Esc Challenge
Game application for enhancing executive functions

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ABSTRACT – Executive functions, which encompass significant cognitive processes, are found to be a major role in being used as basic skills to enhance critical thinking skills in children; whereas, critical thinking is found as a set of significant skills that helps one to come up with a rational decision with an appropriate behavior [1]. However, the results of PISA, the program for international student assessment, showed the trend of decreasing critical thinking skills in Thai Grade 9 students [2]. According to the study, one of the causes appears to be traditional teaching methods delivered to students which might not support critical thinking skills development. However, the problem can be lessened once related brain skills were developed at an appropriate age range, which is 7 - 11 years old [3]. Therefore, a game application is chosen as an approach to help children effectively practice executive functions from provided game tasks. Also, parents could acknowledge their child's progress from analyzed results via web browser while gaining a better understanding of the applied cognitive skills, and support their child development. Furthermore, the game is implemented to reinforce more attractive and interesting education method that can strengthen executive functions. From the experiment, the results show that the implemented game application could be beneficial to both players and parents for practicing and monitoring those brain skills.

KEY WORDS – Child Development, Executive Functions, Critical Thinking Skills, Brain Game, Brain Training, Puzzle, Educational Application

1. Introduction

People nowadays often face with complexities in discriminating false information, which can be referred to any forms of content that have been intentionally represented in a way to confuse and mislead with fabricated facts like fake news, sponsored contents, and parodies especially on social media [4]. Apart from mentioned problems, the studies showed that people could comprehend and distinguish things better once they own a proper level of *critical thinking skills* or ***CT***. In addition, Thai academic policy also emphasizes on developing thinking skills among the students. According to the fourth standard indicator of basic education, students as learners should be able to think and perform things on their own. Learners should be able to think analytically, synthetically, creatively, and critically while being able to adapt themselves to the society [5]. Even though Thai education these days already enhances *CT* development in several subjects (e.g., Social Studies, Science, Mathematics, Thai Language, etc.), the recent result from PISA (Programme for International Student Assessment, which assesses critical thinking skills from students around the world) showed that Thai students got score of 30.5 percent of *CT*, and there are only 2 of 100 persons who got their score higher than 60. From further study, the major problem tends to rely on teaching methods delivered by Thai teachers, which students are normally taught to memorize the contents instead of understand the concept. To illustrate, teachers sometimes only point out what is right or wrong without exchanging further opinions, also with unsupportive learning style that do not actually let students think freely and learn by doing. Moreover, most of Thai students are found having low motivation to enhance their *CT* due to unattractive educating method or platform provided [2, 6].

In theory, *CT* itself refers to an approach of skills needed in developing a reasonable judgement from all evidence instead of simply believe any conclusions without questioning on the widespread hoax, or fake news over the Internet. As in Thailand Research Fund (TRF) Press Forum stated by Assoc. Prof. Dr. Suteera Prasertsan, reading skill found neglected according to PISA result that

students were unable to interpret what is underlined behind a complex question and come up with a certain answer [7, 8, 9, 10]. However, everyone can successfully be a critical thinker once core cognitive skills that has been introduced by Peter A. Facione [11, 12, 13] are developed skills as below.

1) *Interpretation*: Refers to an ability to comprehensively understand and express the meaning behind the context like experiences, situations, data, beliefs, opinions, or rules.
2) *Analysis*: Identification of how statements, questions, concepts, descriptions, or expression of belief, judgment, experiences, information, or reasons related to each other.
3) *Evaluation*: To assess or measure if a statement or other representations in are logical or creditable or not like judging credibility of authors or speakers in account from environmental factors and judging logical strengths according to doubtful situations.
4) *Inference*: Relevant information consideration of flow between data or any pieces of evidence for stating such a reasonable conclusion.
5) *Explanation*: The way of supported reasons are being presented with a clear big picture by describing used methods and deliverables in detail while defending the audience or the reader in reasonable ways and conceptually explaining.
6) *Self-Regulation*: Introduced as self-monitoring enhancement using analysis and evaluation skills for inferential judgements of a person by questioning, confirming, validating, or correcting reasons or result conducted with the help from self-examination and self- correction.

Moreover, according to studies of the enhancement of *CT* through the integration of other skills, with the enhancement of skills included in *CT*, the abilities of one to understand and solve a particular problem will become more effective and rational when one's mind has been practicing in cognitive processes since childhood. At this point, *executive functions* or ***EF*** become one of the major skills that could help one owns cognitive control of behavior with a rational mindset while being able to interpret and analyze things better either related to themselves or surroundings. Furthermore, *EF* and *CT* found appropriate to be developed during middle to late childhood (7 - 11 years old) since children at this age just start to learn logical thinking and concrete operational skill with lesser thought limitation.

EF were found as a set of important skills to prevent one from letting unawareness leads his or her life into unpleasant way. In details, *EF* are a set of mechanisms, which physically located in the prefrontal area of the brain. *EF* theoretically associated with one's thought, feeling, and behaviors to be performed in a good and organized way for successful life. In accordance to RLG (Rakluke Learning Group) Institute definitions, *EF* can be distinguished into 3 distinctive types of skills as follows:

1) *Core Skills*

Working Memory: Ability to memorize information in one's mind for a specific purpose in completing a task.

