Journal of Information Systems Engineering and Management
2025, 10(41s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Interactive Game Development to Improve Children's Concentration and Cognitive Abilities: A Game-Based Approach to Concentration and Thinking

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ARTICLE INFO

Received: 17 Dec 2024

Revised: 19 Feb 2025

Accepted: 26 Feb 2025

ABSTRACT

Cognitive abilities in children are crucial for their overall development. In the long run, this ability will significantly influence future success. Therefore, it is essential to stimulate cognitive development and concentration through traditional and mobile-based games. The development of gaming applications today is not only focused on entertainment but also on educational aspects. One of the challenges in developing intelligent mobile games for children is the abundance of existing applications; however, not all of them have high academic value, especially in terms of cognitive development and concentration. This research aims to design and develop an engaging educational game application that can enhance children's concentration and cognitive skills. This research uses the GDLC (Game Development Life Cycle). This method consists of four main stages: idea/concept, alpha version, beta version, and release version. This research involved 20 users as respondents with SEQ and SUS testing. The results of the study indicate that the valid concentration and thinking game can be used as an educational medium that can enhance children's concentration and cognition, and it is well-received by users as it is considered easy and enjoyable to use.

Keywords: Educational Games; Concentration and Cognitive; Smart Mobile; Interactive Games; Children;

INTRODUCTION

Children in the elementary school age range (7-12 years) still require adult support to grow and develop physically and cognitively. At this stage of cognitive development, children are in the concrete operational period, where they exhibit a high level of curiosity and an active attitude in exploring various things. Children's learning activities can be observed through their involvement in discussions, role-playing, and various other types of games. (1). Cognitive abilities in children are crucial for their overall development. In the long run, this ability will significantly influence future success. (2). Therefore, it is crucial to stimulate cognitive development and concentration through play, both traditional and mobile technology-based games (3).

The advancement of technology has brought various innovations that support the world of education, including educational game applications specifically designed. (8). Advancements in mobile technology provide significant opportunities to enhance children's education. The use of mobile devices among children has drastically increased due to the high internet penetration and access to mobile devices in Indonesia. Mobile technology, which has various features that support educational gaming applications, also significantly impacts children's learning methods, especially for Generation Z. (12-14).

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The development of gaming applications today focuses on entertainment and educational aspects. Serious games can make learning more enjoyable and challenging, especially with the digital format that allows children to play anytime and anywhere. Games have proven to be one of the most immersive, engaging, and exciting forms of entertainment. (18–20). The game engine functions as middleware that integrates various resources into assets that blend with graphical information, content, and physical simulation parameters. These features meet the needs of modeling, visualization, simulation, and learning media. (21). Although gaming applications are usually more for entertainment when applied in an educational context, they can provide significant benefits by offering tailored learning for children, complete with automatic feedback that can enhance their motivation to learn. (22–26).

One of the challenges in developing intelligent mobile games for children is the abundance of existing applications. However, not all of them have high educational value, especially regarding cognitive development and concentration. (27). Many games prioritize entertainment without providing enough stimulation to enhance children's cognitive abilities. According to previous research, two key factors influence the success of game application development, namely gameplay and storyline. (28–30). In designing a game as an educational medium for children, it is essential to consider the children's interests and the learning experiences they will gain. (31). Therefore, to create a mobile game application that effectively enhances children's concentration and cognition, it is necessary to adopt appropriate learning techniques in designing the content, gameplay, and storyline. This research aims to design and develop an engaging educational game application to enhance children's concentration and cognitive skills.

LITERATURE REVIEW

A. Educational Game

An educational game is a game developed for the purposes of education and entertainment. Therefore, innovation and alternative methods are needed to enhance the development of educational games to meet learning needs. (19). Game-based learning platforms have advantages in terms of self-directed learning, namely (i) allowing for personalized learning, (ii) increasing difficulty as the game levels progress, (iii) enabling students to "go back to the beginning" and review material, (iv) providing automatic feedback from actions taken, and (v) online games can be accessed via the internet, meaning students can access content whenever they need it. (22).

