Increasing Programming Self-Efficacy (PSE) Through a Problem-Based Gamification Digital Learning Ecosystem (DLE) Model

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The researchers initially undertook a systematic literature review concerning problem-based learning (PBL), gamification, digital learning ecosystems (DLE), and programming self-efficacy (PSE). Using recent studies and papers from Google Scholar, a preliminary gamified and DLE model was proposed to help Thai students PSE. Further analysis was conducted on gamification mechanics, dynamics, and aesthetics (MDA). After an assessment by nine educational experts using four educational assessment tools from the Joint Committee on Standards for Educational Evaluation (JCSEE) of the proposed seven-step A3S3R (advise, assign, analyze, search, synthesize, summarize, and report) DLE Management Model, the model's suitability was judged to be 'very high' (mean = 4.40, SD = 0.59). Consequently, the development of this learning management model will result in learners recognizing their abilities better in programming and having better programming skills. It can also potentially increase students' critical and analytical thinking skills and computational thinking and allow them to apply new knowledge or skills to new situations. Finally, researchers can develop new practical learning styles for use in teaching and learning.

Keywords: digital learning, gamification, problem-based learning, programming skills, Thailand

INTRODUCTION

In an era where the world is changing rapidly, the challenges of cutting-edge technology, sluggish economies, and the havoc of the COVID-19 global pandemic have resulted in every organization needing more and more skilled workers to meet the changing and challenging 21st century related work environments (Wongdaeng & Hajihama, 2018).

Beyond the needs for things such as digital literacy, computational thinking (CT) (Aumgri & Petsangsri, 2019), and critical thinking skills (CTS), programming skills have also been identified as a necessity for economies moving more and more into robotics and the Internet of Things (IoT) (Durak et al., 2019; Hutamarn et al., 2017). As a result, people must adjust accordingly, transitioning from 3rd generation related skills to 4th generation digital knowledge worker skills (Ruenphongphun et al., 2021). In Thailand, this has been identified as Thailand 4.0 (Duangpummes & Kaewurai, 2017; Intaratat, 2021).

Therefore, educational institutions are one group that can help create quality individuals that meet the needs of the changing working world. However, these students moving from their academic lives into the real-world workforce must believe they are capable, have patience and perseverance, and are not easily discouraged.

These ideas are supported by many years of scholarship. One recognized leader in the importance of a person's perception and belief in their abilities is articulated by Bandura (1986, 1989, 1997), whose *Social Cognitive Theory* (SCT) implies that the perception of one's abilities directly affects the actions of an individual. Even when people have different abilities, they can be expressed in different qualities.

Using SCT as the tool for evaluation, Compeau and Higgins (1995) observed that students, who interacted with IT systems, influenced their performance ability behavior (self-efficacy) and the perception of their expected outcomes. Therefore, PSE (programming self-efficacy) is a student's belief that they can do a computer-related job and that their self-efficacy in using computers affects their expectations about their future success.

However, researchers have found that in Thailand, ICT (information communication technology) student use has no significant effect on educational outcomes unless tailored to educational proposes (Srijamdee & Pholphirul, 2020). Also, in Thailand, numerous studies and teacher observations have detailed the problems in achieving the desired results in 21st-century student skills such as analytical thinking skills (ATS), CTS, computational thinking, and problem-based learning (PBL) skills (Aumgri & Petsangsri, 2019; Hutamarn et al., 2017; Meepung et al., 2021).

Furthermore, years of Thai student Programme for International Student Assessment (PISA) testing and its subsequent analysis have highlighted the continued drop in test scores. The drop in scores highlights the potential future danger to the nation's economic vitality as Thailand's export economy is highly dependent on highly skilled and digitally-enabled knowledge workers who possess higher-order thinking skills (HOTS) (Kruger, 2013; Yangjeen et al., 2021).

Related to PISA score drops in science and mathematics, it has been pointed out that in some Bangkok urban universities, multi-year failure rates in computer programming are as high as 1/3 of the class enrollment each year. This is consistent with Bergin and Reilly (2005), who have reported that in Computer Science Education (CSE) courses in the United Kingdom, many students have problems with programming courses, which frequently leads to high dropout and failure rates. In the United States, internal ACM Education Council reports have noted that failure rates for programming students in colleges can be as high as 90%. In contrast, in large (4,000 plus students) universities, failure rates can reach 72% (Bennedsen & Caspersen, 2007, 2019).

