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INTERACTIVE LEARNING PLATFORMS TO STEAM (I-LPS) GAMIFICATION FOSTERING COMPUTATIONAL INNOVATORS AND CREATIVE THINKING IN TEACHER EDUCATION

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ABSTRACT

The purpose was to develop and study aims to analyze, synthesize, design and develop interactive learning platforms with STEAM (I-LPS) gamification fostering computational innovators and creative thinking in teacher education. The research instruments included a manual for I-LPS, active learning lesson plans, an active citizenship competencies test, and a satisfaction questionnaire. Statistics for data analysis were percentage, mean, standard deviation, and dependent sample t-test. The research is an application of the concept of Research and Development (R&D) and defines the framework for conducting research into 5 phases: Phase 1 (R1) Study and synthesis of the conceptual framework for the development of interactive learning innovative media with a simplified active learning model. Phase 2 (D1) Conceptual Framework for Developing Interactive Learning Materials with Active Learning Model Phase 3 (R2) Evaluation of the Conceptual Framework of the Gamified Digital Learning Ecosystem by Asking for Expert Opinions Phase 4 (D2) Creating Interactive Learning Materials with Gamified Active Learning Model to Promote Innovative Skills Phase 5 (R3) Evaluation of Achievement and Satisfaction. The overall student satisfaction with the interactive learning materials remains was high (mean = 4.29, S.D. = 0.65) and indicating that the results of the measurement before studying and the learning achievement after studying with the normal teaching method were statistically significantly different at the .01 level.
Keywords: *Interactive Learning Platform, STEAM, Computational Innovators, Creative thinking*

1. INTRODUCTION

Thailand is currently entering the digital era in a true sense. In the 4.0 era, the government has emphasized the expansion of an economy driven by innovation, technology, and creativity. This emphasis is reflected in the 13th National Economic and Social Development Plan [1], which accelerates the development of strategic foundational factors in various areas. These include increasing investment in research and development, advancing science, technology, and innovation, and concurrently raising the skill levels of both new entrants to the labor market and those currently employed, aligning them with target production and service sectors and technological changes. Additionally, the overall development of individuals is prioritized, ensuring that people at all life stages are well-equipped to manage changes in their living environments. Particularly, human capital development is emphasized through the enhancement of education quality, learning, skill development, and the improvement of public health services to be accessible in all areas. This is highlighted in Strategic Issue 1: Enhancing and Developing Human Capital Potential, which involves accelerating the

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development of an integrated information system for workforce demand and supply across relevant agencies. It also includes the establishment of information and consulting centers to support new students and independent careers, aligning with the 20-Year National Strategy [2], which discusses the development and enhancement of human resource potential, as well as the creation of opportunities for social equity and equality. The interactive learning platforms with STEAM (I-LPS) gamification fostering Computational Innovators and Creative Thinking in Teacher Education. These environments enable learners to interact with the content, thereby enhancing comprehension and retention. This ecosystem also promotes learner engagement by utilizing responsive and adaptive media, resulting in increased enthusiasm and participation. Additionally, the I-LPS offers diverse content tailored to individual learner needs, allowing them to choose topics of interest that align with their personal learning objectives. Moreover, the system can simulate complex scenarios, effectively developing learners' creative thinking skills, critical thinking skills, problem-solving skills, and communication skills [3], [4].

Place-based educational innovation serves as a mechanism for examining learners' identities within local and spatial contexts, which relates to their learning experiences [5]. Studies on positive outcomes from place-based education include academic achievements [6], community engagement, social and emotional values, as well as increased competencies in thinking and learning skills. The innovation that promotes good citizenship among learners [7]. Innovation serves as a mechanism to examine identity within spatial and local contexts of students, which relates to their learning experiences [8]. The investigation of student learning that yields positive outcomes from spatially based education includes academic results, which are linked to community engagement, social and emotional values, and enhanced competencies in thinking and learning skills [9]. Spatially based education is therefore an innovation that fosters good citizenship among students [10]. The study also found that students' awareness of their local context can make public education a contributing factor in developing positive relationships between students, schools [11],[12] and communities, Key information focuses on exploring the conditions that both constrain and enhance the potential of spatially based educational models [13], [14]. This mechanism leads to educational decentralization, educational reform, and the enhancement of true educational equity and value for learners. Given the above-mentioned spatial context, it aims to promote high-quality education aligned with the identity of diverse local communities. The data from this study can be developed into a prototype learning innovation that transforms schools into hubs for cultivating quality personnel and human resources [15],[16]. This will help reduce educational inequality and increase opportunities for learner development, emphasizing the use of spatially based educational frameworks to nurture quality personnel and enhance learners' opportunities for self-reliance [17],[18] support lifelong learning, and effectively drive society in alignment with social contexts [19],[20].

