The Design of 6E Model for STEAM Game Development

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Abstract: The purposes of this study aims to integrate STEAM (Science, Technology, Engineering, Art, and Mathematics) Maker education with digital game-based learning (DGBL) method for developing a STEAM game via 6e teaching model. This study develops a STEAM teaching plan and material that includes a STEAM lecture and a STEAM education game by using APP Inventor2 program. The STEAM teaching materials in APP Inventor2 will be tested and evaluated to measure their reliability and validity. Further, in this study, we will teach students through our designed STEAM lectures and then helped them to finish their creative STEAM education game in APP Inventor 2. The learning performance of STEAM education will be evaluated through our designed questionnaire. Finally, this study proposes several key suggestions for STEAM education researchers.

Key words: STEAM (science, technology, engineering, art, and mathematics), digital game based learning (DGBL), 6E teaching model, learning performance, learning motivation.

1. Introduction

Although STEM education has been developed for many years, there are always problems of "teachers" and "teaching materials." Many teachers do not have enough STEM professional knowledge to implement the curriculum, and they lack sufficient materials for teachers' reference and use [1, [2]. Current, textbooks for STEM courses mainly focus on physical operations [3]-[5]. The importance of representing STEM combined with game-based learning has gradually gained importance. In recent years, research has begun to develop computer education combined with the spirit of STEM game such as physics courses [6] and chemistry courses [7].

Since computer games can simulate real-world situations, using computer games as STEM materials can achieve a “hands-on” experience at a low cost, and can solve the problem of insufficient STEM teaching materials. The advantage of combining game-based learning lies in the fact that the simulation of computer games can give students a strong and realistic experience [7], so that the discipline is not a phenomenon that can only be read in textbooks [8]. The practical stimuli of simulated learning help students memorize more curriculum knowledge [9], making digital game technology more and more important in combination with learning content [6]. Therefore, the purpose of this study is to develop a STEAM Marker teaching material with DGBL and then uses it to improve learners’ learning performance, creativity, and motivation.

2. Literature Review

The planning of STEM educational games must conform to the concept of cross-sector learning of STEM education and integrate the four major fields of science, science and technology, engineering, and

mathematics. This study collates the STEM educational games used or developed in the past literature (Table 1) and finds the following two points: (1) The proportion of using 3D virtual rendering is quite high. If the 2D game related to the physical concept is used to simulate real physics The phenomenon indicates that the STEM education game must pay attention to the realism of the "hands-on" process; (2) Most of the games provide open exploration freedom, allowing players to trigger incidents on their own initiative to learn. Representing STEM educational games needs to be improved as much as possible. The freedom of operation allows learners to try more without limit.

Table 1. Summary of STEM Games

STEM Game	Brief introduction of the game
Name: Quest Atlantis Subject: 4th and 5th grade elementary school students Theme: geography	Game provides 3D world geographic imaging, allowing students to send lost foreigners in Turkey back to their country of origin based on clues provided by the game [10].
Name: CRYSTAL ISLAND Subject: 5th grade elementary school students Theme: science	Students will assist NPCs on the island to solve life problems and learn from science, geography, mathematical calculations and other cross-domain knowledge. [11].
Name: HOME I/O Subject: Students at high school and university. Theme: Smart control	HOME I/O simulates real-world smart houses and provides learning on topics related to automation, energy efficiency and smart homes [6].
Name: Metaverse Subject: 4th and 5th grade elementary school students Theme: Nuclear education	Metaverse combines the "online curriculum" and "virtual experimentation" functions, taking into account the links between "theory" and "hands-on" [7]。
Name: Cut the Rope Subject: 9th grade junior high school students Theme: Physics	The objects in the game all simulate the physical phenomena of the real world. Students must be familiar with the physical characteristics of each tool and apply the concepts of circular motion, pendulum, elasticity, and buoyancy to accomplish each task. [12]。
Name: Zeldenrust Subject: Junior high school students Theme: Mathematics	Let learners act as student-students, engage in refrigerator replenishment, cocktails and beverage services in hotels. The more work you do, the more money you can earn. [13]。

3. Research Method

3.1. The Development of Evaluation Materials

Phrase 1: Development of STEAM lecture and evaluation questionnaires: The teaching content planning and measurement questionnaire preparation of this study will be conducted using the expert group discussion method, bringing together relevant teachers and students in the field of physics and digital content technology to form an expert group to discuss the planning.

