DESIGNING DIGITAL GAMES FOR USE IN SECOND-GRADE MATHEMATICS EDUCATION

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Abstract

Digital transformation in education is an inevitable trend and has been increasingly promoted in Vietnam over the past few years. The application of digital games in mathematics instruction not only alleviates students' stress and pressure but also fosters engagement and motivation in the learning process. This paper clarifies key concepts related to digital games as well as presents a set of principles and a design process for digital games using the web-based application Pink Cat Games. Based on a proposed four-step process, the paper illustrates the design of a digital game integrated with the mathematics curriculum for second grade. The findings of this research are to provide practical guidance for teachers in designing digital educational games, thereby augmenting the effectiveness of their pedagogical practices.

Keywords: digital games, mathematics, second-grade

1. Introduction

The rapid development of science and technology in recent years has profoundly transformed numerous domains, notably in education. The application of information technology in teaching is not merely a trend but a fundamental imperative aimed at enhancing the quality of teaching and learning. Within this context, digital games are considered effective tools that simultaneously spark interest as well as facilitate the development of students' thinking and cognitive skills.

Digital games have been proven to be effective educational instruments, offering significant benefits in the teaching and learning process. Students who learn mathematics through digital games tend to achieve higher academic performance and retain knowledge better than those using traditional methods (McLaren et al., 2017). Research by Matic et al. (2024) shows that digital games create intriguing interactive learning environments, boost motivation and encourage learners' active participation. Furthermore, they stimulate students' critical thinking and problem-solving skills (Jensen et al., 2022). The personalized learning experiences and instant feedback provided by digital games allow learners to quickly correct their mistakes and adjust their learning strategies effectively (Alqahtani et al., 2022). According to Senad Orhani (2023), game-based learning has a

positive impact on knowledge acquisition and student satisfaction in mathematics. In general, the appropriate use of digital games in teaching significantly enhances the quality and effectiveness of Mathematics instruction.

However, teaching and learning Mathematics through digital games still face some challenges, such as the low level of integration of digital games into teaching by teachers due to a lack of professional knowledge and information technology skills (Jensen et al., 2022). Besides that, finding or designing digital games that are suitable for the curriculum content and learning objectives of Mathematics is a significant dilemma for teachers (Matic et al., 2024). Therefore, this paper proposes a design process for building digital games on the Pink Cat Games web application. Additionally, an illustrative game aligned with the second-grade Mathematics program is also presented to guide teachers on how to create digital games that meet teaching requirements.

2. Literature Review

There are numerous definitions of digital games. Zyda (2005) emphasizes their entertainment aspect and views digital games as intellectual competitions on computers followed by specific rules for the purpose of entertainment or winning rewards. While Juul (2003) describes digital games as structured systems governed by rules with changeable and measurable outcomes, in which players strive to achieve the best results and are responsible for their choices. Overall, digital games are defined by the following characteristics: having specific goals and structured systems; having constraints from the system of game rules; having interaction and feedback between players and the system or with other players; bringing positive emotions and entertainment to players; being playable on digital platforms such as personal computers or mobile phones (Nguyen et al., 2024).

According to Prensky (2001), the term "Digital Game-Based Learning" (DGBL) refers to the integration of digital games into the teaching process to enhance learning outcomes. It is considered an active teaching method, where students engage in learning through interactive game-based activities (Van Eck, 2006). Kiili (2005) defines DGBL as an educational approach using games on digital devices to improve knowledge acquisition and problem-solving skills by overcoming in-game challenges.

In education, over the past three decades, digital games have been widely studied and applied in various subjects and educational levels (Chen et al., 2021; Hussein et al., 2022; Nguyen et al., 2024). The integration of digital games in teaching Mathematics in elementary school creates an engaging learning environment, helping students feel interested and eagerly participate in the learning process (Bouzid, 2021). It also positively affects students' ability to absorb information and enhances their academic performances (Sun, 2021). In Vietnam, teaching through digital games has garnered significant attention from many educators. Studies by Le et al. (2023) have addressed the approach and application of digital games in teaching. They also highlight the advantages of integrating information technology into education, such as attracting and motivating students to learn. Furthermore, numerous articles have focused on the design and use of digital games in mathematics education. Trinh et al. (2022) and Nguyen et al. (2024) have proposed guidelines for teachers on designing and integrating digital games into mathematics instruction.