The motivation for this study is grounded in the continued evolution of educational methodologies amid digital transformation and interdisciplinary learning. Recent 2024 literature underscores the significance of STEAM education, enhanced through gamification, for developing comprehensive skill sets that address complex, real-world challenges. Research indicates that gamification fosters student engagement, leading to deeper learning and better retention, while the integration of STEAM promotes the application of interdisciplinary knowledge [25]. However, a gap persists in applying these gamified, STEAM-based models specifically within teacher education to cultivate computational thinking and creative skills. This study aims to address this gap by developing an interactive learning platform, contributing to the broader discourse on educational innovation and aligning with strategic educational goals such as those in the 13th National Economic and Social Development Plan and the 20-Year National Strategy.

Educational development and workforce enhancement are pivotal for advancing the nation's economy through innovation, technology, and creativity within a knowledge-based framework. Addressing the development of teachers and educational personnel is essential, as students, who are key drivers of economic growth, benefit from interactive learning innovations that incorporate proactive STEAM-based gamification to foster creative and innovative skills. These innovations aim to equip students with the knowledge, skills, competencies, and positive attitudes needed for self-development and successful career advancement. Strengthening workforce capacity development supports lifelong learning and aligns with the digital and creative economy, in accordance with the objectives of the Thailand 4.0 development model.

Research Gap and Research Question

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Despite substantial advancements in the integration of STEAM education and gamification within educational settings, there remains a notable gap in the systematic implementation of these elements specifically targeted at teacher education to cultivate computational thinking and creative skills. This research aims to fill this gap by exploring how interactive learning platforms with STEAM-based gamification can effectively foster creative innovation and computational competencies among teachers and pre-service educators. The central research question guiding this study is: *How can an interactive learning platform incorporating STEAM education and gamification be designed and implemented to enhance creative thinking and computational skills in teacher education?*

2. RESEARCH METHOD

2.1 Research Objectives

1. To conduct the PRISMA and the bibliometrics analysis of research related to interactive learning platforms with STEAM (I-LPS)

2. To develop interactive learning platforms with STEAM (I-LPS) with gamification fostering computational innovators and creative thinking in teacher education.

3. To assess the creative thinking skills of users of I-LPS with gamification fostering computational innovators learning ecosystem in teacher education.

2.2 Population and sample

1. The population used in the research is comprises teachers and educational personnel in schools under local administrative organizations in Chachoengsao Province, and pre-service teachers major in Computer Education, Faculty of Education, Rajabhat Rajanagarindra University, Thailand.

2. The sample group of 30 teachers and educational personnel from local administrative schools in Chachoengsao Province, and 30 student teachers from the Computer Education Program, Faculty of Education, Rajabhat Rajanagarindra University, totaling 60 participants.

2.3 Variables

1. The independent variable is the I-LPS with gamification fostering computational innovators and creative thinking in teacher education.

2. The dependent variable is creative innovation skills in teacher education.

2.4 Research tool and data analysis

An assessment of the development of an interactive learning innovation using an active learning model with STEAM gamification to promote creative innovation skills will involve a satisfaction survey questionnaire administered after the completion of learning activities using the participatory learning management model. This is to assess the effectiveness of the participatory learning management model. Mean and standard deviation will be calculated. For analyzing pre-test and post-test performance, dependent samples t-test statistics will be used. Finally, students' satisfaction towards classroom activities using the participatory learning management model will be analyzed, with the expectation of measuring high levels of satisfaction.

2.5 Procedure

study of analysis and synthesis of components of innovative interactive learning media with active learning model of steam gamification to promote creative innovation skills

Table 1: The Characteristics of I-LPS

Characteristics	Description	Reference
STEAM Education	STEAM Education refers to an instructional approach that integrates five disciplines, consisting of S(Science), T(Technology), E(Engineering), A(Arts), and M (Mathematics), to develop learners' skills in applying knowledge to solve real-life problems	[21],[22],[23]
Creative Thinking	The components of creative thinking associating skills, problem solving skills, observing skills, experimenting skills and networking skills	[24],[25],[26],[27]
Gamification	Gamification to the process of applying game concepts and mechanisms in instructional design to motivate learners and encourage active participation in an enjoyable learning experience. It creates a positive learning atmosphere and helps learners understand complex topics more easily.	[28],[29],[30],[31]
Interactive Learning Platforms	The process consists of five steps: defining the problems, designing tools, producing instruments, testing and refining the solution and presenting to sharing the results or the solution with others.	[32],[33]
Online Platforms	The various online tools and platforms, such as interactive learning platforms, digital education tools, forums, line, chatbot, gamification, and video conferencing, to facilitate communication and collaboration.	[34],[35],[36]

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From Table 1. The Characteristics of I-LPS, it can be concluded that the interactive learning platform integrated with STEAM education and gamification offers a dynamic and multifaceted approach to teaching and learning. The platform's focus on the integration of science, technology, engineering, arts, and mathematics (STEAM) encourages learners to develop a comprehensive skill set, including problem-solving, creative thinking, and critical analysis.

