

Table 2 indicates limited exposure to active approaches. Only 17.68% of students reported participating "often" or "very often" in STEM design/manufacturing activities related to oscillations (Q2.1), while 46.95% reported "never" or "rarely". Similarly, only 21.34% reported that teachers "often" or "very often" used simulation software for teaching oscillations (Q2.2), whereas 43.29% reported "never" or "rarely". These findings suggest that students have relatively few opportunities to experience learning conditions that support

competence and autonomy, which may contribute to the perceived difficulty and limited autonomous learning reported in Table 1.

Descriptive statistics were consistent with these results. Mean scores were below the scale midpoint for both participation in STEM design/manufacturing activities (Q2.1: M = 2.51, SD = 1.14) and teachers' use of simulation software (Q2.2: M = 2.65, SD = 1.14), confirming a relatively infrequent exposure to these active learning approaches. The standard deviations (SD = 1.14) suggest moderate variation in students' experiences, though overall responses consistently skewed toward low-to-moderate frequencies.

Table 2. Frequency of use of STEM products and simulation software in learning the the "Oscillations" topic

No.	Question	Never (%)	Rarely (%)	Occasionally (%)	Often (%)	Very often (%)
Q2.1	I participate in design and manufacturing activities for STEM products related to oscillations (e.g., making a pendulum, a wave-generating device, etc.).	41 (25.00%)	36 (21.95%)	58 (35.37%)	21 (12.80%)	08 (4.88%)
Q2.2	Does your teacher use simulation software (e.g., PhET Interactive Simulations, Crocodile Physics, Algodoo, GeoGebra, etc.) to help you understand lessons about oscillations?	32 (19.51%)	39 (23.78%)	58 (35.37%)	25 (15.24%)	10 (6.10%)

In contrast, Table 3 shows strong perceived value of STEM and simulation integration. Students largely agreed that these approaches support visualization and understanding (Q3.1–Q3.2), increase interest through hands-on creation (Q3.3), make lessons more engaging (Q3.4), and improve confidence in understanding (Q3.5). From a Self-Determination Theory perspective, these perceptions align with potential support for competence (visualization and feedback), autonomy (student-led design/inquiry), and relatedness (collaborative work), which are conditions for enhancing intrinsic motivation (Deci & Ryan, 1985; Ryan & Deci, 2000). From a social constructivist perspective, STEM tasks and simulation-based inquiry may function as mediating tools that promote discussion, scaffolding, and active knowledge construction in an abstract topic. Taken together, the combination of limited actual exposure (Tables 1-2) and strong perceived value (Table 3) points to an implementation gap: students recognize the potential benefits of STEM-oriented tasks and simulations, but these approaches are not yet systematically integrated into everyday instruction on oscillations.

Descriptive statistics were consistent with these perceptions. Mean scores ranged from 3.82 to 3.91 (SD = 0.89–0.98), indicating generally positive evaluations of STEM-oriented

activities and simulation use in learning oscillations. The standard deviations, remaining below 1.00, demonstrate low-to-moderate variability and reflect a high level of consensus among students regarding the educational value of these approaches.

Table 3. Assessment of the role of STEM products and simulation software in enhancing students' learning interest in the "Oscillations" topic

No.	Question	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
Q3.1	STEM products help me visualize abstract oscillation concepts more clearly.	07 (4.27%)	01 (0.61%)	45 (27.44%)	73 (44.51%)	38 (23.17%)
Q3.2	Simulation software helps me easily observe, experiment, and gain a deeper understanding of oscillation phenomena.	07 (4.27%)	0 (0.00%)	39 (23.78%)	75 (45.73%)	43 (26.22%)
Q3.3	The hands-on creation of STEM products makes me feel more interested and want to learn more about oscillations.	03 (1.83%)	02 (1.22%)	49 (29.88%)	63 (38.41%)	47 (28.66%)
Q3.4	Learning through STEM products and simulation software makes Physics lessons more engaging and less boring.	07 (4.27%)	02 (1.22%)	42 (25.61%)	68 (41.46%)	45 (27.44%)
Q3.5	I feel that I understand the lesson faster when learning through STEM activities and simulation software.	04 (2.44%)	02 (1.22%)	52 (31.71%)	63 (38.41%)	43 (26.22%)
Q3.6	I desire to learn Physics more frequently through a method that combines STEM and simulation software.	05 (3.05%)	01 (0.61%)	45 (27.44%)	68 (41.46%)	45 (25.44%)

