Synthesis of Problem-Based Interactive Digital Storytelling Learning Model Under Gamification Environment Promotes Students' Problem-Solving Skills

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Abstract—The aims of this study were to synthesize and evaluate the efficiency of problem-based interactive digital storytelling learning model under gamification environment for promoting students' problem-solving skills. This study was divided into two phases, (i)develop learning model by studying research and related documents and (ii) assessing the appropriateness of the model by nine experts in computer and education using a focus group method. In this current study, show the learning model consisted of three main components: preparation, learning activities, and evaluation and there were four parts of the learning activities, which are: problem-based learning, reflection of learning, interactive digital storytelling, and gamification environment. The results show that the overall suitability assessment of the developed learning model was averaged at 4.56 (S.D.= 0.60), being at the most appropriate level. These results lead to a conclusion that the developed problem-based interactive digital storytelling learning model under gamification environment can significantly promotes students' problem-solving skills. This learning model is suitable and can be applied to develop desired learners' achievements and skills.

Keywords—problem-based learning, digital storytelling, gamification, learning model, problem solving skills

1 Introduction

Developing problem-solving skills is a person's ability to deal with problems that arise using old and new experiences with planning and the process of solving problem rationally and appropriately [1, 2]. Problem-solving skills are one of the 21st century learning skills (3Rs8Cs) that necessary for living according to the national strategy. However, a study reports that Thai students have a low level in analytical thinking ability due to non-effective teaching objectives in school for analytical thinking and/or measuring analytical thinking [3]. It is necessary to improve people as human resources in all dimensions and all ages to be competent and ready to propel the country's development forward to their full potential. Educational foundation plays important role in the improvement of people In Thai education, all learners have a potential to improve themselves

according to the most important vision that "All Thai people receive quality education and lifelong learning. Live happily in line with the philosophy of sufficiency economy and changing the world of the 21st century". This vision aims to improve every learner to have the characteristics and learning skills of the 21st century 3)Rs8Cs) [4]. Therefore, effective teacher learning management according to the national education guidelines can directly affect the learners.

Learning management system affects the development of problem-solving skills of learners to focus on the thinking process that arises from real practice. Problem – based learning is a learning method leads students to face real problem situations, practice the problem analysis process, and solve problems together as a group [5, 6]. The applications of information and communication technology in the problem-based learning become a teaching aid to organize various learning activities such as presenting complex problems with images, graphics, animations, and multimedia systems. Such applications can be used to clearly simulate the situation of the lesson about phenomena or procedures [7].

Using digital storytelling in teaching and learning activities can help learners to develop skills for critical thinking and problem solving. The use of digital media for telling, exchanging, and sharing knowledge to by freely creating a piece of work that harmonizing images, music, storytelling, tone, and perspective lead to meaningful learning [8, 9, 10]. Moreover, learners can learn better when they have a self-motivation. Kammanee [11], summarized the Kurt Levin's theory of field learning as follows: organizing both physical and psychological environments to attract and satisfy the learners' needs, including creating motivation or driving force that will lead students to the desired destination, which are necessary for the learner's learning process.

Gamification learning concepts create a fun and motivated learning environment. There are important strengths of these concepts such as attracting attention and motivating learners which help teachers to achieve the objectives of teaching [12]. Gamification is leading the mechanics, dynamics, and aesthetics of the game to use in non-gaming activities for motivating learning activities, stimulating act, promoting learning outcomes, enhancing problem solving ability, and improving learner behaviors [13, 14]. Game mechanics are the main action structures whereas game dynamics are the human needs that act upon a given game mechanism in interacting with activities, the aesthetics of the game are formed. It shows that using gamification environment in learning process can give positive feedbacks on learning atmosphere and learners' emotion. As the concept of Cavanagh [15], emotions influence learning processes in at least three aspects: (i) in the presence of strong emotions, the concentration and readiness of the brain to learn increases, (ii) some emotions promote deep and connected learning, and (iii) emotions promote powerful learning. Thus, an effective learning model should adopt consistent teaching methods and technologies which can improve the learners to eventually achieve their goals. That is the importance of this study whose objectives consist of the following:

1. To synthesize a problem-based interactive digital storytelling learning model under gamification environment to promote students' problem-solving skills.
2. To evaluate a problem-based interactive digital storytelling learning model under gamification environment to promote students' problem-solving skills.