B. Multimedia

Multimedia is a technology that conveys messages through text, images, audio, video, and animation (33,34). It has become an engaging way to use media in education. Learning media becomes more appealing by utilizing multimedia elements (text, images, audio, video, and animation).

C. Cognitive Abilities of Children

The cognitive development of elementary school students is at the concrete operational stage. At this time, children have a high curiosity, as shown by their active attitude to learn about various things. Children's cognitive abilities are crucial in their development. In the long run, these abilities will play a significant role in determining their success. (2). To stimulate children's cognitive development and concentration, this can be done through traditional and mobile technology-based games. A broader cognitive meaning is the acquisition, organization, and use of knowledge. Following further developments, the term cognitive has become well-known as a domain or area of human psychology, encompassing every cognitive behavior related to understanding, reasoning, information processing, problem-solving, intentionality, and beliefs (3).

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RESEARCH METHOD

The design and development of the game "Concentration and Thinking" uses the GDLC (Game Development Life Cycle) method. This method consists of four main stages: idea/concept, alpha version, beta version, and release version. (32). The stages of the GDLC method are shown in Figure 1.

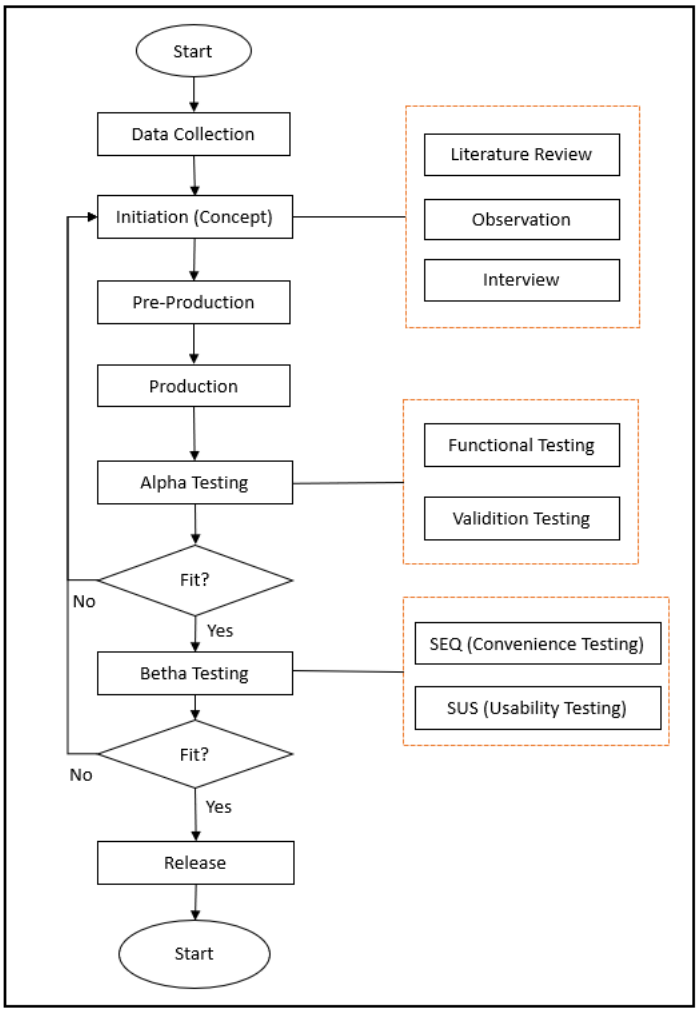

Figure 1. GDLC Flowchart

Based on the stages shown in Figure 1, here is a detailed explanation of each stage:

A. Data Collection Stage

In this stage, a comprehensive literature review on children's cognitive development and relevant materials to improve their concentration and cognitive abilities was conducted. Observations to understand children's play and learning behaviors. Interviews with experts and elementary school teachers were conducted to identify specific needs in the development of children's cognitive ability and concentration. This information served as the basis for designing appropriate content in the game.

