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Design Methodology of Bebras Thematic Game

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Abstract: In recent years, computational thinking has gained much attention that more and more countries have implemented it into compulsory education. The design of course content has been an important task. This study aims to describe the design methodology of thematic digital game that integrates computational thinking using Bebras. This paper presents the process of how to integrate computational thinking International Bebras Challenge questions into a game by aiming the target user group, define computational thinking levels, choosing Bebras questions corresponding to teaching content, and designing storylines to form the game scenario. It can inform future computational thinking games for various age groups in different instructional contexts.

Keywords: Computational Thinking, Bebras, Digital Game-Based Learning, Game Design Methodology

1. Introduction

Technology has been widely used in the educational environment, and the change in learning tools has indirectly affected the students' perception of the learning environment, leading to consequential boredom to lecture-type instruction. In order to stimulate students' learning motivation, games are widely used inside and outside of the classrooms. For example, Hooshyar et al. (2021) used a digital game called "Auto Thinking" for the students to learn computational thinking and found that students were more willing to learn through digital games. Digital learning games normally adds strategy, quizzing, and feedback mechanisms (Rojas-Mancilla et al., 2019). Several studies demonstrated its use, for instance, Shih's (2016) integrated robots in the table game and students' coding path showed that students immerse in the games and enhance computational thinking skills. Similarly, Schez-Sobrino et al. (2020) designed a game system called RoboTIC, in which road traffic signs are embedded in a game simulation environment to demonstrate programming logic for tasks.

Although Bebras is a well-known CT activity, it is in test forms. Question-based learning might be distant and tedious to students after long-time usage. Therefore, this study aims to transform Bebras CT test questions into CT digital games to increase students' motivation. This paper illustrates the instructional design methodology with an example <Captain Bebras> so that it can be used in the future CT game design for other age groups and in various thematic contexts.

2. Related work

2.1 Bebras

Bebras Challenge is an international initiative aiming to promote Informatics and computational thinking (CT) among school students at all ages, but later was used and as tests that refers to the ability to think through a problem to come up with a solution or to understand it more clearly (Selby et al., 2014). Bebras was initially proposed by Valentina Dagienė of Vilnius University in 2004, Lithuania. Bebras means "beaver" in Lithuanian and are known as "nature's engineers" because of their habit of cutting wood, digging ditches, and using branches and soil to change the environment around them. Therefore, Bebras expects

students to be as versatile as beavers in solving life problems, so most of the questions are contextualized which are classified into eight computational thinking components, namely Abstraction, Logic, Data Analysis, Decomposition, Algorithms, Simulation, Systematic
Evaluation, Generalization. Generalization. (https://www.bebras.org/)

All students of the right age can sign up for the Bebras Challenge through their teachers' classes. Taiwan first joined hosting the Challenge in 2012, and in only a few years, it has attracted 511 teachers leading 217,640 students in 2020.

In order to promote the learning of computational thinking to younger students, Bebras categorizes questions into levels in terms of age groups. For example, Benjamin refers to the 5th and 6th grade group, and Cadet refers to the 7th and 8th grade group. It shows a general atmosphere of recognizing computational thinking to be a skill that needs to be developed in the young age.

2.2 Digital Games

A good teaching process requires not only appropriate materials but also active participation of learners to produce better learning outcomes. Digital games have been shown to have strong motivational factors that can stimulate learners' motivation (Laine & Lindberg, 2020). In addition to the interesting and fun features, game design must also consider how to visualize the physical learning content, so that the concepts that are expressed or explained in the traditional classroom can be expressed in the virtual world. In order to strike a balance between educational design and game design, a designer with rich experience in both fields is needed to successfully complete the project (Viudes-Carbonell et al., 2021).

Game design often requires the construction of a virtual world in which players can quickly adapt to learning, so the design of the game context becomes important. For example, the use of up to 13 game scenes can lead to a physical teaching environment (Frossard et al, 2019), or the use of a "videogame storyboard" to create a virtual story that simulates reality (Moreno-Ger et al, 2007). To motivate learners, it is necessary to establish game scenes, where multiple scenes and stories can engage learners to participate more actively. Game design must also be challenging, and the concept of game theory applies to digital games (Taylor et al, 2019), meaning that the game needs to increase in difficulty as the scenario progresses, while the player can gradually adapt to higher levels of play through the experience gained in the previous level.

Finally, game designers should observe whether the learning content and game elements of digital games are smoothly integrated and balanced based on the system records of players' play (Hong et al, 2009), and design more adaptable game play based on experience in the future (Taylor et al, 2019).