Phrase 2: Design of teaching activity and questionnaire reliability and validity evaluation: Validation of the teaching activities and the validity of the questionnaires will be conducted using "experimental methods." The subjects at this stage selected a college class to perform the exercises.

The experimental process is illustrated as follows:

Pre-test: Prior to the experiment, “pre-test of learning effectiveness”, “pre-test of learning motivation”, “pre-test of creativity” and “measurement of learning style” were conducted.

Learning #1: The operation was conducted by a physical balance game developed by the researcher and this stage is expected to take 30 minutes.

Learning #2: The learning focus at this stage is for students to use App Inventor to develop balance mobile games. Under the guidance of teachers, students will learn the development skills of App Inventor,

and follow the teaching steps to complete the game development. This stage is expected to cost 9 lessons.

Post-test: Conduct post-test of “learning motivation”, “learning performance”, “creativity”, “game flow”.

3.2. Research Tools

The purpose of this study was to develop a balanced digital education game and examine the impact on student learning effectiveness and motivation. Therefore, the required research tools include (1). STEM teaching activity planning, (2). Physics balance digital game,

This study uses the concepts of "physics and mechanics" and "mobile phone makers" to achieve STEM education. The teaching activity design of this study is based on the theory of "physical balance", combining the two scientific concepts of "torque and lever" and "rotational balance" as the application principle, and the development of "mobile phone program maker" as a concrete realization method. After the “Equal arm balance structure”, the students created a virtual mobile digital balance mobile game, and finally introduced the calculation of the auxiliary torque formula for the “equal axioms” and “multiple equations” mathematical solving skills.

The concept of STEAM teaching activities planned for this study is described as below. Science (S): 1. Torque and lever, 2. Turning balance; Technology (T): 1. Leverage development, 2. Leverage application; Engineering (E): 1. Equal arm balance structure, 2. Mobile APP and Maker; Art (A): 1. Design the user interface, 2. Design the graphs in game; Mathematics (M): 1. Axioms of Equality, 2. Multivariable linear equation.

The development of the teaching activities discussed in this study will follow the 6E model. While developing the lesson plans, we will consider the teaching objectives and the connotation of STEAM knowledge, and develop the contents of the “teacher teaching” activities and “student learning” activities so that teachers can play the role of guidance and understanding. The students follow the guidance of the teacher or teaching system to complete the tasks of each stage and produce learning results. The teaching model of this study is shown in Fig. 1.

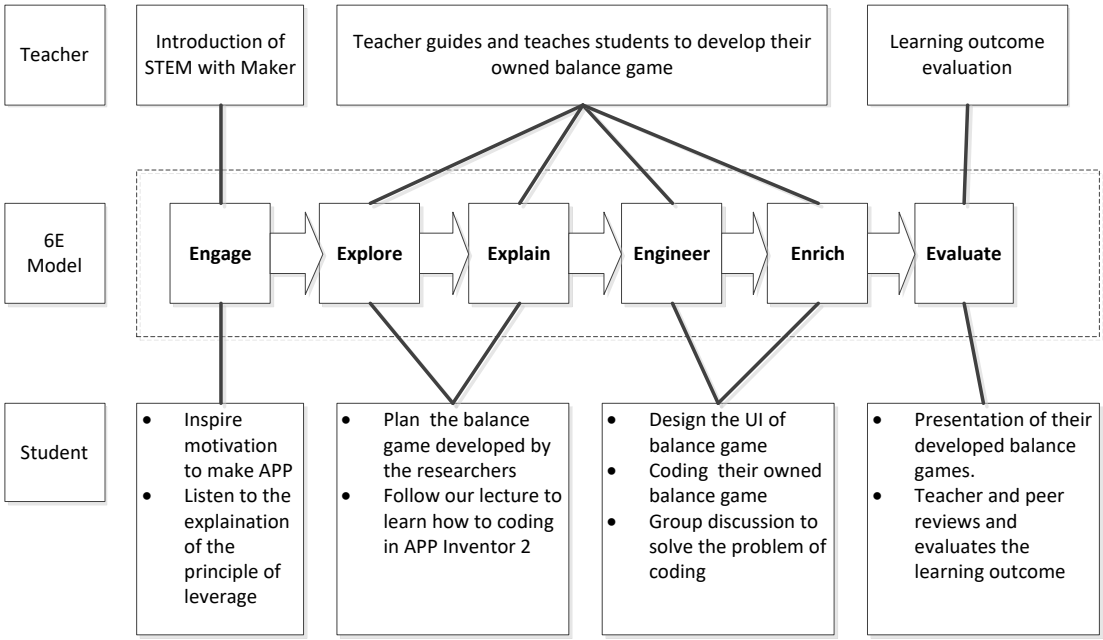

Fig. 1. 6E teaching model of STEAM.