B. Initiation Stage

This stage involves the creation of ideas or concepts for the game Concentration and Thinking. The functional and non-functional requirements of the system are determined by designing and developing a mobile game application that can enhance children's concentration and cognitive abilities.

C. Pre-Production Stage

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In the pre-production stage, game design is carried out based on the ideas and concepts that have been established. The game Concentration and Thinking is designed to challenge children's concentration and thinking skills through various engaging math problems and logical reasoning tasks.

D. Production Stage

The production stage began with creating a game prototype, which was then followed by developing game assets, including images, text, audio and animation. Using Unity Engine with C# as the main programming language. Once all the assets are created, integration is done to produce a ready-to-use Concentration and Thinking game application.

E. Alpha Testing Stage

Testing is the stage of evaluating the production results. At this stage, alpha testing is conducted by the development team, which includes functional testing and validity testing. This testing aims to ensure that all features function properly and that the game content meets the needs to enhance users' concentration and cognition.

F. Beta Testing Stage

A limited group of users conducted beta testing. The Concentration and Thinking app was tested by measuring the usability and ease of play. Usability testing used the System Usability Scale (SUS) method, while ease of use was measured with the Single Ease Question (SEQ).

G. Release Stage

The final stage of this research is releasing the game application "Concentration and Thinking" to enhance children's concentration and cognitive skills. The application release is done through the Google Play Store.

RESULT AND DISCUSSION

A. Initiation (Concept)

At the initiation stage, the basic concept of the Concentration and Thinking educational game was created to create a challenging and interesting game for children that can improve their cognitive abilities and concentration. The game is designed with a mechanic that involves controlling a ball that falls vertically on a tower. To succeed in the game, children must maintain their focus in directing the ball to avoid restricted areas. This is done to train the synchronization between hand movements and brain responses, thus consistently training their concentration throughout the game. In addition, there are math and visual logic problems designed to become increasingly complex, starting from simple problems and progressing to more complicated ones. The inclusion of non-numerical symbols aims to train children's analytical abilities and improve critical thinking skills, providing a well-rounded cognitive challenge.

Game Description

The game "Concentration and Thinking" is an application designed to enhance its users' concentration and cognitive abilities. This game is an adventure of a falling ball in a tower that seems to have no end. At each level of the Tower, the ball will come to a stop. Players can drive the ball to the next level by shifting to the right and left. Players must answer the questions at this stage by directing the ball to the correct answer section. The ball must not hit the forbidden area. If it does hit the forbidden area or touches the wrong answer, the player will lose.

The game provides calculation and reasoning questions. In addition to the calculation mode, a Reasoning Mode is designed to sharpen players' abilities to recognize and analyze images. The reasoning mode presents questions through pictures of fruits and vegetables. Players must choose the

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correct answer based on visual logic, grouping, or relationships between images. This mode offers a more exciting gameplay variation beyond just math problems.

Purpose of Game Development

The game "Concentration and Thinking" was developed as an engaging game application that can enhance children's concentration and cognitive abilities.

Functional Requirements

As a reference in the design and development of the game application "Concentration and Thinking," it is necessary to specify the functional and non-functional requirements of the system to produce a game that meets expectations.

B. Design

Game Interface

The interface of the game "Concentration and Thinking" is designed as a tower with a freely falling ball. Users can steer the ball by rotating the Tower left and right. The appearance of the game interface for "Concentration and Thinking" is shown in Figure 2.

