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Integrating STEAM4Innovator Learning, Gamification, and Design Thinking to Enhance Students' Innovative Skills

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Abstract

This study aimed to develop an integrated learning approach that combines STEAM4Innovator, gamification, and design thinking to enhance students' innovative skills. The approach was created through a four-step process, including empathising and defining insights with learners, ideating and generating WOW! ideas, prototyping and developing a business model, and testing and producing the final solution. The approach was implemented with 109 Year 12 students, and the results indicated substantial improvements in their academic performance (78.47% improvement), innovative skills (62.09% improvement), and satisfaction with the learning process (86.97 out of 100), thereby highlighting the effectiveness and appeal of proposed approach. In addition, the success of approach is attributed to its capacity to foster learning and innovation skills, namely inspiration, imagination, creativity, integration, and hands-on implementation. This study demonstrates the effectiveness of integrating STEAM4Innovator, gamification, and design thinking in enhancing learning outcomes and encouraging the development of innovative skills.

Keywords: STEM, STEAM4Innovator, Gamification, Design thinking

Introduction

Education plays a crucial role in national development and is entrusted with the vital responsibility of developing human resources, promoting social equality, and driving economic growth and prosperity. In 2015, Thailand joined the ASEAN community to create regional stability and peace, foster economic cooperation, and improve the quality of life for ASEAN citizens (Foreign Affairs Division, 2021). This regional integration has implications for education systems in member countries, requiring them to develop individuals to their full potential and contribute to sustainable societal development (Pimmas, 2018).

Thailand should enhance its workforce to meet international standards and prepare for the twenty-first century. This requires not only core academic knowledge but also essential competencies such as learning and innovation, information and technology literacy, and life and career skills. The country's 20-year National Strategy (2018–2037) prioritises human resource development, with the aim of improving the quality of education and ensuring its accessibility for all (The Office of the National Economic and Social Development Council, 2018). The Ministry of Education is responsible for developing a competitive workforce and has introduced educational

reforms to achieve this objective. The Office of the Permanent Secretary for the Ministry of Education has established policies that place emphasis on active learning, digital literacy, and communication skills (The Office of the Education Council Secretariat, 2017).

Learning and innovation skills are crucial in today's rapidly changing world, enabling individuals to adapt and thrive. Teachers play a vital role in cultivating these skills, fostering inquiry, creativity, and innovation in their students. Such skills emphasis on analytical thinking, problem-solving, and cross-disciplinary knowledge integration, essential for preparing students to succeed in the twenty-first-century workforce (Chompoo *et al.*, 2023).

However, the current education system faces challenges, including a lack of student motivation, inadequate analytical and problem-solving skills, and insufficient integration of knowledge across disciplines. The 2018 PISA results indicated that Thai students scored below the OECD average in reading, mathematics, and science, particularly in analytical thinking and problem-solving (The Institute for the Promotion of Teaching Science and Technology, 2021). This underscores the need to strengthen students' higher-order thinking skills and integrate knowledge from multiple subject areas.

Design thinking, a twenty-first-century teaching approach, can be used to develop these skills (Mayuree & Pichaya, 2021). It is a systematic process that begins with understanding the needs of others, followed by collaborative brainstorming and hands-on implementation. One practical approach is the STEAM4Innovator model, which combines STEAM (Science, Technology, Engineering, Arts, and Mathematics) with entrepreneurship skills (The National Innovation Agency, 2022). This model enhances students' twenty-first-century competencies, promotes creative learning through experiential activities, and cultivates both innovative thinking and entrepreneurial potential. Furthermore, gamification can be used to increase motivation and engagement in the learning process (Natchaporn, 2022).

Takpittayakhom School, where this innovation was developed, is a large school in Tak Province, Thailand. Despite being one of the leading schools in the province, the 2022 Self-Assessment Report (SAR) indicated that students' abilities to gather knowledge independently, work collaboratively, and apply knowledge creatively was below the target (Takpittayakhom School, 2022). This highlights the need for integrated learning approaches that foster innovation and its practical application.