2 Review literatures

2.1 Problem-based learning

The problem-based learning is the learning approach uses appropriate problem situations as a tool to stimulate students' thinking processes [6, 16, 17]. It's focusing on problem analysis, setting learning objectives, researching data, integrating theory and practice, and apply knowledge and skills to develop possible solutions using a combination of previous experiences and new experiences and evaluate the best solution [6, 18, 19]. Working together as a group by asking and answering among different group members, learners will develop their analytical thinking skills, solve complex problems, enhance their communication skill, and improve teamwork efficiency [19]. The problem scenario is very important for this learning approach because it determines the direction of the learning process. It has to focus on questions that positively affect the motivation and interest of the learners [20].

2.2 Interactive digital storytelling

Interactive digital story telling technology helps in explaining the content, making it easy to understand and resulting in better teaching efficiency. The core of digital storytelling is being a creative storyteller [8, 21]. Interactive digital storytelling combines digital technologies such as images, audio, video clips, and text to tell stories [22, 23, 24] as well as their interactions [25]. The story that is created has to have an element of the narrator's feelings involved [25]. Digital storytelling enhances learners' digital abilities and increases learning ability about the diverse individualisms which reflect a meaningful learning [24].

2.3 Gamification environment

Gamification environment refers to an establishment of a learning environment in the nature of the game [26] that is the implementation of game design techniques and game mechanics in a non-gaming context [12, 27, 28] to stimulate and respond to basic human needs behavior. This gamification learning innovation has a positive impact on student learning abilities [29] and can be applied to any problem-solved scenario that affects human motivation and behavior [30]. This is because the implementation of the gamification can enhance motivation, satisfaction, participation in activities, teaching efficiency and learning achievement [29, 31, 32]. Game mechanics affect motivation and human behavior by many ways such as points, levels, challenges, trophies, badges or medals, virtual goods, scoreboards, etc. [33]. Each element of the game mechanics is related to human needs such as reward, status, achievement, self-expression, competition, altruism, etc., depending on how the game mechanics drive the main human needs [34].

2.4 Problem-based interactive digital storytelling learning model under gamification environment

This learning model uses digital problem situations as a tool to help learners as group forbrainstorming using systematic solving problem through storytelling, communication, sharing of knowledge and understanding of the problem-solving process. Teachers and learners are presented with a problem-solving process using interactive digital storytelling which can reflect knowledge, understanding and thought processes. In addition, this learning model is organized in a game-like learning environment and using game mechanics in a learning context to stimulate and satisfy human desire which results in joyful, motivation, satisfaction, participation in activities, and academic achievement [6, 8, 22, 25, 12, 29].

2.5 Problem-solving skills

The personal ability to find solutions through finding answers, processing to gain an understanding of concepts and meanings, organizing information and linking one idea to another to achieve goals [1, 35, 36]. Problem solving is the highest level of learning. It is complex, emphasizing on teaching to create and evaluate solutions and choose effective ones [37]. Problem solving includes advanced thinking skills such as visualization, association, abstraction, comprehension, reasoning, analysis, and synthesis. Generalization needs to be managed and coordinated [2]. Well-structured problems can be solved by algorithms and synthetic thinking. On the other hand, an approach to quasi-structured problem solving uses heuristic approaches (solutions that do not have clear guidelines or rules) and poorly structured problems require different thinking and creative problem-solving techniques [38].

3 Research method

3.1 Participants

This study included 9 participants who are computer or education experts in educational institutions, either public or private by purposive sampling. Their expertise is appropriate to develop learning model in focus group discussion.

3.2 Instrument

A master model assessment form that evaluated problem-based interactive digital storytelling learning model under gamification environment to promotes students' problem-solving skills. It consists of 2 parts which are principle and particulars of learning model using 5-rating scales (Likert rating scales). The results of suitability were interpreted from the mean values as follows: very suitable (4.50 - 5.00), suitable (3.50 - 4.49), neutral (2.50 - 3.49), inapplicable (1.50 - 2.49), and very inapplicable (1.00 - 1.49).

3.3 Procedure

This research was divided into two phases as followed:

Phase 1: studied and synthesized learning model. Initially, it was a study to find approaches for promoting problem-solving skills, study related document and research and synthesize data to develop suitable learning model.