3. Game Design Methodology

3.1 Define Student Participants

To design a game, first is identify the target audience and its age group before defining the game difficulty level. Observing the number of participants in the Bebras Challenge over the years, it is found that the Cadet group is the fastest growing and most popular group at present. It can be a good lead-in to start design game-based Bebras to attract the students to enhance their CT skills. In Bebras, each test question has clear identification of its difficulty level corresponding to its grade level with CT ability values. However, to design thematic games, it is not possible to include all the questions and sometimes need to mix levels.

This study choose Cadet Group as the target age group of the thematic game <Captain Bebras>.

3.2 Select Appropriate Questions

Bebras questions can be scattered on the Internet since there are many scholars and teachers participating it, among which the officially certified Chinese versions are the 2016 and 2017 tests (*Figure 1* and *Figure 12*). There are 15 to 20 questions in three difficulty levels for each of the four age groups, namely Benjamin, Cadet, Junior, and Senior. Other than that, it can be helpful to use "Bebras Discover Computational

Thinking" (*Figure 3*) to start with which details the eight types of computational thinking and the categorization and interpretation of the questions summarized by Bebras. Each Bebras question was tagged with algorithm keywords linking to the computational thinking test. It is easy for designer to search and align questions for thematic storylines. A table of contents lists (*Figure 56*) all the eight components with informatics concepts at a glance.

In <Captain Bebras>, the team selected six questions for the Cadet age group with the alignment of CT competency and categories with keywords (Figure 5). For example, the Bebras question used in Task 5 of <Captain Bebras> (*Figure 3*4) is about "Euler Circuit" and "Graph" with the corresponding CT competence "Data Analysis" and "Systematic Evaluation".

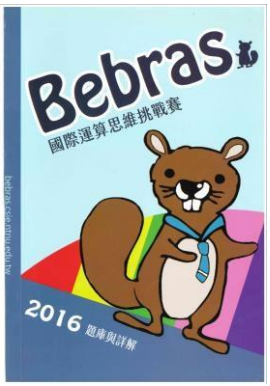

Figure 1. 2016 Bebras Challenge Questions

Figure 2. 2017 Bebras Challenge Questions

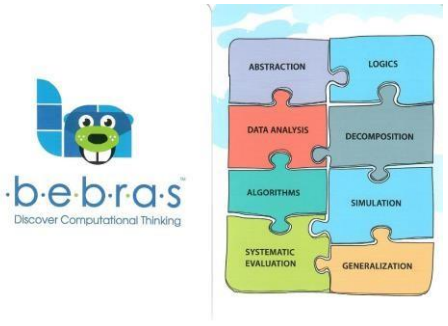

Figure 3. Bebras Discover Computational Thinking

*Figure 4.*One of the 2016 topics

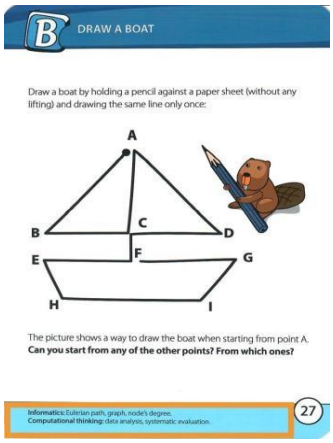

Figure 5. Bebras question & CT

Figure 6. Bebras CT classification list

3.3 Draft Thematic Context

This study proposed three steps to integrate Bebras CT questions into digital game design.

The first step is "Determine Story Theme". Designers should draft a clear chronological story background. The context can be in the past, in the future, real, or fictional. Set up a time interval for the story can help the arrangement of game missions. In <Captain Bebras>, the Great Voyage time is chosen so the storyline is related to sailing. Related historical events should be determined for arranging game missions later.

The second step is "Determine Player's Role". The role in the storyline guides the player through the game. Every decision the role makes (answer to Bebras questions) will lead to different game feedbacks and affect the value to proceed the following missions. For example, in <Captain Bebras>, the student play the role as Magellan, the famous navigator in the Age of Discovery. As the captain of the fleet, the player tries to complete the missions.

The last step is "Define Game Goal". Instead of solving individual CT questions, the player has a final goal to accomplish so they would try hard to pursue the final game goal. In <Captain Bebras>, the player need to earn certain amount of money, decide to buy chosen goods, and distribute goods to various locations for tribute, etc.

3.4 Design Thematic Missions

With the storyline, the game stages can be designed to comprise missions. It is suggested to align missions with CT levels from low to high so that the players would progress gradually instead of facing hurdles and want to give up. In <Captain Bebras>, there are five stages in the game, and each stage embeds a mission with the corresponding CT competency (*Figure 7*). When the player completes all missions, he learns all eight CT components. The player can repeat the same mission until he passes.