In this study, the integration of STEAM4Innovator learning, gamification, and design thinking is of central improtance. This approach draws on the strengths of STEAM, gamification, and design thinking to create a learning environment that promotes creative thinking, problem-solving, and the development of students' innovative potential. Such skills are essential for preparing students to succeed in the twenty-first-century workforce and to contribute to Thailand's 4.0 economic development goals.

Methodology

The approach was developed by empathising with learners and understanding their needs, followed by a thorough research phase. Learners' needs, interests, and prior learning styles were identified through questionnaires administered to students during the first semester of the 2022 academic year. Analysis of the data revealed key challenges and motivational factors influencing students' learning experiences. These insights helped to clearly define specific problems, which in turn informed the design of a learning approach aimed at addressing the identified needs and challenges. Subsequently, extensive research was conducted, including a review of relevant documents such as the learning standards for Physics. In addition, concepts, theories, and prior research related to design thinking, STEAM4Innovator, gamification,

and twenty-first-century skills were examined.

A prototype of the approach was then developed. This phase involved setting clear objectives and designing activities that integrated STEAM4Innovator, gamification, and design thinking. Gamification was implemented using ClassPoint® software to enhance student engagement and motivation. The prototype was tested with a pilot group of students in the first semester of the 2022 academic year. Learning activities in Physics subject for Year 12 were implemented with one class (n = 30), and data were collected through questionnaires, classroom observations, and student interviews. This pilot study allowed for the evaluation of the feasibility and effectiveness of learning approach. Feedback from the pilot indicated that certain activities required more time, particularly the brainstorming and testing phases. Students also recommended clearer task instructions during prototype construction. Based on this feedback, the learning activities were refined to improve pacing, clarity, and instructional support before the full-scale implementation in the 2023 academic year.

The approach was implemented in Physics, specifically in the Heat and Gas unit, for Year 12 students during the first semester of the 2023 academic year. This study employed a quasi-experimental research design using a one-group pre-test–post-test method to examine the effects of the integrated learning approach. All four Year 12 classes (12/1 to 12/4) participated under the same instructional conditions. The integrated learning approach was implemented uniformly across all classes, following the same sequence of activities, materials, and assessment tools. All sessions were facilitated by the same teacher (the author), ensuring consistency in delivery, classroom management, and data collection procedures. To provide a clearer insight into the classroom implementation, the integrated learning approach was applied to the Heat and Gases unit in Physics 5 (W33205), taught to 109 Year 12 students across four classes (Grade 12/1–12/4). The learning design followed a structured, four-phase framework that merged the STEAM4Innovator process with design thinking and gamification via ClassPoint®. Each phase was aligned with the physics content and targeted innovation competencies. The instructional design emphasized real-world relevance by assigning students to solve problems related to heat and gas in everyday contexts. To illustrate this, gamification was specifically integrated into each lesson through targeted ClassPoint® tools. For instance, during the exploration of heat transfer mechanisms, students participated in interactive multiple-choice quizzes covering conduction, convection, and radiation, earning points for speed and accuracy. A live leaderboard was displayed at the end of each session to recognize top-performing teams and to promote friendly competition, reinforcing both content mastery and engagement. Lessons spanned ten 60-minute sessions, integrating inquiry-based learning, group work, and digital tools. The instructional phases, sample classroom activities, and gamification tools used in this unit are summarized in Table 1. This structure offers practical guidance for educators seeking to apply the approach in their own classrooms. Each phase and activity can be adapted to fit different time frames, student abilities, and resource settings, making the design highly transferable. This approach diverged from traditional instruction in both form and function, emphasising collaborative innovation, iterative problem-solving, and hands-on experimentation. Students were not passive recipients but co-creators of knowledge, learning through design cycles, experimentation, and peer review. By incorporating gamified elements and entrepreneurial thinking into a physics context, students developed not only subject mastery but also innovation-oriented mindsets, aligned with the five core competencies of STEAM4Innovator: inspiration, imagination, creativity, integration, and hands-on implementation.

Table 1 Instructional Phases, Sample Activities, and Gamification Tools in the Heat and Gases Unit.