Gamification components such as clearly defined goals, structured rules, reinforcement mechanisms, time management, and feedback loops significantly enhance learner motivation and engagement. These elements create a positive learning environment where students are actively involved in the learning process, which promotes deeper understanding and retention of complex concepts. Moreover, the platform's emphasis on interactive and online learning tools supports collaboration and allows for real-time feedback, further contributing to a high level of student satisfaction. Overall, the characteristics of the I-LPS indicate its effectiveness in fostering computational innovators and creative thinkers, aligning well with the demands of 21st century education.

3. RESULTS

The bibliographic map in Figure 1, generated from queries on "I-LPS" in the Scopus database, illustrates the interconnectedness of various themes and concepts related to interactive learning platforms, computational thinking, and creative thinking. Each node represents a specific topic or keyword, while the lines between nodes show the strength of co-occurrence and relationships among these concepts in the literature.

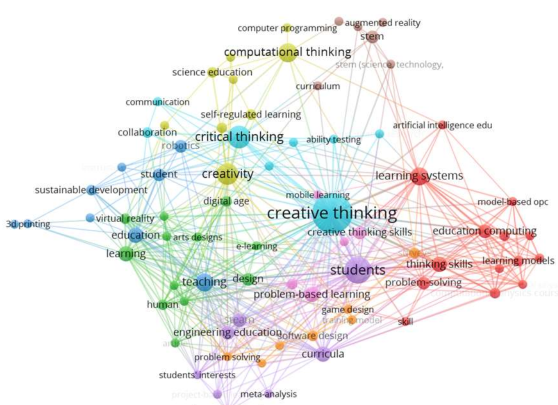

Figure 1: Bibliographic from I-LPS queries in Scopus database

3.1 Key Observations:

Creative Thinking and Students: The largest node in the network represents "creative thinking" central to the bibliographic map, signifying its critical role in research related to I-LPS. The concept of "students" is also closely connected, indicating that most studies focus on how I-LPS impacts student learning outcomes, particularly in fostering creativity.

1.Computational Thinking: This node, positioned prominently, is linked to "computer programming," "problem-based learning," and "critical thinking," emphasizing the integration of computational skills with broader educational strategies in I-LPS environments.

2.Critical Thinking and Creativity: "Critical thinking" and "creativity" are highly connected to each other and other surrounding nodes, such as "self-regulated learning" and "collaboration." This highlights that I-LPS approaches not only aim to foster individual creativity but also emphasize critical thinking and collaborative learning strategies.

3.STEM and STEAM Education: Keywords like "technology," "engineering," "arts," and "science education" are clustered together, reflecting the role of STEAM in interactive learning platforms. These disciplines are central to the development of computational innovators, as the integration of these fields helps students apply creative and critical thinking to real-world problems.

4.Gamification and Learning Systems: The inclusion of "gamification," "augmented reality," and "learning systems" nodes indicates the increasing use of technology-enhanced learning environments to motivate students and enhance engagement through game-like elements.

5. Pedagogical Focus: Terms such as curricula, problem-based learning, and learning ecosystems reflect the instructional strategies commonly employed in research on I-LPS. These strategies are key to fostering critical thinking and problem-solving skills.

The bibliographic analysis visually underscores the interdisciplinary nature of research surrounding interactive learning platforms with STEAM (I-LPS) gamification. It highlights the centrality of creative and computational thinking in fostering critical skills among students, while also revealing the importance of integrating various pedagogical approaches and technological tools in I-LPS environments.

3.2 The Systematic reviews and Meta-Analyses (PRISMA) and the bibliometrics analysis of I-LPS

After querying results with Communities of Practice keywords published in Scopus, the 8,385 research papers were analyzed using a bibliometric analysis. The results are shown in Figure 1. Therefore, the research papers from the Scopus database were used to systematically review the literature and meta-analysis. According to the research selection criteria,

- excluding "creative thinking" research, there were 282 research papers remained,
- excluding non-immersive or computational research, there were 282 research papers remained,
- excluding non-open access language English, there were 226 research papers remained.
- excluding research document type published since 2010, there were 274 research papers remained,
- excluding research document type that was not published in research journals and academic conferences, journal and journal there were 221 research papers remained,
- excluding studies included in review, there were 106 research papers remained.

The Studies included in review for Meta-Analysis were 106 research papers.

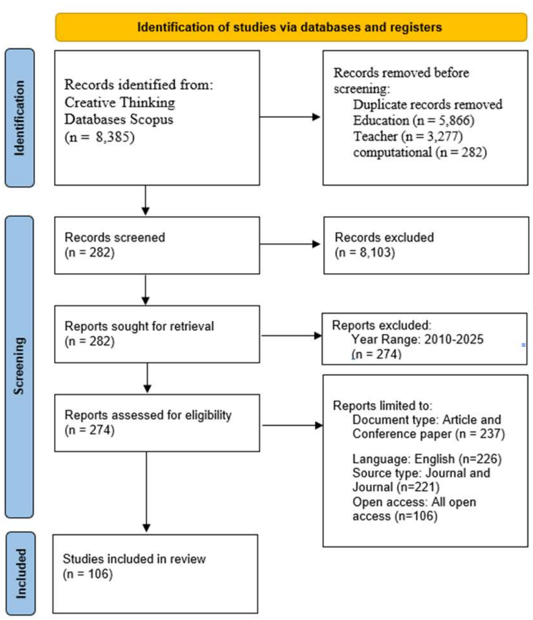

Figure 2: The Systematic reviews and Meta-Analyses (PRISMA) of I-LPS

The flowchart presented in Figure 2 follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, demonstrating the process of study identification, screening, eligibility assessment, and inclusion for a systematic review and meta-analysis of I-LPS (Interactive Learning Platforms with STEAM Gamification)