4.2. Current status of applying STEM products and simulation software

4.2.1. Student-reported implementation

Figure 1 indicates that technology use in teaching "Oscillations" is reported more frequently for illustrative media than for student-centered active learning. A relatively large proportion of students reported that teachers' use of online videos/animations to illustrate oscillation phenomena was most commonly reported as frequent (39.63%; item Q1F1), whereas fewer students reported frequent student participation in STEM design-and-making activities related to oscillations (17.68%; item Q5F1). Students also reported that assignment of STEM-related learning

projects occurred mainly at an occasional level (32.93%; item Q2F1). Regarding simulations, teachers' use of simulation software in instruction was most commonly reported at the "occasionally" level (35.37%; item Q4F1), while frequent student self-use of simulations for exploration was reported less often (14.64%; item Q3F1). Overall, the pattern suggests that current practice may still emphasize teacher-led illustration rather than sustained student-led inquiry or design activities.

Descriptive statistics were consistent with these findings. Mean scores ranged from 2.36 to 3.35 (SD = 1.06-1.20), indicating a generally low-to-moderate implementation of STEM-oriented and simulation-based activities. The highest mean was observed for teachers' use of videos and animations to illustrate oscillation phenomena (Q1F1: M = 3.35, SD = 1.06), whereas assigning STEM-related learning projects received the lowest rating (Q2F1: M = 2.36, SD = 1.20). Standard deviations around 1.00 suggest moderate variability in students' reported experiences, reflecting diverse classroom practices across different schools or classes.

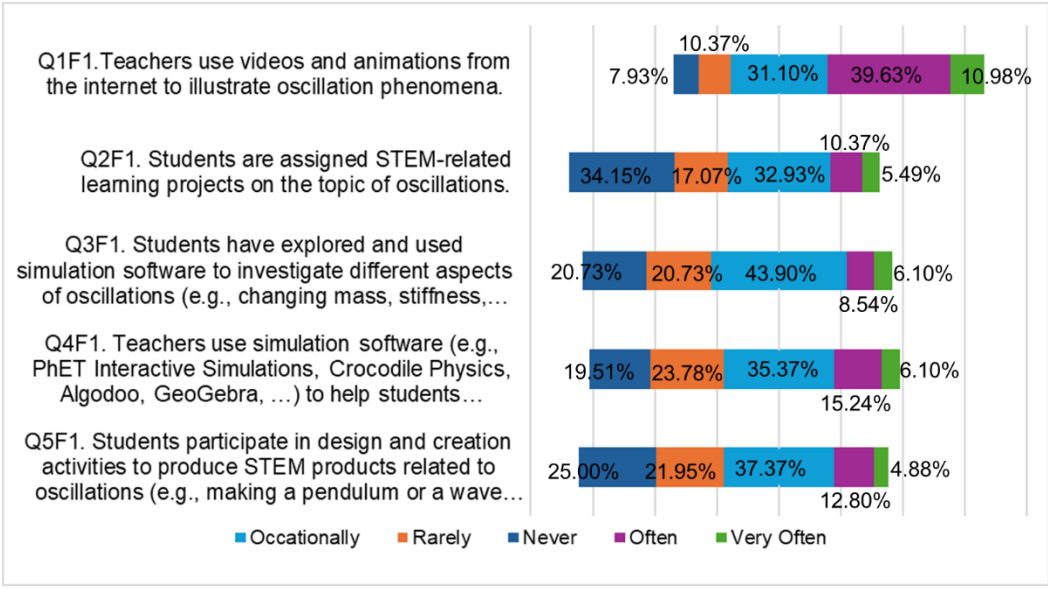

Figure 1. Student survey results on the use of STEM activities and simulation software (the "Oscillations" topic)