3.3. Design of 6E Model in STEAM Game

According to the six phases of 6E teaching model development, the implementation priorities and research tools described as follows:

3.3.1. Engage

The physical theory of physics is introduced through teacher's static slides, such as the principle of moment, lever, and rotation balance, which are linked with the lesson plans of the original course.

3.3.2. Explore

The focus of this phase of study is to enable students to operate the "physical scale" digital games developed by researchers, so that students can deepen the concept of Libra operation by means of self-exploration. This game is designed as a webpage game. It integrates physical concepts such as moments, levers, and rotation balances. It also displays physical calculation formulas to facilitate the application of mathematical principles, and the problem-solving step recording system can accurately record each student's Operation history for research and analysis.

3.3.3. Explanation

The learning focus at this stage is for teachers to explain App Inventor's operating environment and program functions to students, and to practice and prepare for the establishment of "physical scales" mobile games. At this stage, we provide programming instructions for programming, such as the description of App Inventor and the functions about game development.

3.3.4. Engineering

The focus of this phase of learning is to use App Inventor to create their balance games. Students can follow the guidance of teachers and implement them in the following three stages: "conception", "game interface design" and "game programming implementation". At this stage, teachers need to demonstrate the game interface and functions in prototype game of balance game in order to help student to develop their balance games.

3.3.5. Enrich

The focus of this phase of learning is on students' creative freedom. After completing the requirement of balance mobile game by the teacher, students can add on their wanted functions and game interface to develop a unique balance game in mobile phone.

3.3.6. Evaluation

The evaluation phase of this study divided into "Learning Motivation Assessment", "Learning Effectiveness Evaluation", "Digital Learning Game Mental Flow Assessment" and "Williams Creativity Tendency Measurement Form" and "ILS Learning Styles Questionnaire". Four major projects, such as evaluating the quality of STEM program maker education and evaluating students' learning outcomes.

4. STEAM Game Design

Based on the STEAM 6E learning model mentioned above, this study designed a user interface for the prototype of the balance game (see Fig. 2) and provided it to students as a reference. The top button (-1~-5) represents the upward force. The lower column (+1 ~ +5) represents the downward force. The third column represents the sum of forces on the left and right sides. The fourth column represents that the user can place the force on the left and right forces above the position. The left button (reset) in the bottom row represents the reset game value, and the right button represents the check that the current left and right forces are balanced or not.

After adding the designed graphics, the screen for the game's completion is shown in Fig. 4. The balloon represents the upward force (-1~-5) and the weight represents the downward force (+1~+5). Players can freely choose any balloon or weight to be placed on either side of the bridge below. The program will

automatically calculate the current sum of forces on both sides. When the user presses the 'check' button, the program checks whether the forces on both sides are balanced or not. As shown in Fig. 5.

Fig. 2. Design of user interface of balance game (prototype).