3.3 Detailed Breakdown:

Identification Phase:

A total of 8,385 records were initially identified from the Scopus database by querying with keywords related to Creative Thinking, Computational Research, and Teacher Education. These records represent a wide range of literature pertaining to interactive learning platforms with a focus on STEAM education and gamification. During the identification process, duplicate records and irrelevant studies were removed. After filtering out duplicates, 282 records remained for further screening.

Screening Phase:

The 282 remaining studies were subjected to a thorough screening process. Studies that were deemed irrelevant or outside the research scope, such as those not focusing on immersive learning environments or computational research, were excluded. Additionally, non-English language articles were removed, resulting in a pool of 226 studies that were further assessed for eligibility. Following additional exclusion criteria (e.g., document types not related to research journals or academic conferences), 221 studies were retained for a more in-depth review.

Eligibility Phase:

At this stage, 274 research papers were evaluated based on their alignment with the selection criteria. These included open-access availability, language of publication (English), and publication year (papers published since 2010). Studies that did not meet the eligibility criteria (e.g., not published in relevant academic journals or conferences) were excluded, narrowing the pool to 106 studies that were considered suitable for inclusion in the meta-analysis.

Inclusion Phase:

A final set of 106 research papers was included in the systematic review and meta-analysis. These studies met all the predefined criteria and were assessed in terms of their contributions to the field of I-LPS, focusing specifically on how STEAM education and gamification foster computational innovation and creative thinking. The flowchart systematically illustrates the rigorous process of filtering and selecting research studies for inclusion in the meta-analysis. By adhering to the PRISMA guidelines, the methodology ensures that only high-quality, relevant studies contribute to the final analysis of interactive learning platforms with STEAM and gamification in educational contexts. The 106 papers included in the final review represent the core literature on this topic, providing a solid foundation for understanding the impact of I-LPS on fostering creativity and computational thinking in educational environments.

3.4 The interactive learning platforms with STEAM (I-LPS) gamification fostering computational innovators and creative thinking in teacher education

Results of the suitability assessment of the ecosystem for interactive learning innovation media using active learning with STEAM gamification to promote creative innovation skills. The results of the suitability assessment of the ecosystem framework were obtained by presenting the suitability assessment form for the components of the ecosystem for developing interactive learning innovation media using active learning with STEAM gamification to promote creative innovation skills to 7 experts for evaluation. The assessment results are shown in Figure 3-4 and Table 2.

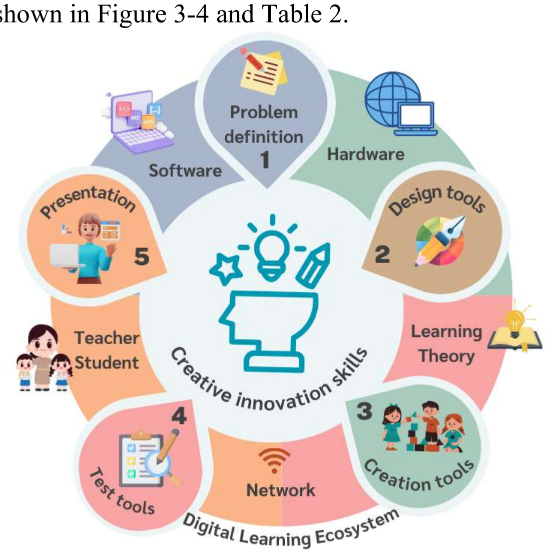

Figure 3: The I-LPS digital ecosystem of steam gamification to foster creative innovation skills

The diagram in Figure 3 visually represents the structure and workflow of the Interactive Learning Platform with STEAM (I-LPS) ecosystem, which is designed to foster creative innovation skills. The ecosystem integrates multiple elements including problem-solving, design thinking, technological tools, and pedagogical strategies. The central theme of the ecosystem is the development of creative innovation skills among learners, achieved through a sequence of interactive learning phases.

3.5 Key Components of the Ecosystem:

Problem Definition:

This phase emphasizes the identification and analysis of a problem, which sets the stage for the entire learning process. Learners define the real-world problems they aim to address using STEAM principles. Tools used in this stage include both software and hardware resources, encouraging learners to frame the problem effectively.

Design Tools and Learning Theory:

Once the problem is identified, the ecosystem moves to the design phase. Here, learners employ various design tools, guided by sound learning theories, to devise solutions. This phase integrates educational theories that support creativity and critical thinking, ensuring that the design process aligns with pedagogical best practices.