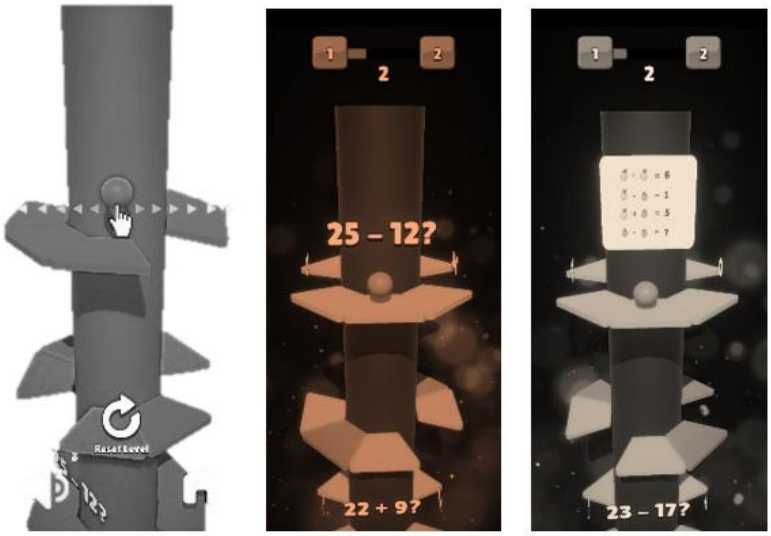

Figure 2. Game Interface Display

Gameplay

Calculation Mode

Players will control a ball that moves vertically down a series of levels on a tower while facing math challenges and avoiding obstacles. Each level of the Tower presents math problems according to the difficulty level. Players must answer questions by jumping to the section that contains the correct answer. If they choose the wrong answer, they will return to the beginning of the game to try again, while if they choose correctly, they will continue their journey downward.

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Reasoning Mode

In Reasoning Mode, players control a ball that moves vertically through a tower, but their challenges include images as symbols. Players must analyze the image to find the correct answer. Questions can include logical sequences, grouping appropriate fruits/vegetables, or identifying the odd image in a series of pictures. If the players choose the wrong answer, they will return to the game's beginning and have to try again.

Game Mechanics

Ball Control

Players move the ball by swiping the screen left or right to rotate the Tower until it reaches the appropriate section. The jump is performed automatically when the player selects the part with the correct answer. If wrong, the character will return to the beginning of the game.

Game Rules

Main Objectives

The “Concentrate and Thinking” game app has two main modes: Calculation Mode and Reasoning Mode, which are designed to improve children's concentration and cognitive abilities. In Calculation Mode, players must solve a series of math problems with the correct answers to reach the end of the level. Meanwhile, Reasoning Mode requires players to solve a series of counting problems with non-numerical problems to complete the level. The game mechanics involve the player swiping the screen left or right to select the platform with the correct answer, be it in Calculation Mode or in Reasoning Mode. The jump is performed automatically when the player selects the correct answer, however, if it is incorrect, the player returns to the starting platform. Each platform displays a question with multiple answer options. If the player answers incorrectly, they will return to the previous platform. The system is designed to stimulate children's concentration, thinking speed, and decision-making skills in a fun and challenging environment.

Leveling System

Calculation Mode

This mode contains 20 levels that offer gradual difficulty levels to accommodate the development of children's abilities. In levels 1 to 8, categorized as easy difficulty, players are faced with addition and subtraction problems. Each level at this level consists of 3 to 5 questions, providing an opportunity for children to build their confidence in solving basic math problems. Moving up to levels 9 to 15, the difficulty level becomes intermediate with the introduction of more complex multiplication and subtraction problems. At this level, each level has 5 to 7 questions, challenging players to improve their calculation speed and accuracy. Finally, at levels 16 to 20, which is the highest difficulty level, players are faced with more complicated division and multiplication problems. Each level at this level consists of 7 to 10 questions, testing the player's ability to apply more advanced math concepts in situations that require high concentration and quick thinking.