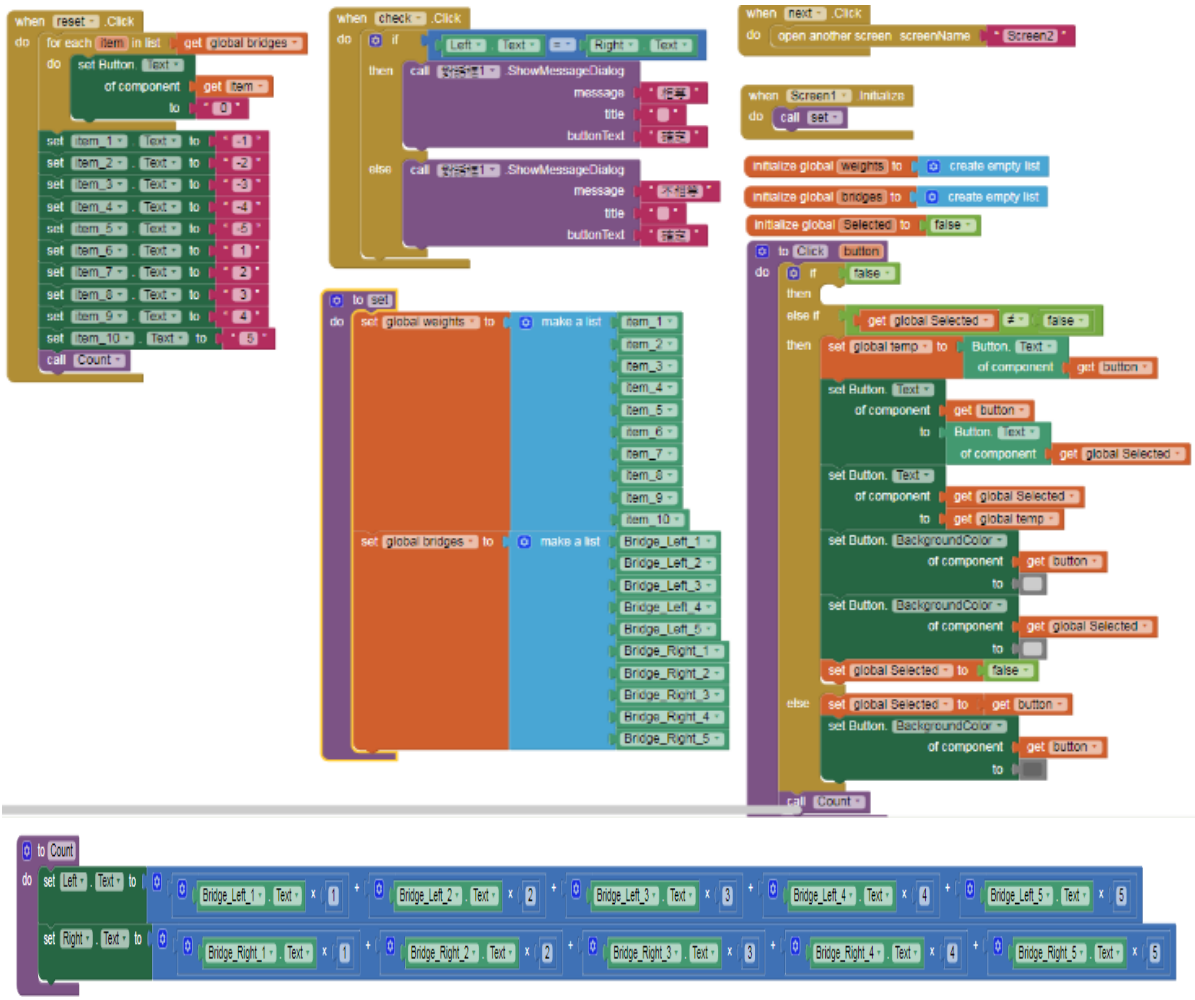

Fig. 3. Demo codes for balance game in APP Inventor2.