3. Methods

In this research, a theoretical research method, specifically the method of document analysis and synthesis, is employed to systematize concepts related to digital games in education and to identify the principles and processes for designing digital games in mathematics teaching. In addition, the study collected feedback from 32 experts - primary school teachers currently working at many institutions - using a 4-point Likert scale questionnaire on Google Forms to evaluate the feasibility of the proposed design process and the developed game.

4. Results

4.1. Principles for Designing Digital Games in Mathematics Teaching

Drawing from prior research analyzing educational game design fundamentals and digital game characteristics, the principles for designing digital games for teaching Mathematics are summarized and proposed in the following table:

TABLE 1. The principles for designing digital games in teaching Mathematics

No.	Principles	Explanation	Source
1	Ensuring alignment with learning objectives	The game must be designed to align with the learning objectives and curriculum.	Kiili (2005)
2	Ensuring intrinsic integration	Learning objectives and content need to be closely integrated and connected with the game.	Habgood & Ainsworth (2011)
3	Ensuring interaction and prompt feedback	The game should provide instant feedback to help learners adjust and improve their learning strategies.	Shute (2008)
4	Ensuring personalization	The difficulty of tasks (challenges) in the game can be adjusted to suit the students' learning progress and abilities, providing a personalized experience.	Kickmeier-Rust et al. (2011)
5	Ensuring attractiveness and creating motivation for learners	The attractiveness of the game comes from different factors such as challenges, imagination, and players' curiosity.	Malone & Lepper (1987)
6	Coherent goals and rules	The goals and rules in the game need to be clear and transparent to guide players.	Gee (2003)
7	Replayability	Allowing learners to replay helps them practice and understand knowledge more deeply.	Van Eck (2006)
8	Supportive and guided hints	The game should provide appropriate hints or guidance, and gradually decrease as learners progress.	Gee (2003)
9	Ensuring cooperation and competition elements	The game can include elements of cooperation or competition to support learning through interaction.	Vygotsky (1978)
10	Ensuring suitability for each target learner	The content, image, sound and control of the game needs to be suitable to the cognitive abilities and information technology skills of learners.	Nguyen et al. (2024)

4.2. Process of Designing Digital Games for Teaching Mathematics on Pink Cat Games

Trinh et al. (2022) proposes a five-step process for designing digital games in teaching Mathematics as follows: 1) Define the objectives of the game; 2) Develop game content; 3) Develop game format and rules; 4) Select design software and multimedia content; 5) Test the game. More recently, Nguyen et al. (2024) have presented a four-step process including: 1) Analyze student characteristics and learning objectives; 2) Design a draft describing the game; 3) Develop the game according to the draft; 4) Experiment, evaluate and improve. Both of the above studies present the process of designing educational games on different applications (soft wares) without focusing on a specific application. Digital game design applications can be divided into two types. The first type provides pre-made games, which allow teachers to integrate and customize the learning content into the game. The second type requires teachers to have programming skills to build digital games themselves. Therefore, a specific and practical process tailored to each platform is needed to guide teachers in designing digital games for teaching Mathematics. With the goal of assisting teachers in designing mathematics games in a smooth and effective manner on the Pink Cat Games application (an online resource providing educational tools and games where teachers can integrate or customize content for subjects like Mathematics), a three-stage process is outlined below.

Stage 1: Preparation.

Step 1: Determine the target audience of the game, the specific learning content/topic (e.g., adding fractions, solving linear equations, recognizing geometric shapes) and the learning objectives that students need to achieve.

Step 2: Design a set of questions and exercises with answers based on the defined learning objectives. Ensure that the questions are clear, accurate, ranging from easy to difficult, and appropriate to the students' abilities.

Stage 2: Game design on the Pink Cat Games application.

Step 1: Fill in the general information related to the learning content integrated into the game (topic name, learning objectives, grade level, subject, etc.).

Step 2: Enter the designed set of questions and the correct/incorrect answers.

Step 3: Choose the game with the most suitable game mechanics (rules, gameplay, images, etc.) for the learning objectives and characteristics of the learners. For example, the "Feed the Shark" game may be suitable for practicing fast calculations, while the "Quiz Wheel Game" can be used to review concepts.