Thus, many instructors and institutions are looking to alternative teaching pedagogies such as *flipped* and *blended learning* classrooms, where students have the chance to 'master' their content anywhere or anytime (Khan, 2016; Özyurt & Özyurt, 2018; Pattanaphanchai, 2019). Others are even attempting to combine PSS and educational games to teach computer programming courses (Mathew et al., 2019) and robotics programming (Durak et al., 2019).

However, educational games have evolved, and now the terms 'Gamification' and 'GamiLearning' have moved into the educational arena for schools, industries, and governments. Having originated as early as 2002 (Kim, 2015), gamification attempts to bring some element of 'fun' (gaming) into learning as well as 'rewards' for the player's success (Chou, 2013). Therefore, gamification uses game design components in a non-game context (Deterding et al., 2011).

Related to the above issues, and just as critical is Thai student success in acquiring ICT skills and programming skills (Chardnarumarn et al., 2021). As Thailand tries to implement its Thailand 4.0 vision for the future, at the core, a required workforce can program robots and implement and sustain a highly robust ICT infrastructure. However, these students who later become the backbone of the labor force must also be confident and believe in their potential for success (Hines & Lynch, 2019).

This is consistent with studies out of Taiwan, in which students' PSE was examined. Results revealed positive correlations between computer programming experiences and self-efficacy and self-efficacy and learning efficiency (Tsai, 2019; Tsai et al., 2019).

Given the problems and importance of the above overview, the researchers set out to investigate which learning management styles were best suited to a learning management model that can overcome the problem of lack of basic knowledge and skills and high dropout rates of computer programming students.

LITERATURE REVIEW

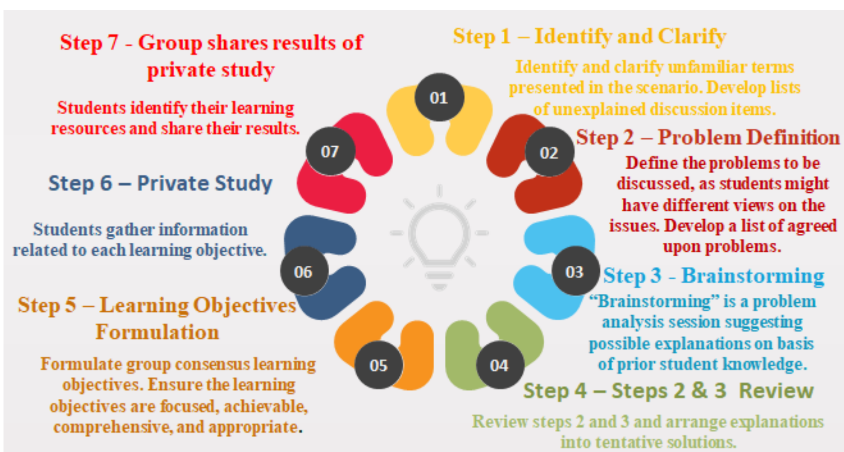
Problem-Based Learning (PBL)

Problem-based learning (PBL) is often a method in which a student-centered approach to education is used in learning a topic (Abdullah et al., 2019). PBL is also focused on allowing students to solve open-ended problems and is a self-direct learning (SDL) approach to education (Leary et al., 2019). In instances where PBL has been combined with virtual elements and 3D design to teach computer science, academic achievement was higher than traditional coders, increasing learner engagement, knowledge acquisition, and SDL (Banic & Gamboa, 2019).

According to Wood (2003), PBL tutorials can be conducted in multiple ways, with the Maastricht "seven jump" process commonly used (Figure 1). Therefore, PBL management models are based on experience-based education, where learners can practice their ideas, learning both the content and the thinking strategies necessary to solve complex problems (Hmelo-Silver, 2004).

Also, in PBL environments, instructors act more as facilitators than teachers as they guide the students towards where the knowledge might lie but not the answer to the problem. PBL education has also been identified in enhancing 21st-century skills, which numerous studies have identified as vital for learner development, lifelong learning, and becoming essential knowledge workers (Wongdaeng & Hajihama, 2018).