4.2.2. Perceived value and the implementation gap

Despite limited reported exposure, Table 3 shows strong student endorsement of the potential benefits of STEM-oriented tasks and simulations. A substantial proportion agreed/strongly agreed that STEM activities help visualize abstract concepts (Q3.1: 67.68%) and that simulations support observation, experimentation, and deeper understanding (Q3.2: 71.95%). Students also reported motivational benefits: increased interest through hands-on creation (Q3.3: 67.07%) and lessons becoming more engaging (Q3.4: 68.90%). Perceived learning efficiency was also endorsed, with 64.63% reporting faster understanding (Q3.5), and 68.90% expressing a desire to learn Physics more frequently through the combined approach (Q3.6). Taken together, these results indicate a clear implementation gap between students' strong perceived value/demand (Table 3) and the relatively low frequency of reported access in practice (Figure 1), which provides a practical basis for proposing feasible integration strategies in teaching "Oscillations". These perceptions are consistent with SDT and social constructivism, as simulations may support competence via feedback/visualization, while STEM-oriented tasks may support autonomy and relatedness through design choice and collaboration.

4.2.3. Teacher-reported implementation

Teacher responses similarly indicate that innovative approaches are highly valued but not yet used systematically. Regarding teacher guidance for student STEM product design and creation (Q4.1), only 17.39% (n = 4 out of 23) reported using this frequently or very frequently, while 82.61% (n=19) selected "occasionally" or below. Assignment of STEM learning projects related to oscillations (Q4.4) was also limited, with only 17.39% (n = 4) reporting frequent utilization and the majority (69.57%, n = 16) selecting "occasionally". These results suggest that constructivist, project-based STEM activities have not yet been fully integrated into routine instruction, likely due to requirements for substantial preparation time, materials, and classroom management. By contrast, teacher use of simulation software to visualize oscillation phenomena (Q4.2) was higher, with 47.83% (n = 11) reporting frequent use and the remaining 52.17% (n = 12) reporting "occasionally". In this context, 56.52% (n = 13) of teachers indicated that they frequently encourage students to independently explore and change parameters using simulations (Q4.3), while 43.48% (n = 10) selected "occasionally". These patterns suggest that, relative to STEM product design, simulations are more readily adopted as a tool for supporting students' self-directed exploration and perceived competence. Additionally, almost all teachers reported high-frequency use of online videos and animations to illustrate oscillation phenomena (Q4.5: 95.66%, n = 22 frequently or very frequently). Looked at broadly, teacher data indicates a clear preference for illustrative digital resources (videos, teacher-led simulations) over time- and resource-intensive STEM project work. This reinforces the implementation gap identified from the student perspective: technology is widely used to support explanation, but constructivist, autonomy-focused activities-especially STEM design projects-are less common, highlighting the need for targeted support in training and resources to expand active learning practices in teaching "Oscillations."

Table 4. Current use of STEM activities and simulation software I n teaching the "Oscillations" topic

No.	Question	Never (%)	Rarely (%)	Sometimes (%)	Often (%)	Very often (%)
Q4.1	Teacher guides students to design and create simple STEM products related to oscillations (e.g., simple pendulum, spring pendulum, wave model, etc.).	0 (0.00%)	02 (8.70%)	17 (73.91%)	03 (13.04%)	01 (4.35%%)
Q4.2	Teacher uses simulation software (e.g., PhET Interactive Simulations, Crocodile Physics, Algodoo, GeoGebra, etc.) to visualize oscillation phenomena.	0 (0.00%)	0 (0.00%)	12 (52.17%)	09 (39.13%)	02 (8.70%)
Q4.3	Teacher encourages students to independently research and use simulation software to explore and change parameters in oscillation problems.	0 (0.00%)	0 (0.00%)	10 (43.48%)	13 (56.52%)	0 (0.00%)