Step 4: Set the game options such as the number of questions, playing time, sounds, etc., depending on the chosen game and the learning objectives that students need to achieve.

Step 5: Create a link and QR code to join the game.

Stage 3: Test and adjustment.

In this stage, teachers can experience the game themselves to check for any possible errors, or they can experiment with a small group of students: Let a few students play to observe how they interact with the game, notice the difficulties they encounter (in terms of Mathematics or gameplay). From there, teachers can make appropriate adjustments.

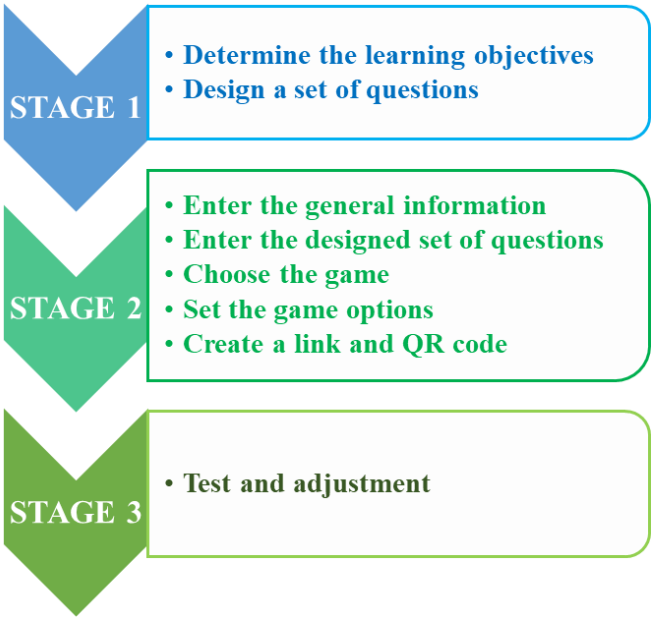

Figure 1. Process of Designing Digital Games on Pink Cat Games

4.3. Illustration of Digital Game Design on Pink Cat Games

Based on the above process, we proceed to design a game in order to introduce basic multiplication in the second-grade Mathematics curriculum.

Stage 1: Preparation.

Step 1: Define the target learners as second-grade students and the learning content chosen as getting acquainted with multiplication. The learning objectives that students need to achieve are: being able to read and write multiplication sentences; being able to write repeated addition as multiplication and vice versa; being able to calculate simple multiplication.

Step 2: Based on the learning objectives, design 10 multiple-choice questions with increasing difficulty and divide into 3 types as follows: 1) Choose the correct multiplication sentence (4 questions); 2) Write repeated addition as multiplication and vice versa (4 questions); 3) Word problems (2 questions).

Stage 2: Game design on the Pink Cat Games application.

Step 1: Fill in the general information related to the topic, objectives, and target audience which is integrated into the game.

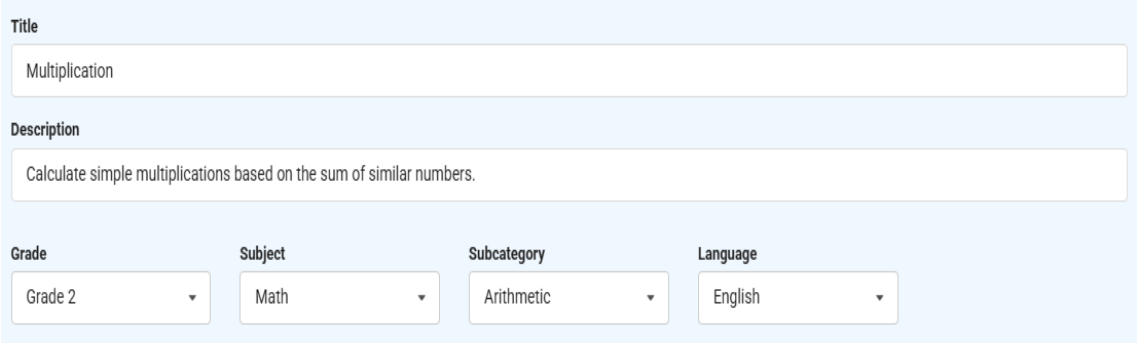

Figure 2. General information related to the learning content integrated into the game

Step 2: Enter the multiple-choice questions and answers.