Creation Tools:

In this phase, students apply the knowledge they have acquired to create tools and solutions for the defined problem. The ecosystem provides both the digital resources (such as coding platforms and modeling tools) and the physical materials (for example, engineering kits or art supplies) necessary for students to build their solutions. The use of STEAM encourages interdisciplinary learning and the creation of innovative solutions.

Test Tools:

After creating the tools, learners move to the testing phase. This phase involves experimenting with and refining the created solutions to ensure that they effectively address the problem.
The ecosystem provides both virtual and physical environments where learners can test their tools, receive feedback, and make iterative improvements.

Presentation:

The final stage involves presenting the developed tools or solutions. Learners showcase their work to teachers, peers, and possibly a broader audience, promoting collaborative learning and peer review.This phase reinforces communication skills and ensures that students can explain the rationale behind their solutions, linking back to their original problem definition.

Network and Digital Learning Ecosystem:

The entire process is supported by a robust digital learning ecosystem, which includes networking capabilities. This allows learners to collaborate with others, access resources, and receive real-time feedback from educators and peers.

The use of a connected ecosystem enhances the learning experience by enabling seamless interaction between all stages of the learning process.

Teacher and Student Roles:

Throughout the ecosystem, both teachers and students are key actors. Teachers facilitate the learning process, while students actively engage in each phase, applying their creativity and computational skills to solve problems.

This I-LPS digital ecosystem diagram effectively demonstrates how a well-structured, STEAM-based, and gamified learning environment can support the development of creative innovation skills. Through a cyclical process of defining problems, designing solutions, testing tools, and presenting results, learners are guided through a comprehensive, interactive, and engaging educational experience. The ecosystem not only emphasizes technical competencies but also nurtures soft skills such as critical thinking, creativity, and collaboration.

Table 2: The results of the suitability assessment of the I-LPS learning ecosystem framework

Indicator	*Mean*	*S.D.*	Consensus Reached
1. I-LPS of the Learning management process based on the learning ecosystem			
1.1 Definition stage	4.88	0.33	High
1.2 Tool design stage	4.82	0.39	High
1.3 Tool construction stage	4.94	0.24	High
1.4 Tool testing stage	4.82	0.45	High
1.5 Presentation stage	4.88	0.33	High
Summary of Learning STEAM Education	4.87	0.34	High
2. Gamification learning process			
2.1 Goal	5.00	0.00	High
2.2 Rule	4.88	0.33	High
2.3 Reinforcement	5.00	0.00	High
2.4 Time	4.94	0.24	High
2.5 Feedback	4.88	0.33	High
Summary of gamification learning process	4.94	0.18	High
3. Evaluation			
3.1 Innovation Skills Test Assessment	5.00	0.00	High
3.2 Creative innovation performance	4.94	0.24	High
3.3 Academic assessment	4.88	0.33	High
Summary of evaluation	4.91	0.29	High
Overview summary	**4.91**	**0.27**	**High**

Table 2 presents the results of the suitability assessment of the Interactive Learning Platforms with STEAM (I-LPS) learning ecosystem framework, evaluated by experts across various components of the learning management and gamification processes, as well as evaluation methods. The findings reveal consistently high mean scores, ranging from 4.82 to 5.00, with minimal standard deviation, indicating strong consensus among experts on the framework's effectiveness. Each phase, from the problem definition, tool design, and testing to the gamified components of goal setting, reinforcement, and feedback, was rated highly suitable for promoting creative innovation skills. The evaluation components, including innovation skills testing and academic assessments, also received strong scores, further reinforcing the suitability of the I-LPS framework for fostering computational and creative thinking in teacher education. Overall, the framework demonstrates robust support for enhancing active learning through STEAM and gamification strategies.

Table 3: Comparison of academic achievement results before and after learning between the experimental group and the control group.

Group	n	Total score	Pre-test		Post-test		t-test Independent	Sig
			Mean	*S.D.*	*Mean*	*S.D.*		
Control group	15	60	15.20	2.57	43.50	6.02	24.30	.000 **
Experiment group	15	60	15.80	3.24	50.03	6.40		

**p <.01

Table 3, the results of the comparison of the learning achievement before and after studying of the students between the experimental group and the control group are as follows:

Group 1, which studied using the I-LPS with gamification fostering computational innovators and creative thinking in teacher education, after studying, the mean was 50.03, the standard deviation was 6.40, before studying, the mean was 15.80, the standard deviation was 3.24, indicating that the results of the measurement before studying and the learning achievement after studying with the learning ecosystem of I-LPS to promote creative innovation skills were statistically significantly different at the .01 level.

Group 2, which studied with the normal teaching method, after studying, the mean was 43.50, the standard deviation was 6.02, before studying, the mean was 15.20, the standard deviation was 2.57, indicating that the results of the measurement before studying and the learning achievement after studying with the normal teaching

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method were statistically significantly different at the .01 level.