Phase 2: Evaluated the suitability of developed learning model. This phase is the evaluation for suitability of developed learning model by organizing focus group method which appoints the assessor as a computer and education experts in educational institutions, either public or private by purposive sampling. After that, the recommendations of experts were applied to improve the learning model.

4 Research finding

4.1 The synthesis results of problem-based interactive digital storytelling learning model under gamification environment promotes students' problem-solving skills

In the study of related documents and researches can be synthesized into learning models as followed:

Problem-based interactive digital storytelling learning model under gamification environment promotes students' problem-solving skills (Figure1) can be divided into 3 components: 1) preparation, 2) teaching and learning activities, and 3) evaluation. The details of each component are as followed:

Component 1: Preparation. It is a component to prepare teaching methods and teaching tools for learners. At this step, students were divide into different groups and were evaluated for knowledge and skills. There are steps as follows:

- Step 1: Prepare learning tools/learners It is the process of preparing tools for learning such as lesson plan, instruction media, measurement tools and learning system including preparing students to use clip creation tools and using the teaching management system.
- Step 2: Orientation It is the process of explaining to learners the details of teaching related to summary of course content, methods of learning using problem-based interactive digital storytelling learning model under gamification environment, using of tools, measurement and evaluation and make a positive attitude.
- Step 3: System registration It is an operation for learners to know the learning system and how to use it.
- Step 4: Pre-test Measure learners' knowledge with a quality, four-choice pre-test for learners to know their own abilities and to be compared the assessment of learning achievement between before and after learning.
- Step 5: Pre-measure of problem-solving skills Measure learners' problem-solving skills with a quality, four-choice pre-test for learners to know their own abilities and to be compared the measure of learner skills between before and after learning.

– Step 6: Make a group Divide the learners into groups of 4-5 students, at the discretion of the instructor. There are duty assignments to the members.

Component 2: Learning Activity. This component is a key element of learning model that led interactive digital storytelling and gamification technique to use in problem-based learning. There are 4 parts:

Part 1: *Problem-based learning.* A researcher studied and synthesized problem-based learning process as in Table 1.

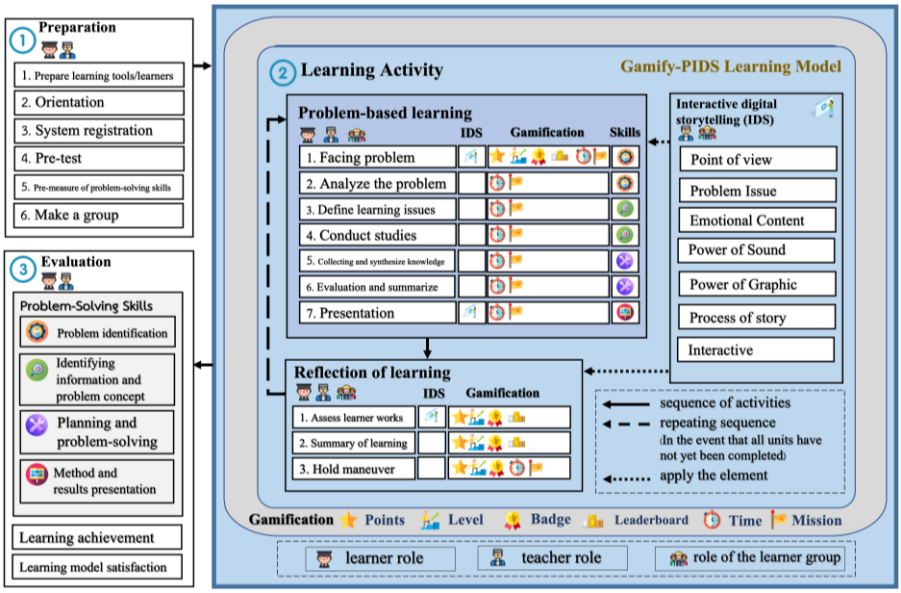

Fig. 1. Problem-based interactive digital storytelling learning model under gamification environment promotes students' problem-solving skills

