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Original Paper

Gamified Learning Environment with Block-based Programming to Enhance System Thinking in Grade 9

Patchara Pawnsawan, PhD[1]

[1] Educational Research Development and Demonstration Institute, Srinakharinwirot University, Nakhon Nayok, Thailand

Abstract

The purposes of the research study were: 1) to design the gamification learning environment with block-based programming to enhance system thinking in grade 9. 2) to study the ability in system thinking of student after using the gamification learning environment with block-based programming The samples of the research were 30 students who study at Ongkharak Demonstration School, Srinakharinwirot University during academic year 2019. The research tools were 1) the gamification learning environment with block-based programming and 2) The system thinking evaluation form.

The findings were as follows: 1) the gamification learning environment with block-based programming to enhance system thinking in grade 9 consists of 1) Game Mechanics and Game Dynamics 2) block-based programming lesson plan. 2) The comparation result of the system thinking of students before with after studying with gamification learning environment with block-based programming showed that students who study with said environment have higher score at .05 level, considering as high level of system thinking ability.

Keywords: Gamification, Block based programming, System Thinking

1. Introduction

Learning objectives at present are different from the past due to changes in the socio-economic environment. Technologies are adopted in daily life and in the manufacturing and service industries to improve the quality of life, resulting in changes in people's way of life and the society. Advancement in computing and communications technology is used as a tool for improving learning efficiency. Learning about information and communications technology (ICT) alone may not be enough for living in the digital economy where knowledge and skills are required to solve practical problems or develop innovations and use information and communications technology resources to create knowledge or add creative value (IPST, 2018). This is in alignment with the Seven C's of 21st century learning skills: 1) critical thinking and problem solving 2) communication, information and media literacy 3) collaboration and leadership 4) cross-cultural understanding 5) computing and ICT literacy 6) career and learning self-reliance and 7) creativity and innovation (Wijarn Panich, 2012)

Systems thinking is an important intellectual skill for 21st century learners. With systems thinking capability, learners are able to look beneath the surface of an event and see its structure. According to Anderson and Johnson (Anderson & Johnson, 1997: 5) and Montree Yamkasikorn (2003: 2), there are three levels of system thinking: the event level, the pattern level and the structure level. When an event occurs, one will try to understand what the causes of the event are then figure out the causal connection between them. Systems thinking is a holistic approach and focuses on connections and causal relationships between components. It allows a person to deeply understand the problem and its structure and as a result, the person makes a decision and solves the problem differently (Ruetairat Chidmongkol & Somyot Chidmongkol, 2017). Systems thinking is also in line with the core basic education curriculum which identifies the five key competencies of learners as communication capability, thinking capability, problem-solving capability, capability for applying life skills, and capability for technological application (Ministry of Education, 2008). The curriculum objectives are that students have analytical, synthesis, creative and critical thinking capabilities; they can rationally and appropriately solve problems

and overcome obstacles facing them; they can understand the relationship and changes of events in the society; they can seek and apply knowledge to prevent and solve problem; and they can apply these processes in their daily life.

At present, programming is considered one of the key skills in basic education (K-12). Schools adopting this idea teach computer science as a subject and integrate computational thinking into non-computing context (Weintrop & Wilensky, 2015), which is in line with the third strand of grade 9's occupation and technology learning area—information and communications technology. The strand's grade-level indicator is to have students learn the principles of working on projects that use information technology, use appropriate information technology to present the project and use a computer to create a piece of work from imagination or a task in daily life according to the principles of working on projects with conscience and responsibility, as well as learning basic programming (Ministry of Education, 2008).

The science of programming involves the ability to use tools and languages, solve a problem, design a program and apply it effectively. The process of teaching programming starts with teaching the language basics, followed by guiding students through creating structure for the system (Kirsti M. Ala-Mutka., 2004). Programming is considered difficult to learn and the quitting rate is high. It is said that it takes approximately 10 years for an amateur to become an expert in programming (Soloway & Spohrer, 1989). Common problems novice students face are their limited knowledge and their tendency to try to understand the codes line by line instead of trying to understand the program structure. Furthermore, they tend to spend little time on planning and testing codes and try to solve a problem by making small changes in the context of coding rather than analyzing the structure of the program (Kölling & Rosenberg, 1996). They also find it difficult to understand the basic concept of programming structure, design a program to do certain tasks and learn the syntax of each programming language. These problems are normally faced by students who have no problems understanding the basic principles but are unable to adapt such principles to the program structure (Derus & Ali, 2014). As a result of these problems, block-based programming approach has become an increasingly common way novices use to start learning programming and the main approach used to design a learning environment for an introductory programming course, raising the popularity of block-based programming (Weintrop & Wilensky, 2015). Block-based programming is a coding process which is designed to work like building blocks where most of the blocks are categorized by function and each block contains codes for tasks that users can create a program by arranging the blocks (IBM, 2008). Advantages of block-based programming are 1) the developed system can be reused; 2) the value of the development can be maintained at satisfactory level; 3) it does not require IT skills and expertise; 4) the system can be developed at speed; 5) APIs can be added without having to wait for system approval; and 6) it responds to user needs (Mohamad et al., 2011).