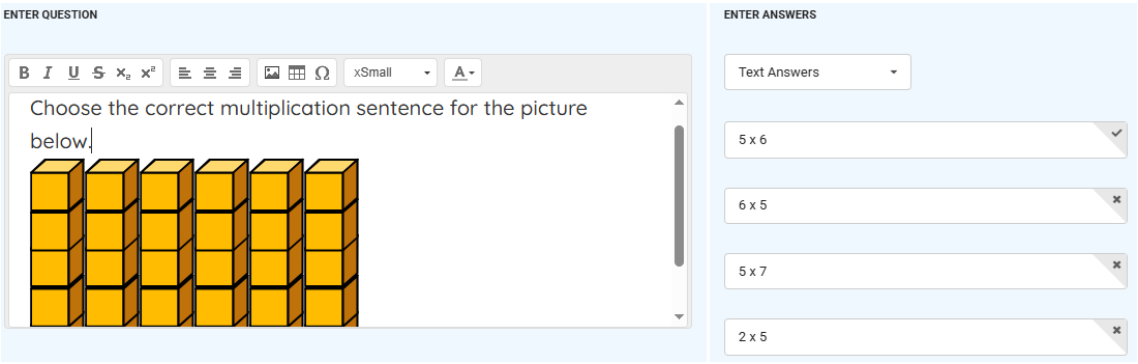

Figure 3. Web interface of composing multiple-choice questions and answers

Step 3: Pink Cat Game provides quite a few types of games (both free and paid), of which the "Feed the Shark" game is chosen. The reason is that it is compatible with the learning objectives. At the same time, this is a game with a user-friendly interface suitable for second-grade students and with simple rules: after each correct answer, the shark will grow because it is fed.

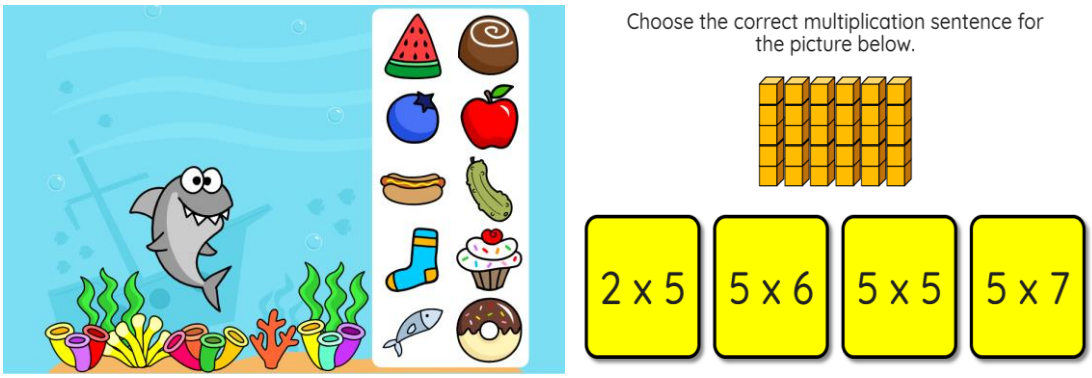

Figure 4. "Feed the Shark" in-game interface

Step 4: Set the game options such as length of time to play, the order of questions, the number of possible answers, etc., depending on the learning objectives and the teacher's requirements.

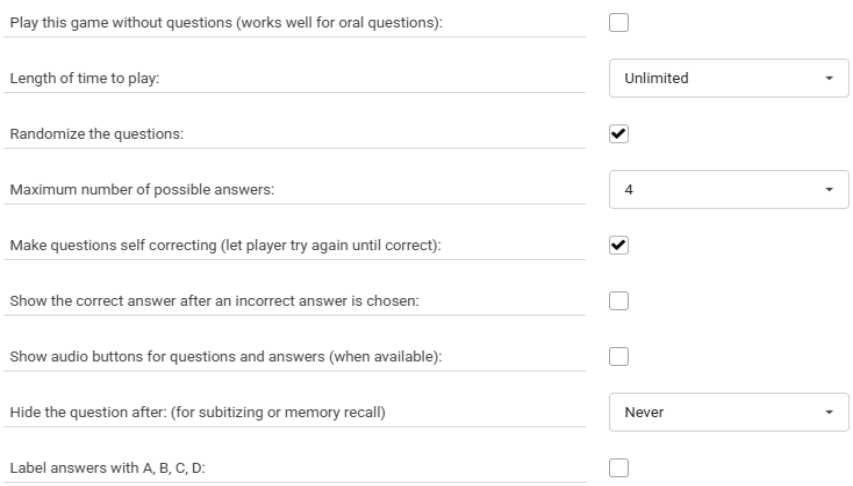

Figure 5. Setting general options for the game

Step 5: Create a link and QR code to join the game.