Phase	Focus	Sample Activities	Gamification Tools (via ClassPoint®)
Empathising with learners and defining insights	Empathise with real-world problems and define clear challenges	- Students interviewed peers about heat-related issues at home - Explored inefficiencies in thermal insulation	- Polls to rank challenges - Quiz on thermal basics
Ideating and generating WOW! ideas	Generate innovative ideas based on physics principles	- Brainstorm ideas for low-cost heat retention devices - Select feasible concepts	-
Prototyping and developing a business model	Develop prototypes and consider value creation	- Build simple models like insulated walls, thermochromic products - Simulate market pitch	-
Testing and producing the final solution	Test, refine, and present ideas to peers and community	- Present solutions to classmates - Reflect and improve via feedback	- Badges for best presentation, creativity, and teamwork

The academic performance, learning, and innovation skills were evaluated, including inspiration, imagination, creativity, integration, and hand-on implementation. The students' satisfaction with learning activities using this approach was also assessed and discussed.

Results and Discussion

Table 2 shows the results of the survey on students' learning needs, interests, styles, prior experiences and learning challenges, based on responses from 114 students in the first semester of the 2022 academic year. The majority of students were female (66.67%). The most preferred learning style was hands-on experiments (65.79%), followed by group activities (19.30%) and learning through digital media (4.77%). The most popular subjects were science (48.24%), technology (17.54%), and engineering (8.77%). The most effective learning methods for understanding were watching videos or teaching materials (37.72%), participating in discussions or exchanging ideas (21.93%) and completing exercises or activities (17.54%). Most students (96.49%) believed that technology played a significant role in their learning. The most common obstacles identified were lack of motivation (64.22%), lack of interaction with peers or teachers (62.82%), and unchallenging activities (58.24%).

Based on these observations, the main areas for improvement in the learning process were enhancing active learning, adjusting activities to be more motivating and interactive, and integrating games and technology to support learning. To address these areas, an integrated learning approach was developed that incorporated design thinking, STEAM4Innovator, and gamification elements.

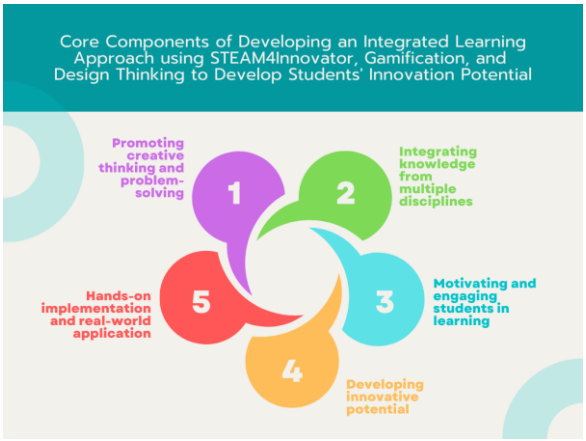

Figure 1 Core components of developing an integrated learning approach using STEAM4Innovator, gamification and design thinking to develop students' innovation potential.

The approach was developed based on the core elements shown in Figure 1, which

include promoting creative thinking and problem-solving, integrating knowledge from multiple disciplines, motivating and engaging students in learning, fostering innovative potential, and emphasising hands-on implementation and real-world application. These elements were derived from analysing student needs and existing research, forming the foundation for the integrated learning approach.

Table 2 Learning preferences, interests, prior learning experiences and problems in learning of Students in the first academic year 2022.

Question	Percentage
1. Gender	
• Male	33.33
• Female	66.67
2. What learning style do you prefer the most?	
• Lecture	1.75
• Group activities	19.30
• Self-directed learning	4.39
• Learning through digital media	4.77
• Hand-on experiment	65.79
• Others	4.00
3. What subject do you enjoy learning the most?	
• Science	48.24
• Technology	17.54
• Engineering	8.77
• Art	1.75
• Math	7.01
• Language	7.93
• Business	7.01
• Others	1.75
4. What learning method do you think helps you understand the content the best?	
• Listening of explanations	14.04
• Reading books/articles	8.77
• Watching videos/teaching materials	37.72
• Doing exercises/activities	17.54
• Discussions/exchanging ideas	21.93
5. What learning method do you think makes you feel the most engaged and interested?	
• Playing games/competitions	30.70
• Working in teams	15.79
• Receiving rewards/praise	19.30
• Creating work	28.07
• Others	6.14
6. What role do you think technology plays in your learning?	
• Very Important	96.49
• Important	3.51
• Moderate	0.00
• Less important	0.00
• Not important at all	0.00
7. What challenges have you encountered in your learning experiences? (multiple answers allowed)	
• Lack of motivation to learn	64.22
• Uninteresting content	48.75
• Unchallenging activities	58.24
• Lack of interaction with peers/teachers	62.82
• Inappropriate learning materials	33.78
• Learning environment not conducive to learning	12.15
• Others	7.23