FIGURE 1
PBL TEACHING METHODS USING THE MAASTRICHT "SEVER JUMP" PROCESS



Source: Adapted from Wood (2003).

Gamification

In the simplest of terms, gamification is defined as the use of game design elements in a non-game context (Deterding et al., 2011), whose learning outcome intent is to encourage learner participation through a process of educational games which award rewards for their participation success.

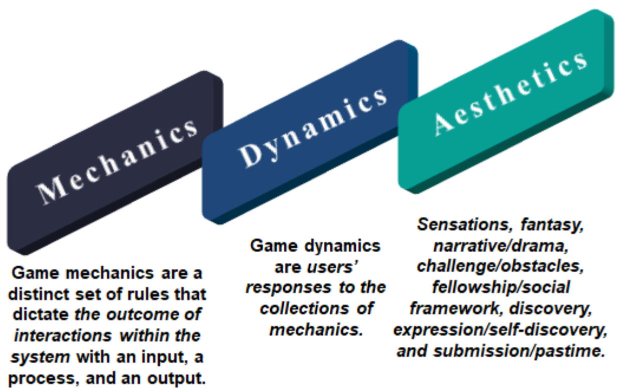
Gamification can also promote good social behavior and thinking within the constructs of games (McGonigal, 2015; Simoes, 2015). Marketers and businesses can use it to generate business (Kim, 2015;

Ryan & Rigby, 2011). Gamification educational management models also motivate learners and their teamwork while having fun in the learning process (Kummanee et al., 2020).

Furthermore, according to Kim (2015), gamification should include multiple game design elements to be successful. These include mechanics, dynamics, and aesthetics, labeled the MDA Framework (Hunicke et al., 2004) (Figure 2). In simple terms, it is the rules, system, and fun that users experience.

Recurring game elements include points, badges, levels, leaderboards, challenges, rewards, avatars, teams, narratives, treasures, and ranks. The game dynamics are the behavior of the game mechanics or describe the behavior of human needs that arise from the game's mechanics or stimulation/driving action in the game. Emotions or game aesthetics are the responses to the emotional needs that arise from the players while interacting in the game, including their satisfaction and fun in the game.

FIGURE 2
THE GAMIFICATION MDA FRAMEWORK



Source: The Authors (2022)

Digital Learning Ecosystem (DLE)

A digital learning ecosystem (DLE) is an interactive online learning system that can help determine the level of understanding of the learners systematically using a learning management component (Meepung et al., 2021; Pane et al., 2015; Schmid et al., 2020).

A DLE also encourages learners in lifelong learning by giving them more flexibility in how, when, and where they learn (Khan, 2016; Sarnok et al., 2019). DLEs are also a teaching and learning style explored to achieve 21st-century learning goals and the necessary integration of digital technologies and teaching management tools (Gütl & Chang, 2008). Other authors have also suggested that ecosystem development and implementation are useful tools across a broad spectrum of human-generated processes and structures (Averian, 2018; Pickett and Cadenasso, 2002).

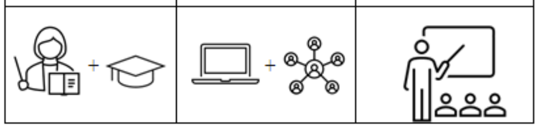
Digital Learning Ecosystems are also a valuable tool to teachers in that they help them improve their content for learners and better organize interactive teaching activities. Digital Learning Ecosystems can also help give students suggestions and help prepare and present student progress reports.

Moreover, a DLE has the potential to take non-traditional digital learning methods and techniques and diversity and shift the paradigm towards a student-centered approach. This paradigm shift to digital learning spans multiple platforms (e.g., flipped learning, blended learning, and e-learning) and digital devices (e.g., desktop computers, laptops, tablets, and smartphones) (Figure 3). DLE has gone far beyond its acceptance as excellent tool in creating student creativity, critical thinking, computational skills, and motivation, to something that became a critical necessity for education under the '*New Normal*' of online learning during the global COVID-19 pandemic (UNESCO, 2020).