No.	Question	Never (%)	Rarely (%)	Sometimes (%)	Often (%)	Very often (%)
Q4.4	Teacher assigns STEM learning projects to students related to the Oscillation topic.	01 (4.35%)	04 (17.39%)	15 (65.22%)	02 (8.70%)	01 (4.35%)
Q4.5	Teacher uses videos and animated images from the internet to illustrate oscillation phenomena.	0 (0.00%)	0 (0.00%)	01 (4.35%)	11 (47.83%)	11 (47.83%)

Descriptive statistics were consistent with these findings. Mean scores for STEM project and simulation-related activities ranged from moderate to low (Q4.1: $M = 2.91$, $SD = 0.51$; Q4.4: $M = 3.04$, $SD = 0.64$; Q4.2: $M = 3.48$, $SD = 0.51$; Q4.3: $M = 3.57$, $SD = 0.51$), indicating occasional to moderate implementation. In contrast, the use of videos and animations received the highest rating (Q4.5: $M = 4.43$, $SD = 0.59$). Standard deviations for Q4.1–Q4.4 remained low (ranging from 0.51 to 0.64), suggesting highly consistent teacher responses. These results further support the conclusion that illustrative digital resources are adopted more frequently than interactive, project-based STEM activities.

4.3. Teacher perceptions and implementation barriers

4.3.1. Teacher perceptions of STEM and simulation integration

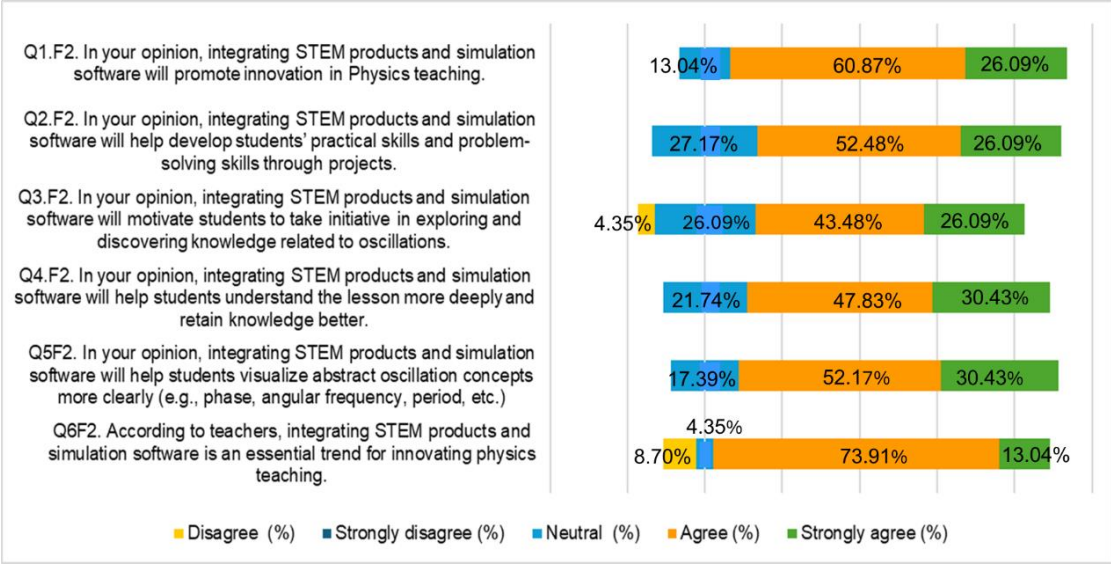

Figure 2. Teachers' survey results on the perceived role of integrating STEM products and simulation software in teaching the "Oscillations" topic

Despite limited reported use, teachers expressed positive perceptions about the role of STEM-oriented tasks and simulations. As shown in Figure 2, large proportions (n = 19 out of 23) agreed that these approaches help students visualize abstract concepts (Q5F2: 82.60%, $M = 4.13$, $SD = 0.68$), increase learning interest and motivation (Q4.F2: 78.26%, n = 18, $M = 4.09$, $SD = 0.71$), promote self-directed learning and exploratory thinking (Q3.F2: 69.57%, n =16, $M = 3.91$, $SD = 0.83$), and develop problem-solving skills (Q2.F2: 78.57%, n =18, $M = 3.99$, $SD = 0.69$). Moreover, 86.95% of teachers (n = 20 out of 23) (Q6F2, $M = 3.91$, $SD = 0.75$) agreed that

integration of STEM and simulations is a necessary trend for innovating Physics education. These results indicate that teachers recognize the value of these approaches not only for knowledge transmission but also for supporting learner competence and autonomy, which aligns with the theoretical rationale presented earlier. However, the contrast between these positive perceptions and the lower reported implementation rates (Table 4) suggests that practical barriers may be limiting teachers' capacity to translate awareness into routine practice.