Reasoning Mode

Reasoning Mode consists of 10 levels with a total of 20 questions, where each level has 2 reasoning questions. Players will face different types of cognitive challenges, including logical sequencing, fruit and vegetable grouping, and visual relationships between images, all integrated with math problems. This mode is designed to provide variety in gameplay and interesting visual logic challenges for players. By combining reasoning and math elements, this mode not only improves players' numeracy, but also develops their problem-solving and abstract thinking skills in a diverse and challenging context.

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C. Production

The "Concentration and Thinking" game application is designed with attention to every detail, from visual aspects to the interactive gameplay flow. The production process begins with asset preparation, which includes selecting appealing colors, designing buttons, creating animations, background music, and other supporting sound effects. After the design is complete, the next stage is programming using Unity as the game engine, integrating all the assets that have been prepared. At this stage, the game logic is developed to create an intuitive playing experience, where players control the ball to move towards the section with the correct answer, both in Calculation Mode and Reasoning Mode. The challenge presented involves math problems and reasoning based on images of fruits and vegetables. Once the development is complete, the application is ready to be tested and implemented, ensuring that each feature functions according to the design that has been planned to support enjoyable and interactive learning. Figure 3 shows the output of the Concentration and Thinking application.

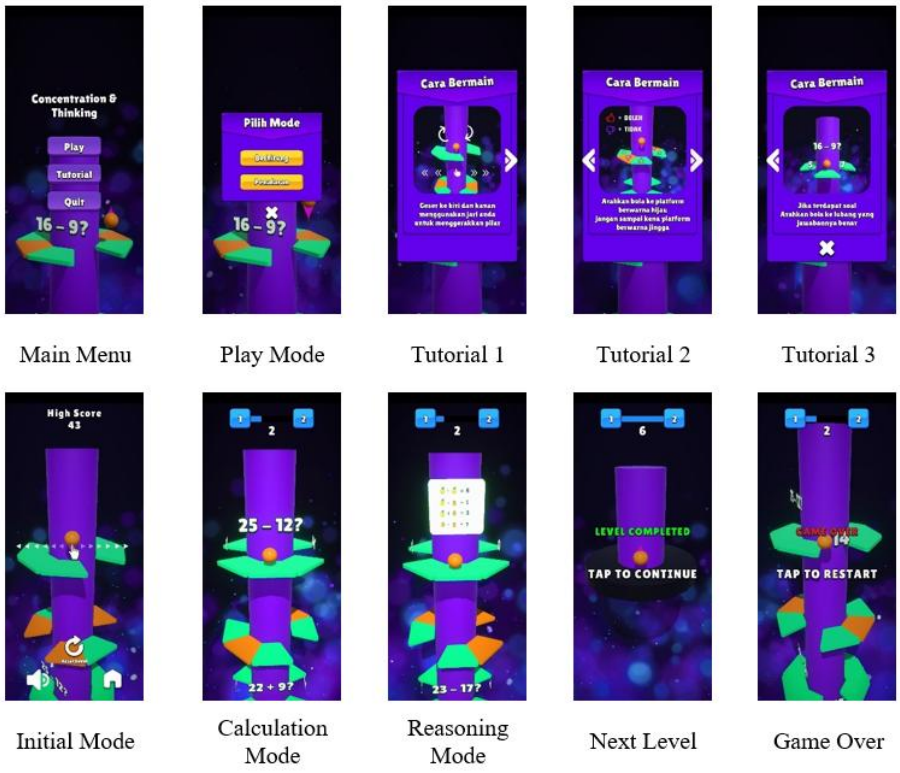

Figure 3. Display of the Concentration and Thinking Application

D. Alpha Testing

Validity testing

Validity testing is conducted by media experts and content experts using the expert judgment method with a Likert scale questionnaire from 1 to 5. Content experts validate two aspects of the material content: its coverage and usefulness. The media expert questionnaire comprises three aspects: physical design, functionality, and feature usefulness.

The results of the media validation conducted by media experts are presented in Table 1, table 2. And table 3.