Apart from designing a learning process that promotes students' systems thinking and programming capability, maintaining the level of the capability by emphasizing, repeating and reviewing are important to the development of systems thinking skill. In an organization, the level of skills can be maintained through everyday learning, competition, reward, recognition and mentoring programs (Nandikolmath, 2015). These factors are in alignment with the elements of gamification, which is to use game mechanics and experience designed to connect to and motivate people to achieve a goal. It is an application of gaming elements to a non-gaming context (Burke, 2014). Therefore, gamification in education can promote cognitive domain, both in emotional and social aspects. In the knowledge and emotional aspects, the development can be proven when learners receive a reward for completing a level and move on to a more difficult and complex level. In the social aspect, development occurs when learners receive a mission or task that must be completed together with other learners or that involves competition; gamification can also develop their emotional intelligence (Dom ńguez et al., 2013).

The aforementioned problems and studies prompted the researcher to design a learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students, so that the students have systems thinking capability, can work and learn together to identify problems and find practical solutions, have the ability to use information technology to learn and exchange knowledge, have the enthusiasm to develop themselves and happily participate in activities with others. The objective was to develop the students so that they are able to think logically, understand and solve problems, become practitioners who can work well with others, and create suitable innovations

that can be used in the future, which are in line with the principles of 21st century learning.

1.1 Objectives

1. To design a learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students

2. To study the results of implementing the designed learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students

1.2 Hypothesis

The level of students' systems thinking capability after learning in the learning environment based on gamification and block-based programming is good or higher.

2. Methodology

2.1 Research Population

The population of this research was grade 9 students at Ongkharak Demonstration School of Srinakharinwirot University in the academic year 2019.

2.2 Sample Group

The sample group of this research was 30 grade 9 students at Ongkharak Demonstration School of Srinakharinwirot University who were enrolled in the Information Technology course in the academic year 2019. They were selected using a cluster random sampling method.

2.3 Research Variables

1) The independent variable was the learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students.

2) The dependent variable was 1. systems thinking capability.

2.4 Research Instruments

1) A learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students

2) Systems thinking capability assessment test

2.5 Research Procedure

The research procedure was divided into 2 phases.

The first phase was the development of a learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students. It involved 1) exploring and synthesizing related literature to identify the components of a learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students; 2) studying concepts and theories related to the development of the learning environment from the literature; 3) developing a learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students; 4) developing a systems thinking capability assessment test for grade 9 students; 5) writing a lesson plan using the learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students; and 6) presenting the learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students to 3 experts for quality assessment.

The second phase was studying the result of using the learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students. It involved 1) giving the students an orientation to explain the learning objectives; 2) assessing their systems thinking capability; 3) implementing the lesson plan; 4) assessing their systems thinking capability after learning in the learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students; 5) gathering the results and analyze the data; 6) concluding the results of using the learning environment based on gamification and block-based programming to

promote systems thinking capability to analyze the data and discuss the results as well as giving recommendations on how the learning environment based on gamification and block-based programming to promote systems thinking capability could be used and how to develop the learning environment.

3. Results

Phase 1: the development of a learning environment based on gamification and block-based programming to promote systems thinking capability of Grade 9 students

The results of phase 2 are as follows:

1. The components of a game-based learning environment as a result of the synthesis of the information from literature by Li et al. (2012), Dom ńguez et al. (2013), Sim ões et al. (2013), Azmi, Iahad and Ahmad (2016), de-Marcos et al. (2016), Garc á, et al. (2017), Yildirim (2017) and Özdener (2018) were game mechanics consisting of 1) points 2) levels 3) badges 4) leaderboards; and game dynamics consisting of 1) rewards 2) achievement 3) challenge. After synthesizing the components, the researcher chose Classcraft, a gamified learning management system in the form of an RPG game in which players were represented by 3 classes: guardians, healers and mages. Each class had different abilities and powers. The element of points was in the form of experience points (XP) and the element of rewards was in the form of coins that could be used to buy clothes, pets or other goods. In the game, players were ranked to stimulate competition. Players could train to level up and receive badges to show that they have completed the training successfully.