Therefore, studying how a DLE can complement a child or young adult's development can create a new progressive educational paradigm in which a learning society progresses to a society of cognition with learning (Spours & Grainger, 2017; Wraithmell, 2021).

FIGURE 3
DIGITAL LEARNING ECOSYSTEMS

(1) Teachers and learners.	(2) Computer equipment, media, programs, and the Internet.	(3) Interaction and learning activities.



Source: The Authors (2022)

Programming Self-Efficacy (PSE)

The global importance of ICT education for PSE comes from numerous studies. In one such study, Gorson and O'Rourke (2020) interpreted PSE as a student's belief in their ability to complete programming tasks, which significantly affects their decision to remain in computer science (CS) studies. This is consistent with Hines and Lynch (2019), who also found that a student's lack of PSE can contribute to a high dropout rate in university CS programs.

Gurer and Tokumaci (2020) and Kanaparan et al. (2019) also added that students' attitudes or beliefs about programming and their PSE positively affected their learning and significantly influenced their learning outcomes. Erol (2020) in Turkey also discovered a significant and positive connection between robotic design activities and the researcher's university students' attitudes towards programming and PSE. Ozturk (2021) also examined how student computational thinking (CT) and PSE development were related and determined that the students' PSE beliefs improved significantly as CT improved. Moreover, in a similar study, Durak et al. (2019) examined 55 secondary student problem-solving skills (PSS) and their influence on CT, PSE, and robotics programming. The findings revealed that students' grade year influenced their CT and PSE. Also, Günbatar (2020) examined student computational thinking skills (CTS), computer programming skills, and PSE and found that computer PSE was a significant predictor of CTS. Finally, Yildiz and Gündüz (2020) examined how peer instruction affected secondary school computer programming teaching and student PSE. Results showed that peer instruction increases students' PSE perceptions greater than traditional teaching methods.

Therefore, self-efficacy is a personal belief in the ability to complete tasks and influences student decision-making (Gorson, 2020), with self-efficacy leading to learners' success in programming (Ramalingam & Wiedenbeck, 1998).

METHODS

Research Objectives

The study's main objective was to increase programming self-efficacy (PSE) through a problem-based gamification digital learning ecosystem model. To do this, three phases were undertaken. There were:

- **Phase 1 -** The researchers reviewed previous studies through a systematic review in the fields related to *problem-based learning (PBL), gamification, digital learning ecosystems (DLE),* and *programming self-efficacy (PSE)* (Junior et al., 2019).
- **Phase 2 -** From this analysis, a digital learning ecosystem management model using gamification was developed to increase Thai student PSE using an online DLE.
- **Phase 3 –** An assessment was performed on the proposed model.

Phase 1 - Systematic Review

The researchers first undertook a systematic review of the literature using Google Scholar, in which purposive sampling was used to target English language references from 2018 or later. Target papers were concerned with *problem-based learning (PBL), gamification, digital learning ecosystems (DLE),* and *programming self-efficacy (PSE)* (Hussin et al., 2019). Subsequent analysis revealed a mix of published academic journal papers, doctoral theses, reports, and related studies on these topics.

Phase 2 - Management Model Development

Development of the digital learning ecosystem (DLE) model was undertaken using PBL gamification to promote Thai student PSE.

Phase 3 - Management Model Development Assessment

Assessment of the digital learning ecosystem (DLE) model used nine academic experts who had obtained a Ph.D. and had at least five years of education teaching experience in their related fields. This included three experts in curriculum design and teaching, five experts in technology and innovation, and one expert in psychology.

Data Analysis

Assessment of the model's suitability was accomplished using the JCSEE monitoring/evaluation process in which *propriety standards, utility standards, feasibility standards*, and *accuracy standards* were assessed (Kelly & Reid, 2021; Laksanasut, 2022; Ruhe & Boudreau, 2013; Yarbrough et al., 2010).

After that, descriptive statistics, including the mean and standard deviation (SD), were used to analyze the data collected. The nine experts' opinions were analyzed using IBM's® *SPSS*® for Windows Version 21 program. The mean interpretive criteria for the experts' input used 4.50 – 5.00 as '*strongly agreed.*' Next was 2.50 – 4.49 as '*somewhat agree,*' 2.50 – 3.49 as '*moderate agreement,*' 1.50 – 2.49 as '*disagree,*' and 1.00 – 1.49 as '*minimal agreement*.'