Figure 4: The I-LPS activity using computational innovators and creative thinking

Figure 4 The I-LPS Activity Using Computational Innovators and Creative Thinking illustrates the five-step process of the Interactive Learning Platforms with STEAM (I-LPS) framework, which is designed to foster computational innovation and creative thinking in learners. The process integrates both STEAM education and gamification strategies, offering a dynamic and interactive approach to learning that encourages innovation. Below is a detailed description of each step:

1. **Definition of Term (Problem Definition)**:
The learning process begins with the identification and definition of a specific term or problem. This step involves a thorough investigation to understand the scope of the issue. Learners are required to research, gather data, and frame the problem in a manner that sets the foundation for the subsequent steps. It engages learners in critical thinking and inquiry-based learning.

2. **Design**:
After defining the problem, learners move on to the design phase, where they conceptualize possible solutions. This phase emphasizes creativity, as students are encouraged to use various tools and strategies from the STEAM disciplines (Science, Technology, Engineering, Arts, and Mathematics) to develop potential solutions. The design phase stimulates innovative thinking by blending theoretical knowledge with practical application.

3. **Create Tools**:
In this phase, learners apply their design plans to create tools or solutions. This hands-on phase encourages students to translate their ideas into tangible products or digital solutions. By engaging with computational technologies, engineering concepts, or artistic creation, students develop skills in both innovation and problem-solving, with a strong emphasis on computational thinking.

4. **Testing**:
Once the tools are created, they undergo testing. This phase involves experimenting with the created solutions, analyzing their effectiveness, and making necessary adjustments. The testing phase allows learners to reflect on their design, engage in iterative improvement, and apply critical thinking to refine their innovations.

5. **Presentation**:
The final phase of the process involves presenting the developed tools or solutions. Learners share their creations with peers, teachers, or a broader audience, facilitating collaborative learning and feedback. This phase encourages communication skills, the ability to explain and justify design choices, and reinforces the entire learning process by allowing students to reflect on their accomplishments.

Gamification elements, which enhance student engagement and motivation. The gamification features include:

1. Goal Setting: Clearly defined objectives that guide learners through the learning process.

2. Reinforcement: Positive feedback mechanisms such as rewards and achievements to encourage continuous effort.

3. Action: Active participation in tasks, with learners taking steps to solve problems and create tools.

4. Reward: Recognition of progress through points, badges, or other incentives that motivate learners.

5. Feedback: Constructive feedback that helps learners improve their tools and designs.

Creative Innovation Output

The culmination of the entire process leads to the development of Creative Innovation. Through the combined efforts in defining problems, designing solutions, creating tools, testing, and presenting, learners can foster innovative thinking and computational skills. The process empowers students to become innovators by engaging them in a holistic learning environment that integrates STEAM disciplines with interactive learning technologies.

Figure 4 encapsulates the comprehensive and interactive nature of the I-LPS framework, emphasizing the importance of each step in promoting computational innovation and creative thinking. By incorporating gamification elements and structured phases, the I-LPS framework provides learners with a supportive ecosystem to engage deeply with problems, develop creative solutions, and apply computational thinking in

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meaningful ways. This approach equips learners with the skills necessary to thrive in a rapidly evolving digital world.

Table 4: The study of students' satisfaction with I-LPS gamification fostering computational innovators and creative thinking in teacher education.

I-LPS with gamification	*Mean*	*S.D.*	students' satisfaction
STEAM learning process The teacher explains the learning objectives to the students learning guidelines	4.47	0.57	High
o Students learn how to define problems.	4.27	0.58	High
o Students understand the process of designing problem-solving tools	4.43	0.50	High
o Students can build tools as designed to solve problems	4.40	0.50	High
o Students learn how to test tools	4.37	0.72	High
o Students can present their knowledge to others	4.13	0.82	High
o Students are inspired to create artistic works	4.10	0.61	High
o Students see the connections between each discipline and the artistry in their own way	4.33	0.71	High
o Students can apply this to their daily lives	4.20	0.71	High
o Students can use their knowledge of science, technology, engineering, art and mathematics together appropriately	4.03	0.61	High
Summary of STEAM learning process	**4.27**	**0.65**	**High**
Gamification processes			
o Students enjoy working in teams	4.10	0.55	High
o Students can work with teams to set goals and solve problems	4.37	0.61	High
o Students can do practical work	4.57	0.50	Higher
o Students are encouraged by their teachers to create their work	4.13	0.63	High
o The time spent on organizing activities and learning units is appropriate	3.80	0.76	High
o Students receive information from teachers about their learning or performance in each assignment	4.40	0.67	High
o Students are motivated to learn	4.30	0.75	High
o Students are satisfied with the learning process in the classroom	4.33	0.61	High
Summary of gamification process integration	**4.25**	**0.67**	**High**