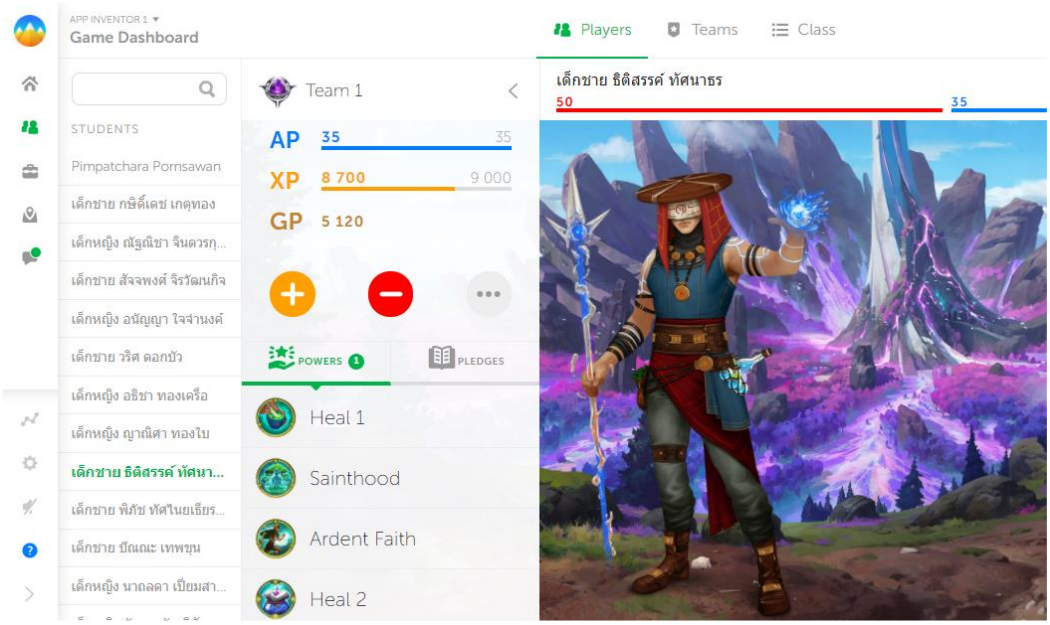

Image 1. A Screenshot of Classcraft

2. The lesson plan was divided into the following topics.

Table 1. Topics of the Lesson Plan for Grade 9 Information Technology Course

Plan No.	Topic	Period amount	Description
1	Think Like a Programmer	2	The students learn about tools used in creating mobile phone and tablet applications, the principles of system structure, and how to write an algorithm to be used in programming to show the relationship between the algorithm and processing. They practice by creating a welcome screen.
2	2 Blocks and More	2	The students learn to write an algorithm with at least two instruction sets to be used in programming to show the relationship between the algorithm and processing. They practice by creating a screensaver.
3	Shoot UFO	2	The students learn how to write an algorithm with an instruction set that gives feedback to users to be used in programming to show the relationship between the algorithm and processing. They practice by creating a simple game.
4	Algorithm to App	2	The students learn to design an application that solves a problem or respond to a user need, write an algorithm for the designed application, apply the knowledge obtained in the course to write an algorithm that has the same output but less complex codes, or write codes that work better or are more complex.
5	My App	2	The students practice by creating an application from the algorithm of the designed application.

3. A systems thinking capability assessment test consisted of 10 items. The indicators for the assessment were 1) the ability to understand the relationship or connection between system operations 2) the ability to clearly identify or decompose a problem 3) the ability to set a clear purpose of the system 4) the ability to understand the system structure 5) the ability to identify the type of a variable or a related factor 6) the awareness of factors that affect the system 7) the ability to gather and use necessary information 8) the ability to identify the impact 9) the ability to reduce the complexity of work process and 10) the suitability of the work for practical use. The systems thinking capability was divided into 5 levels with the following interpretations.

41– 50 points denoted excellent systems thinking capability.

31– 40 points denoted good systems thinking capability.

21– 30 points denoted fair systems thinking capability.

11– 20 points denoted poor systems thinking capability.

1 – 10 points denoted very poor systems thinking capability which needed improvement.

3. The design of a learning environment based on gamification and block-based programming to promote systems thinking capability

Image 2. The Learning Environment Based on Gamification and Block-based Programming to Promote Systems Thinking Capability

4. The result of the suitability evaluation of the learning environment is shown in Table 2.

Table 2. The Result of the Suitability Evaluation of the Learning Environment Based on Gamification and Block-based Programming to Promote Systems Thinking Capability

No.	Evaluated Item	Opinion Level		Suitability Level
		$\underline{X}$	*S.D.*	
1.	The result of suitability evaluation of the game-based learning environment with block-based programming to promote systems thinking	4.63	0.51	Most suitable

As shown in Table 2, the overall suitability of the learning environment based on gamification and block-based programming to promote systems thinking capability is most suitable ($\underline{X}$ =4.63, *S.D.* = 0.51).