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Table 1. Results of Media Quality Testing

No	Criteria	Score
1	Simplicity of layout	4
2	Simplicity of visual appearance	4.5
3	Simplicity of media components	4.5
4	Proportional arrangement of feature images	4
5	Proportional arrangement of letters and numbers	4
6	Easily installable mobile application	4.5
7	Selection of contrasting colors	4
8	Selection of visual display	4
9	The application can meet learning needs to enhance concentration and cognition	5
10	Easy operation of the application on mobile phones	4.5
11	Operation of the application is easily understood by new users	4
Averange		4,27

Validation results of the material by the teacher.

Table 2. Results of Material Quality Testing

No	Criteria	Score
1	I find it easy to use the app/game. The app/game motivates me to support my students.	5
2	The writing in the application is easy to read.	4,5
3	The instructions for using the application are clear.	5
4	The application/game is easy to use.	5
5	The instructions for using the application are fairly easy to follow.	4
6	I prefer being able to use the application to enhance children's concentration and cognition.	4.5
7	The application features an attractive design.	4.5
8	The program adapts to technological advancements.	4
9	I find it easy to use the app/game. The app/game motivates me to support my students.	4.5
Averange		4.5

The results of the language testing by language experts are shown in Table 3.

Table 3. Results of Language Interaction Testing

No	Criteria	Score
	LANGUAGE ASPECTS	
1	The sentences displayed are clear.	4.5
2	Ease of understanding the flow through the use of language.	4
3	The language used is communicative.	4.5
4	The language used is standard.	5
	GRAPHIC ASPECTS	

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5	The design is appropriate with the display, color selection, font type, and font size.	4.5
6	Layout arrangement of image proportions.	4
7	The graphic appearance of the application is appealing.	4.5
8	Clarity of menus and images.	4.5
ASPECTS OF MATERIAL RELEVANCE AND NAVIGATION		
9	Clarity/accuracy of navigation/menu.	4.5
10	The material or instruments used are appropriate.	4.5
11	Relevance of the material or instruments with existing instruments.	4
12	Material, menus, and images are presented clearly and systematically.	4
13	Material, menus, and images are presented completely and are easy to understand.	4.5
Averange		4,38

Based on the media experts' recommendations regarding the three aspects of language, graphics, and the suitability of content and navigation, it is valid without revisions.

E. Betha Testing

Betha testing is the testing conducted by end users. This test was conducted in a limited environment. The number of respondents in this test is 20 people. Beta testing is conducted to determine user responses, particularly regarding the ease of using the application and usability testing. The method used is SEQ (Single Ease Question) for ease of use and the SUS (System Usability Scale) for usability testing. The testing employs the Single Ease Question (SEQ) method with a total of 30 tasks evaluated using a Likert scale from 1 to 7. The assessment categories consist of: Very Easy (7), Easy (6), Not Difficult (5), Fairly (4), Not Easy (3), Difficult (2), and Very Difficult. (1). Table 4 below lists SEQ testing tasks. The results of the SEQ testing are presented in Table 4.

Table 4. SEQ Test Results

No	Testing Scenario	Score
1.	The user opens the application and checks whether the main menu is displayed correctly.	6,05
2.	The user opens the application and checks whether the "Play" button is displayed on the main menu.	6,05
3.	The user presses the "Play" button and checks whether the options for "Calculation" and "Reasoning" modes are displayed.	6,1
4.	The user selects Calculation Mode and checks whether the application starts that mode correctly.	6,2
5.	The user selects Calculation Mode and starts level 1, ensuring that the level begins correctly.	6,1
6.	The player starts the game and swipes the ball left or right, checking the control's response to the swipe.	6,2
7.	The user starts Calculation Mode and checks whether the platform with math questions appears.	6,2