I-LPS with gamification	*Mean*	*S.D.*	students' satisfaction
Digital learning ecosystem: Living Entities			
o The teacher informs the learning objectives	4.27	0.74	High
o Teachers encourage students to dare to think and dare to search for knowledge	4.37	0.61	High
o Teachers arrange learning content from easy to difficult	4.30	0.60	High
o The teacher gives students an opportunity to ask questions and express their opinions together in class	4.50	0.57	High
o Teachers are proficient in using computers	4.47	0.57	High
o Classmates help each other	4.10	0.61	High
o There is an opportunity to exchange ideas among classmates	4.33	0.66	High
o Students can work as a team	4.00	0.69	High
Summary of digital learning ecosystem: living entities	**4.29**	**0.65**	**High**
Digital learning ecosystem: Inanimate objects Interactive learning management system (Genially, Word wall)			
o Easy to use login system	4.33	0.61	High
o The use of the general system is smooth and continuous	4.27	0.64	High
o Using system is easy to understand and not complicated	4.23	0.68	High
o The design of the general system is beautiful and interesting	4.43	0.63	High
o The system has a proper scoring system	4.30	0.70	High
o The system makes learning fun	4.20	0.76	High
Summary of Inanimate objects: Interactive Learning Management System	**4.29**	**0.67**	**High**
Digital learning ecosystem: Inanimate objects Laboratories and learning media o The size of the computer lab in relation to the number of students is appropriate	4.43	0.57	High
o Performance of computer equipment in the computer laboratory	4.20	0.55	High
o Teaching media in the subject are appropriate	4.50	0.51	High
o The Internet is working efficiently	4.37	0.56	High
Summary of Inanimate objects: Laboratory and Learning Media	**4.38**	**0.55**	**High**
Summary Digital Learning Ecosystem Integration: Inanimate Things	**4.33**	**0.62**	**High**
Summary	**4.29**	**0.65**	**High**

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Table 4 presents the results of a study assessing students' satisfaction with the I-LPS (Interactive Learning Platforms with STEAM) using gamification to foster computational innovation and creative thinking in teacher education. The evaluation is divided into three main categories: the STEAM learning process, gamification processes, and the digital learning ecosystem (both living and non-living aspects). Across these categories, high levels of satisfaction were recorded, with most indicators receiving mean scores above 4.00 on a 5-point scale. The STEAM learning process had a summary mean score of 4.27, indicating that students were highly satisfied with how teachers explained objectives, defined problems, and encouraged the use of interdisciplinary knowledge. The gamification processes also scored highly, particularly in practical work (4.57) and teacher encouragement (4.13), with an overall mean of 4.25. The digital learning ecosystem was assessed in terms of both "living Entities " (such as teacher support and peer collaboration) and "inanimate objects" (such as laboratory resources and interactive tools), with both sections showing high levels of satisfaction, scoring 4.29 and 4.33, respectively. Overall, the summary satisfaction level for the I-LPS framework was 4.29, indicating that students generally found the platform highly effective in fostering creative and computational skills.

Strengths and Weaknesses of the Study

This study demonstrates significant strengths, particularly in its comprehensive approach to integrating STEAM education with gamification to enhance creative thinking and computational skills among educators. The use of an interactive learning platform has proven effective in fostering learner engagement and promoting interdisciplinary knowledge application, as evidenced by high levels of satisfaction and improved learning outcomes. However, certain limitations should be acknowledged, such as the relatively small sample size and the study's focus on a specific geographic and institutional context, which may limit the generalizability of the findings. Future research should aim to extend the study to a broader demographic and include diverse educational settings to strengthen the robustness and applicability of the results.

4. DISCUSSION

The development of the I-LPS framework, integrating STEAM education and gamification, has shown to be highly effective in fostering computational innovators. The high satisfaction scores reflect its ability to actively engage learners through structured learning stages, such as problem definition, tool design, and testing, which promote problem-solving and collaboration. Supporting research highlights that gamification can enhance student motivation and active learning, which aligns with the positive outcomes observed in this study. Additionally, emphasized the role of interactive technologies in encouraging innovative thinking, and this research confirms that gamified learning platforms like I-LPS can significantly transform educational experiences by fostering engagement and creativity in learners. This reinforces the findings by that interdisciplinary STEAM learning environments contribute to enhanced problem-solving and creative skills, demonstrating the broader applicability of this framework in modern education.

The assessment of creative thinking skills in I-LPS users revealed high satisfaction, particularly in creativity and innovation, with learners effectively applying interdisciplinary STEAM knowledge. High scores in creative innovation performance (Mean = 4.94, S.D. = 0.24) and academic assessments (Mean = 4.88, S.D. = 0.33) demonstrate the platform's success in fostering both computational and creative thinking. This success is attributed to the collaborative and interactive nature of the platform, where teamwork and idea-sharing encourage the development of innovative solutions. As highlights, integrating STEAM subjects enhances creative problem-solving abilities, which was evident in this study. Additionally, support the notion that interactive technologies are crucial in promoting critical and creative thinking, reinforcing the I-LPS framework's efficacy in creating an engaging environment for experimentation and reflection. The results further align, showing that gamified learning enhances student motivation and creativity, thus confirming the value of gamification in educational contexts.