4.3.2. Reported implementation barriers

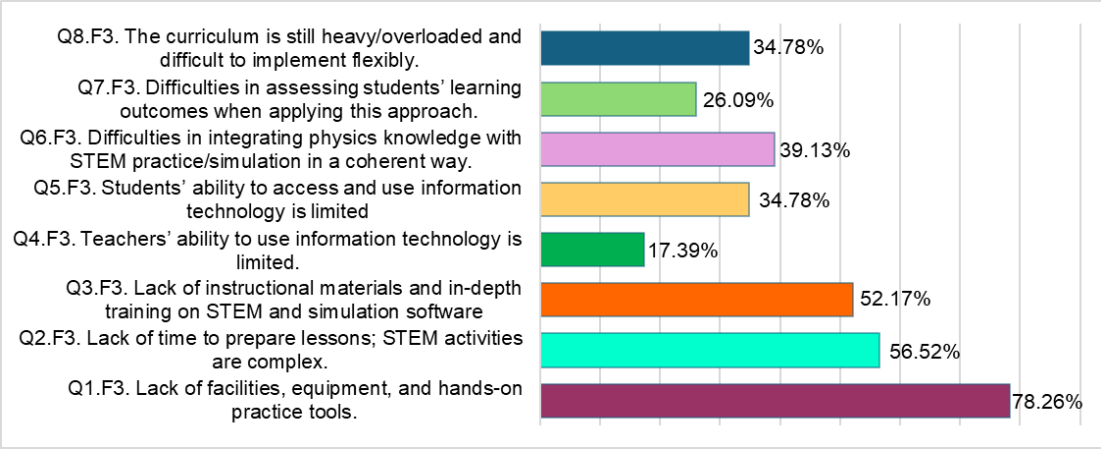

Figure 3. Barriers encountered by teachers when integrating STEM products and simulation software in teaching the "Oscillations" topic

Figure 3 identifies multiple barriers that constrain teachers' implementation of STEM-oriented tasks and simulation software in teaching "Oscillations". The most frequently reported obstacle was the lack of facilities, equipment, and hands-on tools (Q1.F3: 78.26%, n = 18 out of 23), followed by insufficient time to prepare lessons and complex STEM activities (Q2.F3: 56.52%, n =13) and a lack of guidance materials and in-depth training on STEM and simulation software (Q3.F3: 52.17%, n = 12). Pedagogical and curricular barriers were also notable, including difficulty in integrating theoretical knowledge with STEM practice/simulation activities (Q6.F3: 39.13%, n = 9) and a heavy curriculum that limits flexibility (Q8.F3: 34.78%, n = 8). In addition, teachers reported student-related constraints such as limited students' ICT access and skills (Q5.F3: 34.78%, n = 8) and challenges in assessing learning outcomes under these approaches (Q7.F3: 26.09%, n = 6), while limited teachers' ICT skills were reported less frequently (Q4.F3: 17.39%, n = 4). Overall, these barriers explain why teachers may favor low-preparation illustrative resources over resource-intensive STEM projects, contributing to the gap between positive perceptions and modest classroom implementation.

4.4. The role of STEM-oriented tasks and simulation software in enhancing learning interest

Student survey evidence (Table 3). Student responses indicate strong perceived benefits of STEM-oriented tasks and simulation software for learning "Oscillations." Specifically, 67.68% agreed/strongly agreed that STEM activities help visualize abstract concepts (Q3.1), and 71.95% agreed/strongly agreed that simulations support observation, experimentation, and deeper understanding (Q3.2). Motivational outcomes were also endorsed: 67.07% reported increased interest through hands-on creation (Q3.3) and 66.90% perceived lessons as more engaging (Q3.4). In addition, 64.63% reported faster understanding (Q3.5), and a high proportion expressed a desire to learn Physics more frequently through the combined approach (Q3.6). Overall, students'

perceptions suggest that these approaches may address key barriers of abstractness and low engagement by improving visualization, interaction, and perceived relevance.