Table 3 Mean, standard deviation, and percentage of improvement in learning achievement in Physics, heat and gas unit, grade 12 before and after learning with the integrated learning approach.

Topic	Before learning			After learning			% Improvement
	Mean	S.D.	Interpretation	Mean	S.D.	Interpreation	
Learning Achievement (Total score of 20)	4.85	2.20	Not passed	15.83	1.61	Passed	78.47

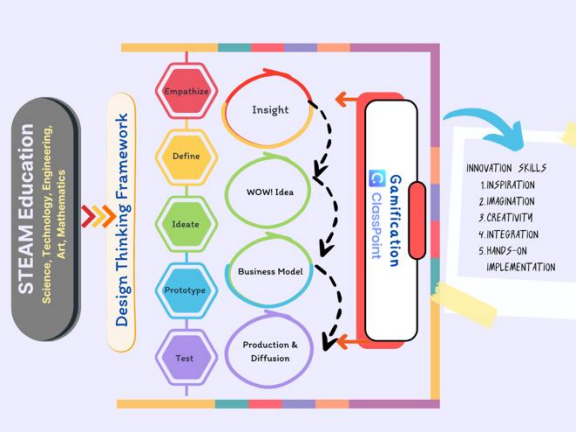

Figure 2 The designed approach integrates STEAM education, gamification, and design thinking to develop students' innovation potential.

As illustrated in Figure 2, the designed approach integrates STEAM education, design thinking, and gamification using ClassPoint® to foster students' innovative potential. The approach includes four steps, i.e.,

1. Empathising with learners and defining insights: This initial step combines the 'Empathize & Define' phases of design thinking with the 'Insight' stage of the STEAM4Innovator model. Students explore the problem's context, exploring relevant principles, theories, and definitions. Through interviews, they pinpoint the core issue and formulate potential solutions. Gamification, implemented via ClassPoint®, injects fun and engagement, encouraging active participation and deeper comprehension.

2. Ideating and generating WOW! ideas: This step merges the 'Ideate' stage of design thinking with the 'WOW! Idea' phase of STEAM4Innovator. Students engage in brainstorming sessions, collectively generating diverse potential solutions. They then critically evaluate these ideas and select the most promising approach to tackle the problem.

3. Prototyping and developing a business model: This stage connects the 'Prototype' phase of design thinking with the 'Business Model' component of STEAM4Innovator. Students translate their chosen solution into a tangible prototype, rigorously testing and refining it. Additionally, they assess the feasibility of their solution in a business context, considering its potential for real-world application.

4. Testing and producing the final solution: This final step links the 'Test' phase of design thinking with the 'Production & Diffusion' stage of STEAM4Innovator. Students finalise their product or solution, putting it to the test in a competitive setting. They showcase their work, comparing its effectiveness and business viability with other teams. Gamification, using ClassPoint®, adds a layer of challenge and competition, motivating students to strive for excellence.

To clarify how the instructional model in Figure 2 was implemented in the actual lessons, the classroom activities aligned with each phase are detailed in Table 1, located in the Methods section.

Table 3 presents the academic average scores, standard deviations, and percentage of the progress of pre- and post-tests in Physics subject (Heat and Gas unit) using an integrating STEAM4Innovator, gamification, and design thinking approach. This integrated learning approach was implemented with 109 students in the first semester of the 2023 academic year. The total score was 20 points, assessed through a teacher-developed test consisting of 20

multiple-choice questions (0.5 points each), 5 short-answer questions (1 point each), and 2 problem-solving questions requiring written solutions (2.5 points each). The items were designed to assess a comprehensive understanding of the key physics concepts in the Heat and Gases unit, including heat transfer, specific heat capacity, thermal equilibrium, and gas laws.