RESULTS AND DISCUSSION

The Conceptual Development of the A^3S^3R Model

Table 1 presents the researchers' results after their systematic analysis of the literature related to problem-based learning (PBL), gamification, digital learning ecosystems (DLE), and programming self-efficacy (PSE).

TABLE 1
BRAINSTORMING OUTLINE OF THE A^3S^3R DLE MANAGEMENT MODEL

DLE	**Gam.**	**PBL**	A^3S^3R Model	**Activities**	
				Instructors	**Learners**
(1) Teachers and learners (2) Computer equipment, media, programs, and the Internet (3) Interaction	(1) Game mechanics (2) Game dynamics (3) Game Aesthetics or Emotions	(1) Understand the problem.	**A**dvise	Suggest learning methods, objectives, and importance of activities. Formulate and articulate the problem.	Understand the problem received and give feedback on the problem given.
		(2) Identify the problem.	**A**ssign	Take care, advise and stimulate learners' interest.	A solution is specified. Questions are asked on topics that students are curious about and find a solution to the problem.

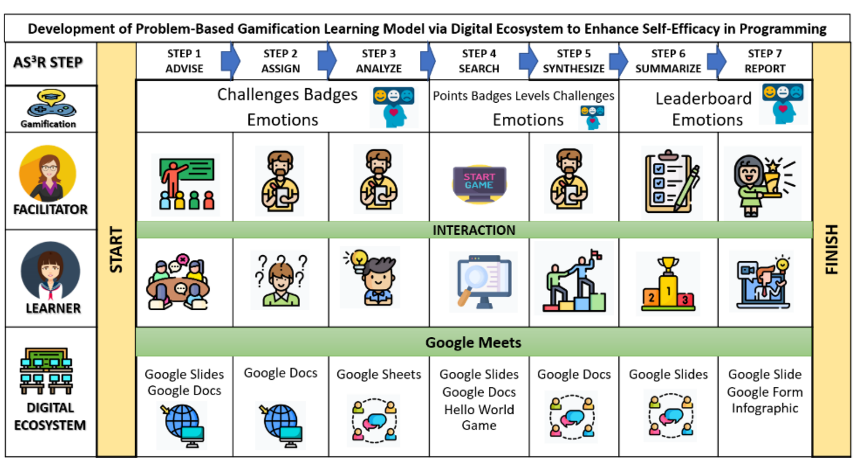
DLE	Gam.	PBL	A^3S^3R Model	Activities	
				Instructors	**Learners**
		(3) Analyze the problem.	**A**nalyze	Take care, advise and stimulate learners' interest.	Students analyze the problem rationally, summarize the knowledge, and formulate assumptions to solve problems.
		(4) Researching and collecting information	**S**earch	Introduction to the use of innovative educational games such as Hello World.	Students self-study and collect information from innovative educational games such as Hello World and Internet browsing.
		(5) Synthesize knowledge and information obtained.	**S**ynthesize	Ask provoking questions to create concepts.	Participate in in-group discussions and synthesize the knowledge gained.
		(6) Summarize the results and evaluate the answers.	**S**ummarize	Collect and rank the scores.	Students summarize their work, evaluate it, exchange information, and express opinions.
		(7) Present and evaluate the work.	**R**eport	Evaluate learning and process skills	Organize knowledge systems and present them in a variety of formats.

Note. DLE = digital learning ecosystem, Gam. = gamification, PBL = problem-based learning

A^3S^3R Model

Figure 4 details the final results for the seven-step A^3S^3R Model to increase PSE through a problem-based gamification digital learning ecosystem (DLE) model.

FIGURE 4
THE A^3S^3R DLE GAMIFICATION LEARNING MODEL



Source: The Authors (2022)

Step 1 – Advise

In the authors' proposed A^3S^3R Model, '*advise'* is introduced as the first step toward PSE development. In this step, objectives and the importance of activities are outlined. Teachers and learners talk to each other through online media, using game mechanics to stimulate students' excitement, fun, and challenges (Banic & Gamboa, 2019; Wongdaeng & Hajihama, 2018; Wood, 2003).