From Teacher survey evidence (Figure 2), teachers similarly expressed highly positive perceptions of these pedagogical approaches. A large proportion (n = 19 out of 23) agreed that STEM and simulations help students visualize abstract concepts more clearly (Q5.F2: 82.60%) and make oscillation lessons more engaging and motivating (Q4.F2: 78.26%). Teachers also valued broader learning outcomes, including promoting self-directed learning and exploratory thinking (Q3.F2: 69.57%, n = 16) and developing problem-solving skills (Q2.F2: 78.57%, n =18). The strong convergence between student and teacher perceptions further validates the pedagogical feasibility and educational value of integrating STEM-oriented tasks and simulations for this specific topic.

Theoretical interpretation and implications. These perceived benefits are consistent with Self-Determination Theory and social constructivism: simulations can support competence through immediate feedback and manipulable representations, while STEM-oriented tasks can support autonomy and relatedness through learner choice and collaboration. However, when interpreted alongside the low reported frequency of implementation, the findings point to an implementation gap. This gap provides a basis for recommendations that focus on feasible integration under constraints (e.g., simplified STEM tasks, ready-to-use simulation guides, and targeted support for facilities and teacher preparation time).

5. Conclusion

This study examined Grade 11 students' learning interest in **the "Oscillations" topic** and explored the perceived role and feasibility of integrating STEM-oriented tasks and simulation software in teaching this topic. The findings indicate that while students show a moderate level of interest, many of them still experience substantial barriers related to perceived difficulty, pressure from formulas, and lack of understanding. At the same time, both students and teachers report strongly positive perceptions of STEM-oriented activities and simulations for supporting conceptual understanding, increasing engagement, and promoting more active, self-directed learning, in ways that are consistent with Social Constructivism and Self-Determination Theory.

However, the results also reveal an implementation gap: active learning approaches such as STEM design projects and systematic use of simulations are reported as being used infrequently, despite high perceived value. Key barriers identified by teachers include limited facilities and equipment (78.26%) and insufficient time to prepare complex STEM activities and lesson plans (56.52%), together with needs for more concrete guidance and training. Addressing this gap requires targeted support, including investment in basic, easy-to-use resources and focused professional development on designing feasible STEM-simulation-integrated activities, so that teachers can gradually and sustainably shift from mainly illustrative technology use to more student-centered, inquiry-based instruction in teaching "Oscillations".

Several limitations of this study should be noted. First, the localized sample and the reliance on self-reported survey data limit the generalizability of the findings. Second, since the survey instruments were adapted specifically for the local physics curriculum, their structural properties require further validation with larger samples. To address these limitations, future research should expand the sample size across different geographical regions and incorporate qualitative methods, such as classroom observations. Additionally, experimental or quasi-experimental designs are needed to evaluate the actual impact of integrated STEM-simulation interventions on student learning outcomes and motivation over time.

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References

Agyei, E. D., & Agyei, D. D. (2021). Enhancing students' learning of physics concepts with simulation as an instructional ICT tool. *European Journal of Interactive Multimedia and Education, 2*(2), e02111. https://doi.org/10.30935/ejimed/11259

Beichner, R. J. (1994). Testing student interpretation of kinematics graphs. *American Journal of Physics, 62*(8), 750–762. https://doi.org/10.1119/1.17449

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association.