The results showed that the students' average score on the pre-test was 4.85 out of 20, which was below the passing threshold of 70%. However, after implementing the integrated learning approach, the average score on the post-test increased to 15.83, exceeding the passing threshold. Compared to the previous academic year (2022), where the same content on heat and gases was taught using conventional instruction, the integrated learning model demonstrated a substantially greater improvement in academic performance. Specifically, the traditional approach yielded only a 48.25% improvement between pre- and post-tests, whereas the integrated approach in 2023 resulted in a 78.47% improvement. This significant improvement in academic performance can be attributed to the effectiveness of the integrated learning approach in enhancing the students' understanding of the subject matter. By integrating elements of STEAM4Innovator, gamification, and design thinking, the approach actively engages students in the learning process, encouraging them to participate in hands-on activities, group discussions, and problem-solving exercises. This dynamic and interactive learning environment motivates students and allows them to apply theoretical concepts to real-world scenarios, enhancing their comprehension and retention. Active learning techniques, such as collaborative group work and interactive problem-solving, led to higher student performance and lower failure rates than traditional lecture-based instruction (Freeman *et al.*, 2014). Similarly, Prince (2004) highlighted that active learning strategies, including experiential and project-based learning, are associated with better student outcomes and increased engagement.

Table 4 Results of students' innovative skills development in Physics, heat and gas unit, grade 12 before and after learning with the integrated learning approach.

Topic	Before learning			After learning			% Improvement
	Mean	S.D.	Interpretation	Mean	S.D.	Interpretation	
Total Innovative Skills Score (Total score of 100)	51.38	1.40	Medium	83.28	2.20	Excellent	62.09

Table 4 shows the students' innovative skills development using the STEAM4Innovator framework, which consists of five aspects: inspiration, imagination, creativity, integration, and hands-on implementation. The 100-point scale was based on five equally weighted dimensions from the STEAM4Innovator model: inspiration, imagination, creativity, integration, and hands-on implementation. Each dimension was assessed using a 5-point Likert-scale observation rubric (1 = Not Demonstrated, 5 = Exceptional), resulting in a maximum of 20 points per dimension. The rubric was developed by the researcher and validated by three subject-matter experts to ensure content accuracy and relevance.

The classroom teacher conducted the assessment through structured observation during key activities such as brainstorming, group collaboration, prototyping, and testing. By applying a consistent and clearly defined rubric, reliable assessment was achieved even with a single evaluator. The results showed that the students' average score on the pre-test was 51.38 out of 100, which falls under the 'medium' level of innovator skills. However, after implementing the approach, the average score on the post-test increased to

83.28, reaching the 'excellent' level. This improvement showed the effectiveness of the approach in enhancing innovative skills. Increasing students' innovative skills due to a creative and interactive learning environment enhances students' problem-solving abilities and engagement. The improvement in students' innovative skills in this study—reflected by a normalized gain (N-gain) of 0.656—is comparable to findings from Witdiya *et al.* (2023), who reported a moderate N-gain of 0.55 in creative thinking skills among Grade 11 students through STEAM-based project learning in Indonesia. While their study emphasized project-based learning, the present study incorporated STEAM4Innovator, gamification, and design thinking, which may explain the relatively higher gain observed in this research. This comparison supports the effectiveness of well-designed STEAM learning environments in enhancing innovation capabilities. Research by Hwang *et al.* (2015) also supports that integrating gamification in education improves students' engagement and motivation, leading to higher learning outcomes.