Mission One	Mission Two	Mission Three	Mission Four	Mission Five
Algorithms Systematic Evaluation	Logic Algorithms Simulation Abstraction Generalization Systematic Evaluation	Abstraction Decomposition Systematic Evaluation	Algorithms Systematic Evaluation	Simulation Data Analysis Systematic Evaluation

Figure 7. Mission and CT

When designing the missions, "Level", "CT", and "Story" are suggested to be decided in order. Three missions of <Captain Bebras> are described to illustrate the process.

The first mission of <Captain Bebras> (*Figure 8*) is Treasure Map. (Level) Simple level is chosen to give students an easy start up. (CT) Since Bebras question chosen to use in this level is to use direction codes to draft a route through the forest, a maritime story about coding, directions, routes is searched. (Story) Captain Bebras uses the treasure map to walk through the forest. Players need to use the clues given to find treasure.

Figure 8. Task 1

The second mission of <Captain Bebras> (*Figure 9*) is Spice Route. (Level) To increase the complexity of game, two simple level questions are chosen for use together. (CT) The keywords regarding "maze" and "order" are mentioned in the questions so related story about search spices in correct order is drafted. (Story) Using the hints obtained from the previous mission, students choose the correct maze map according to the spice trade order.

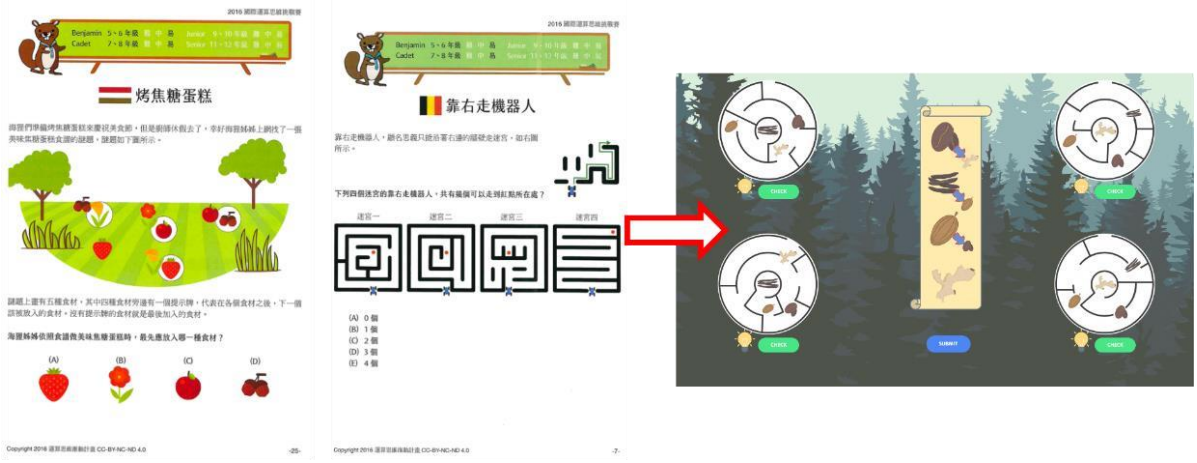

Figure 9. Task 2

The third mission of <Captain Bebras> (*Figure 10*) is Spice Trading. (Level) To increase the difficulty level of game, a question of the intermediate level is chosen. (CT) The keywords of the question permutation and weighing in which players need to arrange the bottles with criteria. (Story) The captain needs to measure his limited budget, buy spices from countries that has lowest price.

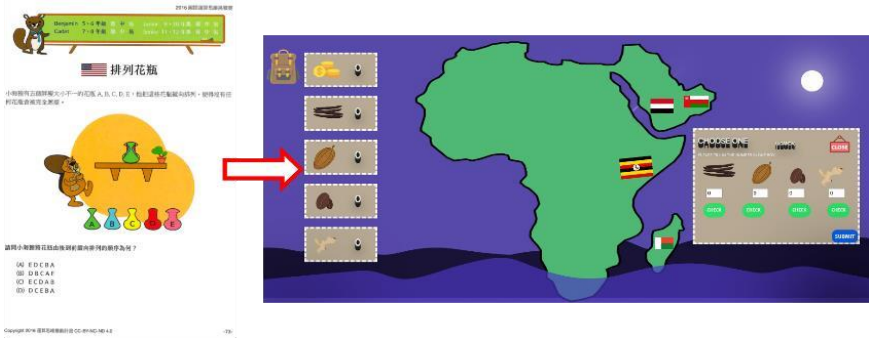

Figure 10. Task 3

4. Conclusion

The study aimed to provide the design methodology for Bebras Thematic Game with the example of <Captain Bebras> so that it can be used in the future CT game design for other age groups and in various thematic contexts. It is hoped that the students can be motivated to learn, and enhance CT competencies at the same time.

Students' gaming data in the online game system will be documented and analyzed to measure their learning effectiveness, CT skills from the mission completion speed and correctness. During the game, learners will be given the Bebras Challenge tests to determine their CT competencies by comparing to the gaming records.

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