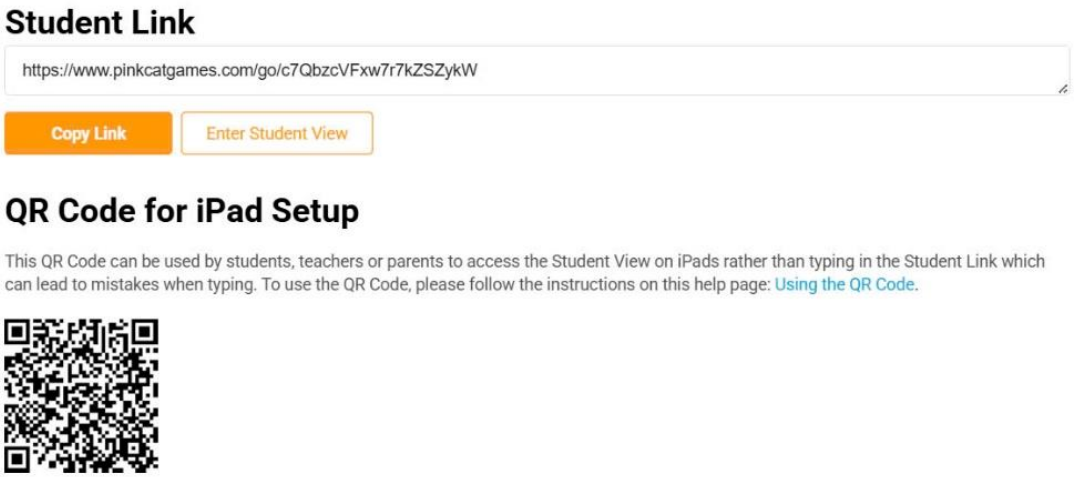

Figure 6. Link and QR code to join the game

Stage 3: Test and adjustment

The “Feed the Shark” game was designed on the Pink Cat Game web application and tested by the research team members to see if there was any error. Below is the QR code linking to the "Feed the Shark" game after testing and adjusting:

Figure 7. Link and QR code to join the game.

4.4. Expert survey results

The study collected feedback from 32 primary school teachers through a Google Forms questionnaire using a 4-point Likert scale. Participants were selected based on their professional expertise and teaching experience to evaluate the feasibility of the proposed design process, considering four criteria: 1) Logical and scientifically structured sequence of stages and steps (**P1**); 2) Clear and comprehensible presentation of stages and steps (**P2**); 3) Effective game-based learning design (**P3**); 4) User-friendliness and suitability for teachers (**P4**). Additionally, teachers also evaluated the applicability of the designed game in real classroom settings according to five criteria: 1) Alignment with learning objectives and content (**G1**); 2) Interactive elements and feedback mechanisms (**G2**); 3) Engaging and motivating qualities for learners (**G3**); 4) Clarity of objectives and game rules (**G4**); 5) Suitability for second-grade students in terms of content, images, and sound (**G5**).

TABLE 2. Expert survey results on the feasibility of the design process

Criterion	Level of Agreement							
	Disagree		Neutral		Agree		Strongly Agree	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
P1	0	0	0	0	17	53.125	15	46.175
P2	0	0	3	9.375	17	53.125	12	37.500
P3	0	0	2	6.250	17	53.125	13	40.625
P4	0	0	0	0	19	59.375	13	40.625

The results show a high level of agreement among experts across all criteria evaluating the feasibility of the proposed instructional game design process. Specifically, 100% of teachers either agreed or strongly agreed that the sequence of stages and steps is logically and scientifically arranged. Furthermore, 90.625% of experts found the steps in the process clearly and comprehensibly presented, with only 9.375% holding a neutral view and none expressing disagreement. For the criterion concerning effective game-based learning design, the total agreement rate reached 93.75%. Notably, the criterion regarding user-friendliness and suitability for teachers very high consensus, with 100% of experts agreeing or strongly agreeing. Thus, according to the experts' opinions, the proposed process is not only logical and clear in its structure but also effectively and easily supports teachers in designing educational games.