Table 1. Synthesis of problem-based learning process

problem-based learning process	[39]	[40]	[41]	[42]	[43]	[44]
Connect with the problem	/	/		/		/
Setting up the structure	/					
Define the problem	/		/	/	/	
Revisiting the problem	/					
Analyze the problem		/		/	/	/
Brainstorming			/			
Identify issues that need further study				/		/
Study and research		/	/	/	/	/
Group discussion			/			
Collecting and synthesize knowledge	/			/	/	/
Summarize and evaluate answer	/	/	/	/	/	/
Presentation and evaluation	/	/	/		/	

From Table 1, the researcher synthesized the problem-based learning process that can be summarized as followed:

1. Facing problem: This step inspires the learner to study a given problem or situation. At this stage, the teacher will inform the learning objectives, explain the content of knowledge with learning activities, giving examples of problem situations, giving examples of how to solve problems. After that, the learner groups were allowed to face the problems through the given situations. The problematic situations are use interactive digital storytelling techniques to stimulate the learner's interest.
2. Analyze the problem: It is the stage which the groups of learners identifies a problem from a given situation, analyze the data using experience to describe the problem details and facts, distinguish between known and unknown information and analyze possible solution concepts.
3. Define learning issues: Groups of learners discuss to determine the important information, divide duties, and determine how to research the information.
4. Conduct studies: Learners study the learning issues that have been established. A variety of learning resources are used such as books, articles, internet, etc.
5. Collecting and synthesize knowledge: Learners have to discuss within the group about the learning issues they have studied. New information is collected and synthesized. Consideration is given to what information is necessary and consistent to support the solution idea.
6. Evaluation and summarize: Learners gather information from existing and new knowledge experience to assess the adequacy that supports the idea of solving the problem. If the information is insufficient, they have to find enough support to summarize the solution.
7. Presentation: In this step, the students' learning process is reviewed at each step of problem-based learning that summarized and presented in an interactive digital storytelling technique for better learners' understanding.

Part 2: Reflection of learning. A reflect of learning that give feedback on knowledge and skills to learners for self-improvement and this process use gamification component in every step, divide into 3 steps:

1. Assess learner works: Instructors assess student group performance scores for the completeness of problem-based learning procedures and presentations. Using interactive digital storytelling techniques and give suggestions for learner's improvement. In addition, students can vote the best group work. Instructors summarize the group votes with the best performance to give awards.
2. Summary of learning: The Instructors summarizes the learning outcomes, the main points of the content being taught, and gives learners the opportunity to ask questions or doubts in the course. At this stage, the results of the learner group with the highest score are also announced and awarded.
3. Hold maneuver: The learners were assigned a problem question and use their knowledge and skills to practice problem-solving abilities.

Part 3. Interactive digital storytelling. A researcher studied and synthesized interactive digital storytelling element as in Table 2.

Table 2. Synthesis of digital storytelling element

Digital storytelling element	[45]	[46]	[21]	[47]	[24]
Point of view/Set a narrative perspective	/	/	/	/	/
A dramatic question/Key point of the story	/	/	/	/	/
Emotional content	/	/	/	/	/
The gift of your voice	/	/		/	/
The power of the soundtrack	/	/		/	/
Image, animation, and video			/		
The richness of story					/
Story line					/
Economy	/	/	/		
Pacing	/	/			/
Publishing and presentation			/	/	
Developing Craftsmanship			/		

From Table 2, the researcher synthesized 6 elements of digital storytelling as followed:

1. Point of view: It is the perspective of the storyteller that conveys the story. It could be the perspective of the narrator himself, someone close to him, or someone outside the event.
2. Problem Issue: Issues or questions of the story that need to be answered.
3. Emotional Content: It is an emotional story presentation element which makes the audience feel emotional with the story.
4. Power of sound: The use of voice acting, music, and sound effects can be appropriately used to accompany the story.
5. Power of graphic: It's an element to bring an image or animation to compose the story. Graphics in and out effects are applied, as a result, the narrative communicates better.
6. Process of story: It is a method of telling a story that is a problem or question with a plan to present from the beginning to the end of the story that concise and easy to understand.
7. Interactive: Storytellers are designed digital storytelling to allow users to interact with multimedia, such as mouse clicks, keystrokes, touching the screen, etc.