Phase 2: Studying the result of using the learning environment based on gamification and block-based programming to promote systems thinking capability of Grade 9 students

The results of phase 2 are as follows:

Table 3. The Comparison of the Students' Systems Thinking Capability before and after Taking the Course

Systems thinking capability	**N**	$\underline{X}$	***S.D.***	**df**	**t**	**p**
Before taking the course	30	27.56	0.79	29	15.49*	.000
After taking the course	30	45.33	0.50			

*p <.05

Table 3 shows that the systems thinking capability of the students who learned in the learning environment based on gamification and block-based programming improved significantly after taking the course (p <.05) with the total score of 45.33, which meant the students' systems thinking capability was excellent. This showed that the learning environment based on gamification and block-based programming could promote the students' systems thinking capability. As shown in Table 4, students have improved in every item.

Table 4. The Comparison of the Students' Systems Thinking Capability by Item

No.	**Evaluated Items**	**Before**		**After**	
		$\underline{X}$	*S.D.*	$\underline{X}$	*S.D.*
1	the ability to understand the relationship or connection between system operations	3.03	0.96	4.43	0.50
2	the ability to clearly identify or decompose a problem	2.80	0.85	4.17	0.38
3	the ability to set a clear purpose of the system	2.83	0.95	4.53	0.51
4	the ability to understand the system structure	3.30	0.92	4.37	0.49
5	the ability to identify the type of a variable or a related factor	3.13	0.86	4.70	0.47
6	the awareness of factors that affect the system	2.50	0.68	4.57	0.50
7	the ability to gather and use necessary information	2.67	0.76	4.17	0.38
8	the ability to identify the impact	2.57	0.77	4.93	0.25
9	the ability to reduce the complexity of work process	2.33	0.61	4.73	0.45
10	the suitability of the work for practical use	2.40	0.62	4.73	0.45
Total		2.75	0.85	4.53	0.50

4. Discussion

The discussion of the research findings are as follows:

1) The learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students consists of three components. The first one is game mechanics and game dynamics, which are used to stimulate competition, collaboration, exchange and challenge. This component encourages students to willingly develop themselves and makes learning activities more fun, attractive and addictive, so that the students participate and remain engaged for an extended period of time. This is in line with Yildirim (2017) who stated that the gamification of lessons makes learners realize that a lesson is a game and they can win the game by completing all the missions. It also makes them aware of the structure of the activities and follow requirements for achievement. The competitive environment that game elements create will help the students succeed in learning because they know

what they have to do to win points, receive badges, level up and gain XP from demonstrating knowledge while completing activities. The second component is the use of a blocked-based programming language, which is a form of coding that allows students to clearly understand the system structure and encourages them to practice systems thinking. This finding is in line with Weintrop and Wilensky (2017) who stated that block-based programming turned text-based programming into building blocks containing codes. Blocked-based programming is like playing a puzzle and the order of codes used in programming is shown. In this environment, programming takes the form of dragging and dropping blocks of codes in the designated area according to syntax. If the dropped block does not comply with the syntax, it cannot be connected to adjacent blocks, preventing novice learners from making syntactic errors. The third component is the holistic approach of systems thinking which takes into consideration elements that connect to one another in a network. There are interconnections between systems and systems, between elements and elements and between systems and the environment. If there is a change in an element, the whole system is affected. This is in line with Arnold and Wade (2015) who stated that the goal of systems thinking is to think with a reductionist approach, which will help the person to see and understand changing and complex context. Systems thinking consists of three things which are elements, interconnections and a goal or function.

2) After using the learning environment based on gamification and block-based programming to promote systems thinking capability of grade 9 students, it was found that the students' systems thinking capability improved significantly. The reason for integrating game mechanics in the educational context is to encourage students to enjoy learning activities and feel challenged and engaged for an extended period of time. As a result, they practice repetitively until they complete learning missions. This is in line with the appropriate gaming elements for training identified in Li et al. (2012). The fantasy element of a computer game can make the experience more emotionally appealing to players. The presence of clear goals helps players understand the tasks they have to complete and they get rewards, which is a common approach to engage players. Feedback can be in the form of scores assigned after players complete a game a level, and the scores can also show their progress. Moreover, block-based programming enhances the students' systems thinking capability through programming structure. This is in line with Techapalokul and Tilevich (2017) who stated that block-based programming language is an effective tool for teaching basic programming to a novice. Learners and users benefit from its visual and syntax-free nature, which have made block-based programming popular both in normal classrooms and in informal education. It encourages learners to explore and learn freely, which will stimulate them to practice programming systematically.

5. Recommendations

1. There should be a session to provide foundational knowledge of block-based programming before having the students do the activity.

2. Further studies could be conducted to explore how game mechanics can be applied to other teaching methods that promotes systems thinking capability, for example, project-based learning, problem-based learning, experiential learning, etc.

3. Those who want to use the learning environment based on gamification and block-based programming to promote systems thinking capability must have knowledge and understanding of gamification mechanics, block-based programming languages and the promotion of systems thinking capability, so that they can plan the lessons accordingly.

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