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8.	The player plays in Calculation Mode and checks whether the score is displayed after answering a question.	6,05
9.	The player completes one level in Calculation Mode and checks whether the next level starts correctly.	6,05
10.	The player answers questions in Calculation Mode and checks whether the application processes the answers correctly.	6,15
11.	The player selects the wrong answer and checks if the game over UI appears correctly.	6,05
12.	In the game over UI, the player checks if the "Reset" button is displayed and functions properly.	6
13.	In the game over UI, the player checks if the "Home" button is displayed and functions properly.	5,95
14.	In the game over UI, the player checks if the "Sound" button appears and works to adjust the sound.	6
15.	The player selects the "Reset" button after losing and checks if the game restarts correctly.	6,1
16.	The player selects the "Home" button in the game over UI and checks if the application returns to the main menu.	6,1
17.	The player selects Reasoning Mode and starts level 1, ensuring that the level begins correctly.	5,95
18.	The player starts the game in Reasoning Mode and swipes the ball, ensuring control response.	6,1
19.	The player answers questions in Reasoning Mode and ensures that the application processes the answers correctly.	6,1
20.	The player starts Reasoning Mode and checks if the platform with fruit and vegetable image questions appears.	6,1
21.	The player plays in Reasoning Mode and ensures that the score is displayed after answering the questions.	6,05
22.	The player completes one level in Reasoning Mode and ensures that the next level starts correctly.	6,1
23.	The player answers questions in Reasoning Mode and ensures that the application processes the answers correctly.	5,95
24.	The player selects the wrong answer in Reasoning Mode and checks if the game over UI appears.	6,2
25.	In the game over UI, the player verifies if the "Reset" button is displayed and functions properly.	6,05
26.	In the game over UI, the player checks if the "Home" button appears and works correctly.	6,15

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27.	In the game over UI, the player ensures that the "Sound" button is present and functions to adjust the sound.	6,2
28.	The player selects the "Reset" button after losing in Reasoning Mode and checks if the game restarts.	6,2
29.	The player plays in Calculation Mode, exits the game, and ensures that the last data is saved and loaded correctly.	6,05
30.	The player plays in Reasoning Mode, exits the game, and ensures that the last data is saved and loaded correctly.	6,1
Averange		6,08

The SEQ method test score is 6.08, and the SEQ percentile rank, presented in Figure 4, indicates ease of use.

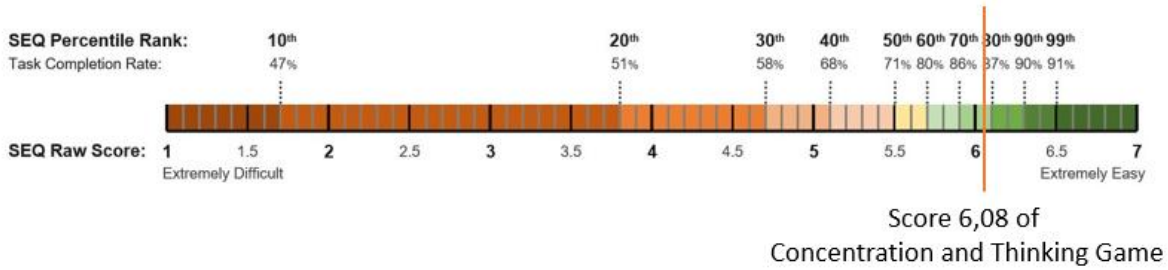

Figure 4. SEQ Percentile Rank of Concentration and Thinking Game

In addition to testing using the SEQ method, usability testing was conducted during beta testing using the SUS method. The results of the usability testing with the SUS method are presented in Table 5.