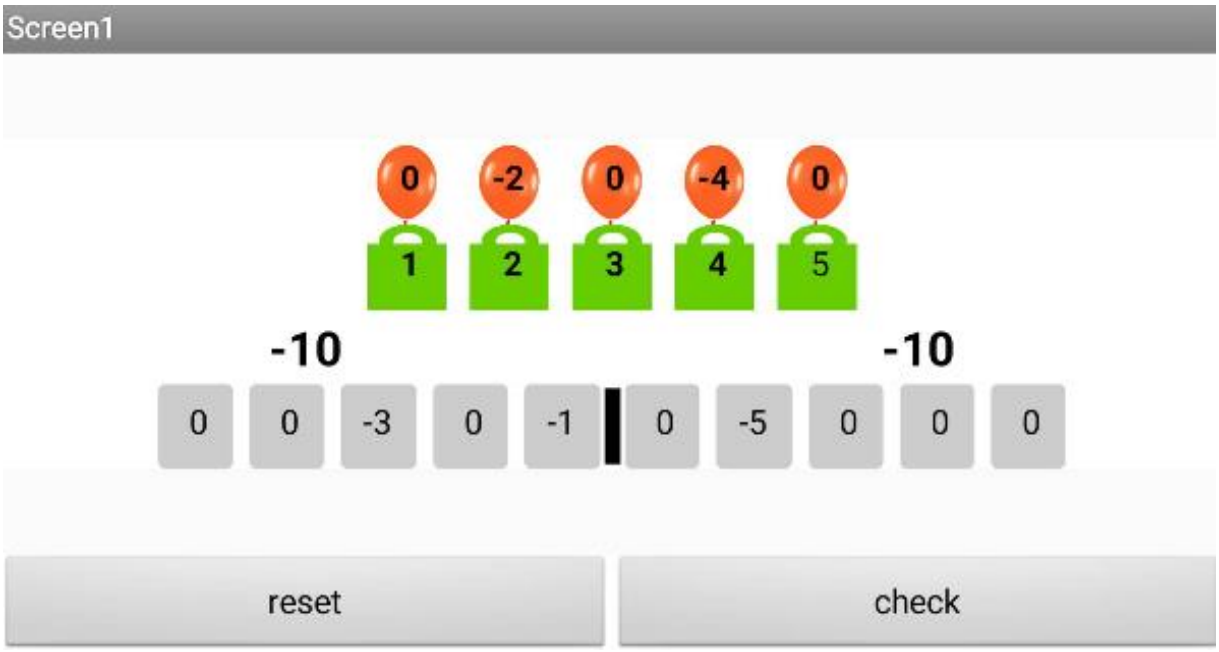

Fig. 4. Demonstration of finished STEAM balance game.

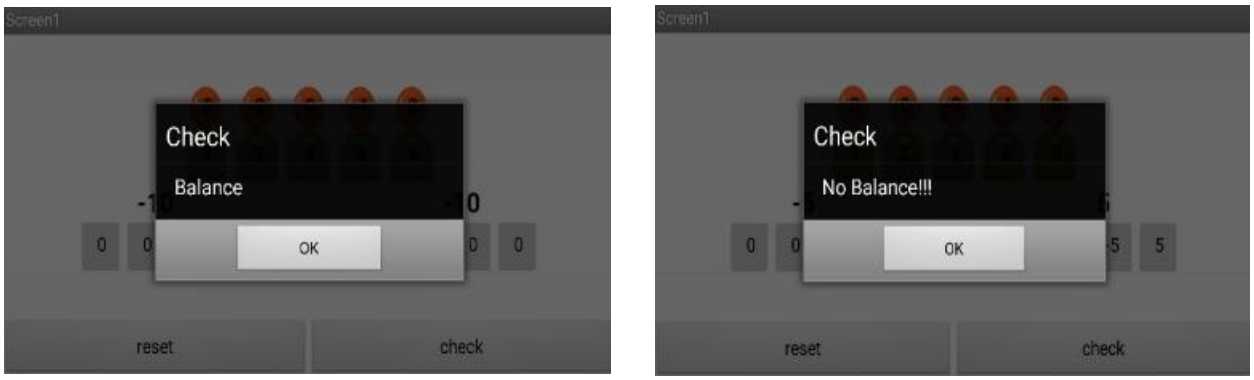

Fig. 5. Screen shot of checking balance or not.

5. Conclusions

To develop and evaluate the feasibility of combining STEM education with game-based learning, this study proposes the following research recommendations and future developments as follows.

5.1. Key Points of STEM Game-Based Learning

STEM emphasizes the learning and application of concept fusion, so it is suitable for the development of teaching steps using 6E programs. In the teaching process, it is necessary to provide a balance between hands-on (practice and trial errors) and minds-on (application and analysis of mathematical principles). Therefore, it is necessary to pay attention to the allocation of proportions of actual exploration and theoretical teaching [14].

5.2. Evaluation Methods for Portfolio Analysis in STEM Game-Based Learning

For STEM education evaluation, the traditional method is based on the test results as the basis for rating scores, but the STEM integrated education strategy focuses on the hands-on process [5] and should include an assessment of the learning process. For example, Wu, Tzeng [5] used physiological signals to detect emotional reactions in the learning process. Feldman et al. [3] used student records to determine the

learning style of the game.

5.3. The Effect of STEM Game-Based Learning on Students' Learning Performance

The past literature has demonstrated the use of game-based learning for evaluating learner motivation [15], learning emotions [5], problem solving skills [6], and creativity [2] and learning effectiveness [14] are helpful. Future research can also consider the effects of Maker Education in STEM game-based learning to students based on the abovementioned research issues.

STEAM/Maker education and game-based learning are innovative educational topics that have caused heated discussion in recent years. This study explored the impact of STEAM education combined with digital game-based learning on learning performance and proposed an effective teaching lecture design for STEAM educational games. The research results can provide for follow-up STEAM gamification research scholars.

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