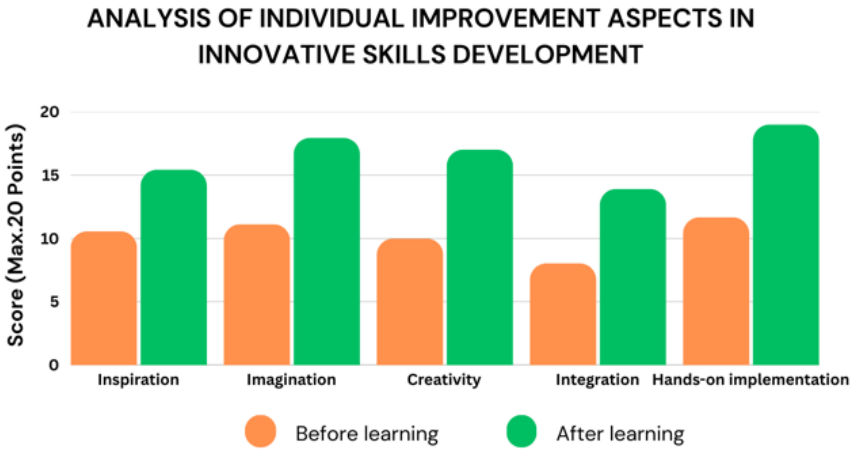

Figure 3 Average individual scores of students' innovative skills before and after the implementation of the integrated learning approach.

Figure 3 shows the analysis of individual improvement aspects in innovative skills development. It was revealed that there was improvement in all five areas. 'inspiration' increased from 10.56 to 15.43, demonstrating a more remarkable ability to inspire and motivate others. 'Imagination' improved from 11.12 to 17.44, indicating enhanced creativity and the ability to envision possibilities. 'Creativity' rose from 10.00 to 17.01, reflecting a greater capacity for generating novel ideas and solutions. 'Integration' increased from 8.03 to 13.91, suggesting a better understanding of combining different concepts to create innovative solutions. Finally, 'hands-on implementation' improved from 11.67 to 18.99, demonstrating an increased ability to put ideas into action and produce tangible results. These findings highlight the effectiveness of the integrated learning approach in fostering the development of well-rounded innovators. According to Guerzon & Busbus (2023) highlights that STEM integration fosters creativity and problem-solving skills by encouraging students to empathize, ideate, and prototype solutions. Furthermore, Zeybek and Saygi (2024) integrate gamification into education, which enhances student engagement and motivation, improving learning outcomes. These elements collectively create an interactive and dynamic learning environment that supports the development of innovative skills.

Figure 4 Student-designed thermal insulation prototypes (A) and an in-class test of heat insulation performance using a heat lamp and temperature sensor (B).

Table 5 Students' satisfaction with the integrated learning approach.

Item	Very satisfied (%)	Satisfied (%)	Neutral (%)	Dissatisfied (%)	Very dissatisfied (%)
1. Overall, I like the learning activities that I have participated in.	81.65	16.52	1.83	0.00	0.00
2. The learning activities are interesting and make me want to learn and participate.	85.32	13.76	0.92	0.00	0.00
3. The learning activities help me think of new ideas and feel more confident in presenting my own ideas.	80.73	14.68	4.59	0.00	0.00
4. The learning activities help me think of new ideas and feel more confident in presenting my own ideas.	91.74	8.26	0.00	0.00	0.00
5. The learning activities help me improve my problem-solving skills and learn to find solution on my own.	90.83	9.17	0.00	0.00	0.00
6. The learning activities help me work better with my friends and learn more from them.	86.24	10.09	3.67	0.00	0.00
7. I enjoy learning in this way and would like to have activities like this more often.	92.66	6.42	0.92	0.00	0.00
8. I have learned new and useful things from these activities.	85.32	7.34	7.34	0.00	0.00
9. The learning activities are challenging but not too difficult or too easy for me.	87.16	3.76	9.08	0.00	0.00
10. I feel that this activity helps me understand the connections between different subjects better.	88.07	6.43	5.50	0.00	0.00
Overall average	**86.97**	**9.64**	**3.39**	**0.00**	**0.00**

In addition to the quantitative findings, student-created outputs were collected as tangible evidence of learning outcomes. During the Prototype and Test phase, students applied concepts of heat transfer by designing thermal insulation devices using everyday materials. These hands-on projects allowed students to demonstrate their understanding of conduction, convection, and radiation through real-world

applications. An example of such a product is shown in Figure 4, which displays a student-designed thermal insulation container. The project was assessed based on a performance rubric covering thermal effectiveness, creativity, material selection, and teamwork. These outputs serve as authentic evidence of the students' ability to synthesize content knowledge and innovation skills.