The findings of this study hold significant implications for industry, particularly in sectors that prioritize workforce development and innovation. The integration of STEAM education with gamification within interactive learning platforms can be leveraged to train employees and enhance their creative problem-solving and computational thinking skills. Such training programs can prepare employees to tackle complex, interdisciplinary challenges, aligning with the demands of industries that require adaptable, innovative, and technologically proficient personnel. Additionally, the scalable nature of these learning platforms enables organizations to implement continuous professional development, fostering an agile and resilient workforce capable of sustaining competitive advantage in an era driven by rapid technological advancements.

5. CONCLUSION

The interactive learning platforms with STEAM (I-LPS) Consisting of 1) Problem definition stage by studying, researching, and collecting data from various learning sources to define the real problem. 2) Solution design stage using mathematics and technology is the application of technology and mathematical knowledge to design solutions. 3) Tool creation stage for problem solving/project use for problem solving is the development of tools according to the created model. 4) Testing, interpreting results, and improving solution methods is the introduction of the designed problem-solving tools or processes to try out in solving problems and then making improvements for efficiency. 5) Presentation stage/problem solving method, learners present their discovered solution approaches or present their created innovations for exchange of learning among learners. Fun learning atmosphere, practicing teamwork with gamification mechanisms. Which consists of 1) Goals, which refer to the purpose of playing the game to challenge players to win the game. 2) Rules, methods of playing, scoring, conditions that players must comply with. 3) Reinforcement, including rewards, points, achievements, challenges, trophies, badges, virtual goods and spaces, levels, leader boards are what players will receive when they achieve their goals. By motivating players to compete to score by organizing the player's score. 4) Time, to motivate players to do activities or act, practice time management, which is an important success factor, and 5) Feedback, reflecting the results of the player's wrong or right thoughts and actions to guide the appropriate way to proceed with the next activity. Each step of the gamification process stimulates learners to practice integrating knowledge skills and participate in teaching and learning activities to find solutions to problems or create innovations. When practicing and reviewing the process, learners will develop creative innovation skills. As for the components of the digital learning ecosystem that are inanimate objects, such as tools, materials, equipment, and learning content, they are another element that plays a significant role in students' learning.

The research findings on the Interactive Learning Platforms with STEAM (I-LPS) and gamification provide a foundation for enhancing both computational thinking and creative innovation in educational settings. To apply these results effectively, educators should incorporate I-LPS in curricula that aim to foster interdisciplinary learning, particularly in science, technology, engineering, arts, and mathematics (STEAM). Teachers can leverage the structured approach starting from problem definition to testing and presentation ensuring students develop critical thinking and problem-solving skills through hands-on, collaborative activities. Gamification elements, such as goal setting, feedback, and rewards, should be employed to increase learner engagement and motivation. Educational institutions can use these findings to integrate digital learning ecosystems that support interactive and reflective learning, optimizing both in-person and remote teaching environments. Furthermore, policymakers and curriculum developers should consider the scalability of the I-LPS framework across various educational levels and cultural contexts, ensuring inclusivity and adaptability to diverse learning needs.

This study contributes to the current body of literature by demonstrating how the integration of STEAM education with gamification within interactive learning platforms can significantly enhance creative thinking and computational skills, particularly in teacher education. Unlike previous studies that primarily focused on single aspects of educational innovation, this research underscores the comprehensive benefits of combining STEAM approaches with gamified learning processes. The results provide empirical evidence supporting the effectiveness of these integrated platforms in fostering not only knowledge acquisition but also engagement system and skill development. This advancement enriches the academic discourse by presenting a practical model that can be adapted for broader educational and industrial applications, thus bridging theoretical frameworks and real-world implementation.

5.1 Conclusion and Resolution of Research Questions

This study successfully addresses the questions posed in the introduction by demonstrating how interactive learning platforms that integrate STEAM education with gamification can effectively enhance creative thinking and computational skills in teacher education. The research confirms that a structured, gamified STEAM approach promotes deeper engagement and practical skill development, fulfilling the need for innovative educational strategies plan highlighted in the literature. By implementing and evaluating the I-LPS

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framework, this study provides a cohesive argument supporting the adoption of gamified STEAM learning environments to prepare educators and learners for the challenges of a knowledge-driven economy. These findings offer a comprehensive understanding of how such frameworks can bridge theoretical insights and practical application, positioning them as essential tools for future educational and professional development.

Contributions and Justifications

The contributions of this study lie in the strategic integration of STEAM education and gamification within an interactive learning platform designed for teacher education. Justification for these choices stems from comprehensive literature supporting the enhancement of creative thinking and computational skills through interdisciplinary and engaging learning environments. The management of key influencing factors—such as learner engagement, interdisciplinary content, and the balance between gamified elements and pedagogical objectives—was carefully considered to ensure the platform's efficacy. The structured approach, validated by empirical data, demonstrates that these components collectively foster deeper learning and practical skill development. This integration aligns with educational frameworks emphasizing active, participatory learning and the preparation of educators who can cultivate innovative, problem-solving capabilities among students.

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