Step 2 – Assign

Step 2 is the '*assign*' step, where learners identify a problem-solving approach through which students can ask questions on the topics they want to know through online media. Learners who can identify solutions to problems earn additional medals through the game's mechanics. This is consistent with other reports that detail gamification and its related elements. These include emblems, points, challenges, leaderboards, and missions. Finally, gamification is a fast-growing phenomenon in higher education and STEM-related courses (Caponetto et al., 2014; Kapp, 2012; Ortiz et al., 2016).

In the *assign* step, teachers should encourage their students' interests. Here, the essential question is introduced that guides the project's inquiry, and teachers assist students in generating their questions.

Step 3 – Analyze

Step 3 entails how students '*analyze*' the problem group-based interaction, leading to hypothesis development. Students formulate assumptions for solving problems through online media. Moreover, using gamification rewards such as medals, the achievement is rewarded, generating positive feedback. Again, teachers serve as guides to the information being sought.

Step 4 – Search

Step 4 involves the '*search*' phase in the model, where each learner uses self-study and innovative educational games provided by the instructor. The Internet is used to *search* for information to answer the project's questions. Instructors encourage fun and facilitate the use of innovative media.

Step 5 – Synthesize

In Step 5, learners '*synthesize*' their knowledge from their own and group research. In this step, information is exchanged, and collaboration happens. Students receive additional medals for the knowledge gained from online media use, students receive additional medals, and the teacher asks questions to encourage further challenges.

Step 6 – Summarize

In Step 6, learners '*summarize'* their work and assess whether the research data is appropriate or not. Instructors collect and rank scores based on educational game innovations and student performance. Then the teachers and students exchange their opinions through online media.

Step 7 – Report

Step 7 is the '*report'* stage, where learners apply the information they have gathered to organize the body of knowledge and present the results in various formats. Students jointly assess their work, and Instructors assess their learning and process skills.

Suitability

Table 2 details the nine experts' standards assessment results using criteria established by the JCSEE (Yarbrough et al., 2010). Results showed that all four standards were *very high*, with the A^3S^3R Model's suitability having an overall value of mean = 4.40, SD = 0.59 (Kelly & Reid, 2021).

TABLE 2
THE A^3S^3R DLE MANAGEMENT MODEL STANDARDS ASSESSMENT

Standards Assessment Module	Experts (*n*=9)		Results
	Mean	SD	
Propriety Standards	4.41	0.63	very high
Utility Standards	4.41	0.50	very high
Feasibility Standards	4.40	0.54	very high
Accuracy Standards	4.37	0.69	very high
Overall model suitability	**4.40**	**0.59**	very high

The *very high* assessment for the study's A^3S^3R Model is consistent with other studies. The development and support of learning management models that use social interaction frameworks help promote critical thinking skills and active learner participation (Hussin et al., 2019; Meepung et al., 2021). Therefore, interactive teaching makes learning more exciting and relevant through gamification and play-focused teaching (Sebastian, 2021).

CONCLUSION

The researchers initially undertook a systematic review of the literature concerning *problem-based learning (PBL), gamification, digital learning ecosystems (DLE),* and *programming self-efficacy (PSE).* Using recent studies and papers from Google Scholar, a preliminary gamified and DLE model was proposed to help Thai students PSE.

After nine educational experts assessed using four JCSEE educational assessment tools of the proposed A^3S^3R DLE management model, the model's suitability was judged to be '*very high*.' Moreover, the model was revealed to include seven steps. These were *advise, assign, analyze, search, synthesize, summarize*, and *report* (A^3S^3R Model).

Consequently, the development of this learning management model will result in learners recognizing their abilities better in programming and having better programming skills. It can also potentially increase students' critical and analytical thinking skills and computational thinking and allow them to apply new knowledge or skills to new situations. Moreover, as a result, researchers can develop new learning styles for use in teaching and learning that focuses on practical skills for learners to develop better practical skills.

ACKNOWLEDGEMENTS

The authors wish to thank the *National Research Council of Thailand* (NRCT) for granting funding for this study. Also, thanks go out to the nine experts who participated in the study and contributed their insight and wisdom to the final model's development. The authors also wish to thank Ajarn Charlie for his contribution in editing and proofing of the multiple manuscripts.

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