Part 4: Gamification Environment. The researcher studied element of gamification environment that use in problem-based learning and reflection of learning steps to motivate learners. It shows in Table 3 as followed:

Table 3. Synthesis of gamification environment

Gamification environment	[30]	[13]	[48]	[49]	[50]
Points	/		/	/	/
Goals/Mission/Challenge		/		/	/
Rules		/			
Levels	/	/	/	/	/
Leaderboards	/		/	/	/
Conflict, competition, or cooperation		/	/		
Time		/	/		/
Reward		/			
Badges	/			/	/
Onboarding	/				
Challenges and quests	/				
Virtual goods			/		
Feedback		/			
Progress bar				/	
Social engagement loops	/				
Story layout			/		
Unlock				/	
Event feed				/	
Testing				/	

From Table 3, the researcher synthesized the gamification environment element that can be summarized as followed:

1. Points: It is an element used to measure the results of work or tasks as assigned. This represents an achievement that will affect the human desire for rewards.
2. Level: Mechanisms that create a sense of progression and challenge in the game. This requires knowledge, skills, and experience from work.
3. Badges: A mark that indicates the success of achieving one of the mission goals or showing the special characteristics of the learners.
4. Leaderboard: Game mechanics that motivate learners to feel challenged to compete with other learners. It is a system to show the cumulative score of the group of learners who have received the highest number of points which motivated to complete the mission and have the best score.
5. Time: It is the element that sets the framework for completing the mission in the timeframe available that encourages students to manage their time and missions effectively.
6. Mission: Assigning tasks to winning or solving problems to achieve the goal that gives learners the challenge, motivation to earn rewards or achievement points for completing a task.

In the implementation of gamification techniques, there have to be always a structure or guidelines for each element of a gamification before learning, for example, what are

the criteria for earning points? when the learner will be level up? What are the missions and conditions? or how long does it take to complete the task? Etc. This depends on the appropriateness of each learning context in which the gamification techniques are applied. These have to be motivated enough to lead a better learning outcome.

In teaching activities in the Gamify-PIDS model, it is a teaching and learning process based on problem-based learning and reflection of learning that take the elements of interactive digital storytelling and gamification environment to occur at each sub-stage of learning. All these processes are organized in a single learning unit and repeat until all the learning units complete in that course.

Component 3: Evaluation. The components that teachers study the results of Gamify-PIDS learning model are assessed in 3 parts as followed:

Part 1: Problem-solving skills. The researcher synthesized of problem-solving skills components for evaluate leaners skills, it show in Table 4 as followed:

Table 4. Synthesis of problem-solving skills components

Problem-solving skills	**[51]**	**[52]**	**[53]**	**[54]**	**[55]**
Problem identification	/	/	/	/	/
Identifying the cause of the problem/ Explore the problem/Problem analysis	/	/	/	/	
Problem solving planning	/	/	/	/	/
Finding information to solve problems					/
Collecting, Analyzing, Synthesizing					/
Problem solving simulation		/	/		
Proof the answer/Check the Solution	/	/	/	/	/

From Table 4, the researcher synthesized the problem-solving skills that can be summarized as follows:

1. Problem identification: Ability to identify problems, cause, and condition of problems in accordance with the situation.
2. Identifying information and problem concepts: The ability to collect information that corresponds to the problem and considering possible problem-solving.
3. Planning and problem-solving: The ability to plan work and solve problems according to the planned steps correctly and appropriately.
4. Method and results presentation: It is the ability to present detailed troubleshooting steps and the result of solving the problem completely.

Part 2: Learning achievement. It is a post-test to measure learners' knowledge with a quality 4-choice test and is consistent with the learning objectives. There was a comparison of academic achievement between before and after test.

Part 3: Learning model satisfaction. After completing the learning process, learners assessed their satisfaction with 5-rating scale to the problem-based interactive digital storytelling learning model under gamification environment promoting students' problem-solving skills.

4.2 The suitability assessment results of problem-based interactive digital storytelling learning model under gamification environment promoting students' problem-solving skills

The suitability assessment of developed learning model was organized a focus group method by 9 experts who have assessed and given suggestion with using 5-rating scales in 2 sections as follows:

- Section 1: Principles and concepts of problem-based interactive digital storytelling learning model under gamification environment promoting students' problem-solving skills.
- Section 2: Details components of problem-based interactive digital storytelling learning model under gamification environment promoting students' problem-solving skills.