In addition, Table 5 shows the evaluation of the students' satisfaction with the integrated learning approach. The results showed an average satisfaction score of 86.97 out of 100, indicating high satisfaction with the learning process. The incorporation of various innovative elements contributed to this positive outcome. The study's findings highlight the effectiveness of the integrated learning approach in enhancing academic performance, developing innovative skills, and improving student satisfaction. The approach's success is attributed to its ability to create a dynamic and engaging learning environment that fosters active participation, collaboration, and creativity. Dym *et al.* (2005) and Dichev *et al.* (2020) revealed that design thinking and gamification enhance student satisfaction by promoting understanding of design and boosting motivation through active participation in experiential learning activities. These approaches create engaging, interactive learning experiences that foster a better understanding of the material. This aligns with the approach described earlier, which integrates design thinking and gamification elements, leading to higher satisfaction levels among students through active participation, collaboration, and creative problem-solving in real life.

While overall satisfaction was high, a small number of students selected 'neutral' responses for some items. Further analysis suggests that these students—typically in upper secondary school—may possess self-regulated learning abilities that allow them to focus directly on academic content. As such, they might perceive structured activities such as gamification or design thinking as unnecessary for their learning process. Panadero (2017) notes that learners with strong self-regulation skills tend to rely on their personal strategies and autonomy, often favoring direct content access over externally guided interventions. These findings underscore the importance of designing flexible instructional models that can accommodate both structured engagement and independent learning preferences.During implementation, several practical challenges emerged that may inform future applications. For example, when students encountered difficulty with the mathematical aspects of gas laws, visual simulations such as the PhET Interactive platform were used to illustrate the relationships between pressure, volume, and temperature more intuitively. To address student engagement—particularly in repetitive or abstract segments—gamification strategies were applied using ClassPoint®, including live quizzes, point-based competition, and digital badge rewards. These elements significantly increased student motivation and participation by transforming conventional activities into goal-oriented challenges.

Additionally, some upper secondary students initially viewed the innovation process as secondary to mastering content. This highlights the need for clear communication of the model's purpose. Teachers are advised to plan time allocations carefully, prepare materials in advance, and incorporate low-cost alternatives to ensure smoother implementation.

Although this study focused on the topic of Heat and Gases in Grade 12 physics, the integrated learning approach combining STEAM4Innovator, gamification, and design thinking has the potential to be adapted for other scientific topics and different educational levels. For instance, in physics, it can be applied to topics such as electricity or mechanics, while in biology, it may be used to explore environmental systems or health-related innovations. Moreover, the emphasis on student-centred learning and innovation makes it suitable for use with younger

learners through scaled-down activities that match their developmental stage.

Conclusion

The integrated learning approach successfully incorporated the concepts of STEAM4Innovator, gamification, and design thinking into the learning process. This resulted in the development of learning activities that enhanced the students' creative thinking, problem-solving, and innovative skills. The approach's four main steps are empathising with learners and defining insights, ideating and generating WOW! ideas, prototyping and developing a business model, and testing and producing the final solution are integrated with the design thinking of STEAM4Innovator and incorporate gamification to improve student motivation and engagement. The approach's effectiveness is evident in the significant improvement in the student's academic performance in physics subject. Furthermore, the students' innovative skills significantly improved. The students also expressed high satisfaction with their approach.

In conclusion, the integrated learning approach's success is attributed to its ability to create a dynamic, engaging learning environment that fosters active participation, collaboration, and creativity. It is a valuable contribution to Thailand's education system, supporting the development of a skilled and innovative workforce for the 21st century. Given its strong alignment with national core curricula and twenty-first-century competencies, this approach holds promise for broader adoption across schools in Thailand and ASEAN. However, as the present study involved a single school and short-term measurement, future research should consider long-term implementations and test its adaptability across diverse educational settings and subjects. To support broader adoption, the approach can be flexibly adapted to different classroom settings. For larger class sizes, teachers can conduct whole-class activities instead of small-group tasks or rotate stations to ensure participation. In resource-constrained environments, low-cost alternatives such as DIY thermometers can substitute standard lab tools. The model's core structure—based on problem-solving through design thinking—can also be applied to other science topics like electricity or mechanics by redesigning the problem context. This adaptability enhances the model's relevance across diverse learning conditions while maintaining its focus on innovation skill development.

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