Chiu, M. H., Wang, T.I., & Tsai, C.-C. (2015). Effects of integrating virtual experiments into a science curriculum on learning achievement and motivation. *Journal of Science Education and Technology, 24*(5), 620–632. https://doi.org/10.1007/s10956-015-9554-5

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Springer. https://doi.org/10.1007/978-1-4899-2271-7

Dominguez, A., De la Garza, J., Quezada-Espinoza, M., & Zavala, G. (2023). Integration of physics and mathematics in STEM education: Use of modeling. *Education Sciences, 14*(1), 20. https://doi.org/10.3390/educsci14010020

Duit, R., & Treagust, D. F. (2012). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 34*(8), 1197–1218. https://doi.org/10.1080/09500693.2011.645131

Hai, N. N., Le, H. T., Thanh, H. N., & Le, V. G. (2023). Perception and behavior of high school students towards developing problem solving and creativity skills to solve physics assignments. *International Journal of Education and Practice, 11*(3), 692–701. https://doi.org/10.18488/61.v11i3.3479

Honey, M., Pearson, G., & Schweingruber, A. (Eds.). (2014). *STEM integration in K–12 education: Status, prospects, and an agenda for research*. National Academies Press. https://doi.org/10.17226/18612

Kim, B. (2001). Social constructivism. *Emerging perspectives on learning, teaching, and technology*, *1*(1), 16. https://scispace.com/pdf/from-emerging-perspectives-on-learning-teaching-and-1a8az28iet.pdf

Leontiev, A. N. (1978). *Activity, consciousness, and personality*. Prentice-Hall.

Ministry of Education and Training. (2018). *General education curriculum: Physics* (Promulgated with Circular No. 32/2018/TT-BGDĐT dated December 26, 2018). Vietnam Education Publishing House.

Ngo, H. (2024). Exploring the factors that influence the love of physics: A case study at Thai Nguyen High School for the gifted. *GPH-International Journal of Educational Research, 7*(7), 98–109. https://doi.org/10.5281/zenodo.13347226

Nguyen, L., Trinh, Q., & Nguyen, P. (2024). Enhancing science education in remote regions: The impact of PhET simulations on teaching electricity in Northern Vietnam. *GPH-International Journal of Educational Research, 7*(2), 61–68. https://doi.org/10.5281/zenodo.10815027

Nguyen, Q. U. (2007). *General psychology* (in Vietnamese). Vietnam National University of Education Press.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Pang, S., Lv, G., Zhang, Y., & Yang, Y. (2024). Enhancing students' science learning using virtual simulation technologies: A systematic review. *Asia Pacific Journal of Education*, 1–21. https://doi.org/10.1080/02188791.2024.2441676

Phong, N. T. (2024). Khai thác và sử dụng phần mềm trực tuyến Desmos trong dạy học một số kiến thức "Dao động" và "Sóng" Vật lí trung học phổ thông. *Tạp chí Khoa học Đại học Cần Thơ*, *60*(2), 180-189. https://doi.org/10.22144/ctujos.2024.256

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K–12 levels: A systematic review of 12 years of educational research. *Studies in Science Education, 50*(1), 85–129. https://doi.org/10.1080/03057267.2014.881626

Quach, N. B. N., Le, T. H., Nguyen, H. A., & Huynh, T. L. (2023). Applying the STEM education model in teaching physics toward competency development for high school students in Thua Thien Hue. *Viet Nam Journal Education, 22*(23), 18–24. https://tcgd.tapchigiaoduc.edu.vn/index.php/tapchi/article/view/601

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Steidtmann, K. (2023). Declining interest in science in lower secondary school classes: The role of teaching quality and cognitive activation. *Journal of Research in Science Teaching, 60*(8), 1389–1411. https://doi.org/10.1002/tea.21794

Tsupros, N., Kohler, J., & Hallinen, J. (2009). *STEM education: A definition*. Learning & Education Center, Institute for Teaching and Learning, Carnegie Mellon University.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations that enhance learning. *Science, 322*(5902), 682–683. https://doi.org/10.1126/science.1161948.

Wieman, C., & Perkins, K. (2005). Transforming physics education. *Physics Today, 58*(11), 36–41. https://doi.org/10.1063/1.2155754

Zacharia, Z. C., & Olympiou, G. (2011). Physical versus virtual manipulative experimentation in physics learning: Which is more effective for conceptual change? *Learning and Instruction, 21*(3), 317–331. https://doi.org/10.1016/j.learninstruc.2010.03.001