The suitability assessment results of principles and concepts for problem-based interactive digital storytelling learning model under gamification environment promoting students' problem-solving skills is shown in Table 5.

Table 5. The suitability assessment results of principles and concepts

Description	Average	Standard Deviation	Interpretation
1. Appropriateness of principles for developed learning model	4.11	0.33	suitable
2. Suitability of learner's characteristics for concepts of learning model	4.22	0.67	suitable
3. Appropriateness of learning process	4.00	0.59	suitable
Overall Section 1	4.07	0.54	suitable

Table 5 was showing the suitability assessment results of principles and concepts for developed learning model in section 1 that is had overall evaluation in suitable level (Mean = 4.07, S.D. = 0.54).

The suitability assessment results of components detail for problem-based interactive digital storytelling learning model under gamification environment promoting students' problem-solving skills is shown in Table 6.

Table 6. The suitability assessment results of principles and concepts

Description	Average	Standard Deviation	Interpretation
Component 1: Preparation	4.70	0.46	very suitable
Component 2: Learning Activity	4.61	0.57	very suitable
2.1 Problem-based learning	4.65	0.48	very suitable
2.2 Reflection of learning	4.30	0.54	suitable
2.3 Interactive digital storytelling	4.52	0.72	very suitable
2.4 Gamification Environment	4.81	0.39	very suitable
Component 3: Evaluation	4.81	0.55	very suitable
3.1 Problem-solving skills	4.78	0.64	very suitable

Description	Average	Standard Deviation	Interpretation
3.2 Learning achievement	4.89	0.33	very suitable
3.3 Learning model satisfaction	4.89	0.33	very suitable
The consistency of learning model	4.22	0.67	suitable
Correspondence between steps and activities and problem-solving skills.	4.11	0.78	suitable
Possibility of implementing the learning model	4.33	0.50	suitable
Overall Section 2	4.61	0.59	very suitable
Overall	4.56	0.60	very suitable

Table 6 showed the suitability assessment results of details components for developed learning model. The overall section 2 evaluation in very suitable level (Mean = 4.61 S.D. = 0.54). When considering each component, it was found that all elements can be interpreted as very suitable and are sorted in descending order as evaluation (Mean = 4.81 S.D. = 0.55), preparation (Mean = 4.70 S.D. = 0.46) and learning activity (Mean = 4.61 S.D. = 0.57). When considering the learning activity component, it was found that the gamification environment implementation was the most appropriate, with a mean of 4.81. Overall, the assessment of the appropriateness of the developed learning model was at the level of very suitable)Mean = 4.56, S.D. = 0.60).

5 Discussion and conclusion

From the synthesis of problem-based interactive digital storytelling learning model under gamification environment promoting students' problem-solving skills by studying related documents, three components were found as preparation, leaning activities, and evaluation. In the learning activities component, there is problem-based learning that uses interactive digital storytelling to stimulate students' thinking and achieve meaningful learning from telling the solution that has been thought up. The setting of the game environment uses game mechanics including points, levels, badges, leaderboards, time, and challenges. It is a structure to drive learning activities. In line with different studies [5, 10, 56, 57] that have taken problem-based learning digital storytelling or game techniques to develop learning achievement, skills which requires motivation to accomplish meaningful learning.

An assessment of a developed learning model that held group discussions by nine experts to express their opinions, exchange learning, and considering the appropriateness of the details, it was found that the average of suitability for learning model was at the highest level demonstrate that the learning model is appropriate and could be used to develop learning achievement and skills. This is because the learning activities component is an important element that directly contributes to effective learning. There is a problem-based learning component, which is the main learning process that enabling learners to have a systematic thinking process and solving problems as well as constructing knowledges [58, 59] along with the use of interactive digital storytelling to stimulate l learning ability, reflecting students' thinking in a systematic way which lead to meaningful learning [60, 61, 62]. The creation of a learning environment in the

context of a game is the component that results in the highest suitability assessment in learning activities. This is because experts think that the element is suitable, interesting, and applicable to the learner's context for motivation [63, 64, 65]. Every component is consistent and combined into an innovative, learner-centered learning style that can develop learners' skills and achievement appropriately.

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