Table 5. SUS Test Results

No	SUS Questions	Final Score
1	I think that I would like to use this system frequently.	92,5
2	I found the system unnecessarily complex.	87,5
3	I thought the system was easy to use.	91,25
4	I think that I would need the support of a technical person to be able to use this system.	90
5	I found the various functions in this system were well integrated	83,75
6	I thought there was too much inconsistency in this system	82,5
7	I would imagine that most people would learn to use this system very quickly.	90
8	I found the system very cumbersome to use.	85
9	I felt very confident using the system.	95
10	I needed to learn a lot of things before I could get going with this system.	90
Averange		88,75

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Table 5 shows that the average SUS test score for the game application "Concentration and Thinking" is 88.75, which means that this application is acceptable to users, as indicated by the SUS metrics in Figure 6.

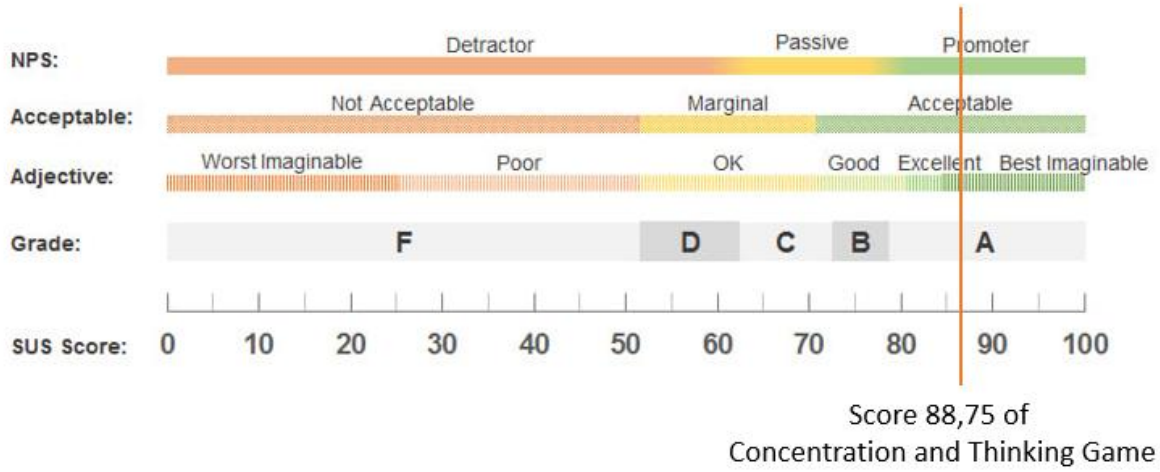

Figure 5. SUS metrics of Concentration and Thinking Game

The results of the tests that have been carried out, it show that the game “Concentrate and Think” successfully combines entertainment elements with high educational value. The progressive leveling system proved effective in maintaining children's interest while gradually increasing the difficulty level. The use of fruit and vegetable images in Reasoning Mode not only trains visual logic but also introduces children to the concept of categorization, which is important for cognitive development.

The high SUS and SEQ scores indicate that the game succeeded in creating a positive user experience, which is crucial for ensuring long-term engagement. Improvements in problem-solving and pattern recognition skills demonstrate the game's effectiveness in improving children's cognitive functioning.

CONCLUSION

This research shows that the design and development of the educational game application “Concentration and Thinking” has been successful and effective in improving concentration and cognitive skills and is attractive to children. Through an approach that combines engaging game elements with structured educational content, the app has proven to be easy to use and useful for users and has fulfilled the need as a valid educational medium that can be used to improve children's concentration and cognitive abilities. This approach has the potential to transform the way children learn and develop important skills, with a lasting impact on their academic performance and mental development. This study contributes to the development of concentration and cognition but has limitations related to content with mathematical formulas. The findings of this research pave the way for further developments in educational technology, with wide-ranging potential applications across various learning contexts, from formal education to cognitive therapy. Further development can be done with different problem scenarios as challenges for users to solve.

ACKNOWLEGMENT

Gratitude is expressed to the Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia as the funding agency that supports this research.

The authors declare that generative AI or AI-assisted technologies were not used in any way to prepare, write, or complete essential authoring tasks in this manuscript.

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