TABLE 3. Expert survey results on the feasibility of the designed digital game

Criterion	Level of Agreement							
	Disagree		Neutral		Agree		Strongly Agree	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
G1	0	0	1	3.125	15	46.875	16	50.000
G2	0	0	4	12.500	14	43.750	14	43.750
G3	0	0	0	0	14	43.750	18	56.250
G4	0	0	1	3.125	18	56.250	13	40.625
G5	0	0	0	0	20	62.500	12	37.500

The data in Table 3 indicates that the majority of experts highly evaluated the presented criteria. Specifically, for the criterion “Alignment with learning objectives and content for second-grade students”, 96.875% of experts agreed or strongly agreed, with 50% selecting “Strongly Agree.”. Regarding “Inclusion of interactive elements and feedback mechanisms”, the agreement rate reached 87.5%, with equal distribution (43.75%) between "Agree" and "Strongly Agree". This suggests that interaction and feedback elements in the game are guaranteed. The criterion “Engaging and motivating qualities for learners” achieved full consensus (100%), with 56.25% of experts selecting “Strongly Agree”. For “Clarity of objectives and game rules”, the total agreement rate was 96.875%, including 40.625% strongly agreeing. Notably, the criterion “Suitability for second-grade students” received absolute consensus from all experts (100%), indicating that the game was designed appropriately for the psychophysiological characteristics and proficiency level of second-grade students. Overall, the survey results confirm the feasibility of integrating the designed game in this paper into practical teaching contexts, as reflected by the high level of agreement across all criteria from surveyed teachers.

5. Discussion

Currently, there are numerous online learning platforms and software tools that assist teachers in designing interactive educational games, such as Pink Cat Games, Classcraft, Kahoot, Scratch, Wordwall, and Genially. Among these, Pink Cat Games stands out as an online application with an intuitive, user-friendly interface, particularly suitable for primary school teachers to create simple yet engaging learning games. These games help students practice calculation skills, memory retention, and quick reflexes. Compared to Kahoot, which excels in multiple-choice quizzes, Pink Cat Games offers greater flexibility for individualized use, aligning with each student's learning pace. While Classcraft emphasizes classroom management through a role-playing gamification model, requiring teachers to invest significant time in building reward systems and quests, Pink Cat Games provides quick game design and deployment in just a few simple steps. Unlike Scratch, which demands programming skills, Pink Cat Games does not require users to possess advanced knowledge of information technology. In contrast to Wordwall and Genially, which focus on interactive lectures and visual presentations, Pink Cat Games emphasizes a "play-to-learn" approach with a rich library of pre-existing games (e.g., Feed the Shark, Basketball Game, Quiz Wheel). This saves teachers' design time and enhances student engagement during lessons. These advantages suggest that Pink Cat Games is a suitable tool for primary school teachers to easily design and integrate digital games into mathematics instruction.

With the set of principles and processes suggested in this study, teachers can easily design engaging and educational digital math games suitable for students, learning objectives and content without requiring too much knowledge and information technology skills (programming). This is also one of the major obstacles that make it difficult for teachers to design digital games. Furthermore, an effective application of digital games in teaching depends heavily on the teacher's educational mindset and ability to integrate and utilize games in the teaching process.

The research results in this paper are limited to the design of digital games for teaching Mathematics and do not consider the effectiveness of applying these games in teaching. This raises a question for further research: Does applying digital games in teaching make learning Mathematics more engaging and intriguing and simultaneously improve students' learning outcomes? This is an urgent issue to be addressed in the future.

6. Conclusion

This paper proposes a set of principles and a process for designing digital games for mathematics instruction using Pink Cat Games. It also illustrates the development of a specific game to teach multiplication to second-grade students. The feasibility of the design process was validated through the survey results from the 32 experts. Furthermore, the educational game designed based on this process received strong approval from primary teachers regarding its practical applicability in teaching. The findings of this study contribute to supporting teachers in easily and effectively designing digital games for teaching second-grade mathematics in particular, and primary education in general, thereby meeting the demands of digital transformation in the Vietnamese education system.

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