Inhibitory Control: Ability when one could stop one's behavior including actions and thoughts of performing within an appropriate time.

Shifting or Cognitive Flexibility: Ability to flexibly move from one to another situation with an enabling of different rules and setting in different environment without negative response.

2) *Self - Controlling Skills*

Focus or Attention: Ability to continuously pay attention to something at a period of time.

Emotional Control: Ability to express emotions in an acceptable level by bearing on feeling using rational thoughts to support.

Self-Monitoring: Ability to examine one's performance and measure according to indicators, a standard, or expectations.

3) *Practicing Skills*

Initiating: Ability to start doing a task based on what have been planned with creativity, without any fear of failure.

Planning and Organizing: Ability to manage progress planned, starting from goal setting, seeing things in a big picture, prioritizing by importance. Without this skill, people could have a problem both working in a team and working as individual.

Goal-Directed Persistence: Ability of eagerness to attain the committed goal without a fear of obstacles along the way.

According to the research, the *CT* can be advanced through development of *EF* [14]. Moreover, these two skills, *CT* and *EF* have probable relationship as they are operated in brain's area of prefrontal cortex. The structures and functions of the prefrontal cortex including two significant parts, dorsolateral and ventromedial, presenting the 10 critical thinking components and 7 executive functions are associated [15].

The 10 critical thinking components consists of Inductive and Deductive Reasoning, Decision-Making, Problem Solving, Creativity, Regulation, Self-Awareness, Knowledge, Motivation, Goal-Orientation, and Attitude. Furthermore, the executive functions consist of 7 skills which are Inhibition, Decision, Flexibility, Updating, Planning, Energization, and Task Fixing. These 10 critical thinking components and 7 executive functions are

presented by the previously defined scientific literature. As the association between 10 critical thinking components and 7 executive functions in the literature, each component of the critical thinking has connection with executive functions as follows;

1) Inductive and Deductive reasoning always connects with Inhibition, Planning, Decision-Making, and Flexibility functions.
2) Decision-Making has main characteristic of Determination functions.
3) Problem Solving process is always intervened by Determination, Planning, Updating and Cognitive Flexibility functions.
4) Creativity involves with Energization, Updating, and Flexibility functions.
5) Self-awareness requires Inhibition functions to achieve processes.
6) Knowledge refers to Updating functions which is Working Memory representation.
7) Regulation consists of Planning and Monitoring functions.
8) Motivation is presented in the Energization functions.
9) Goal-orientation relates to Task Fixing functions.
10) Attitude associates with Personal Cognitive functions in nature, not controlled.

Other than the studies of the relationship between the critical thinking components and the executive functions. There are additional skills of the 9 executive functions which were defined at the very beginning part of this section. Those skills include Working Memory, Focus or Attention, Self-Monitoring, and Planning and Organizing which might directly correlate with the previously defined core critical thinking skills [16, 17, 18, 19, 20, 21].

The relationship between *EF* and *CT* could be used in the design of skill development to improve children's skills at the young age. In order to come up with an effective approach to enhance *CT* in children through game application, plenty of existing games which involved with *EF* and CT were taken to study. Generally, Video Games found to be the best type of games since it gives a better chance for players to gain and approach variety benefits than others mentioned on Wikipedia's article named "List of types of games".

For instance, a video game can be designed to contain skills enhancement functions follow board games from tabletop games type [22], like chess or UNO, that allows players to develop their memory formation, cognitive skills, critical thinking, attention skills, etc. along with encouraging players to play in groups and communicate with other players [23]. Therefore, children could improve skills Therefore, children could improve skills, especially *CT*, the most effective type of skill enhancement is video games [24]. However, according to many existing games nowadays that also work on enhancing *EF*, cognitive skills, *CT*, etc., observing those games could help in matching Esc Challenge and its game type.

Table 1 represents a comparison between games that contain relevant skills with *CT*. In addition, apart from mentioned video games, paper-based game from class activities could be very useful for studying the method of helping one enhance *EF* and Table 2 illustrates existing games on both game application and paper-based that explicitly composed of *EF*.

Based on the previous mentioned research, according to correlation with advanced technologies at this time, Esc Challenge has been created and designed on two platforms. The first one is a game application on smartphone or tablets which can interpose different levels of developing *EF*, and another platform as a monitoring website to approach players' parents to keep track on their children practicing progress through the gameplay.

2. Proposed Method

2.1 Relations among Brain Skills

In accordance with the literature review, the 7 and some of 9 executive functions are the same in term of their definitions except *Focus* and *Self-Monitoring*. Similarly, the 10 critical thinking components and some of the 6 core critical thinking skills are also the

Table 1. Comparison Among Game Applications in Different Perspectives.

Game	Age	Category	Storyline	CT Enhancement	EF Enhancement	Graph Statistics	Parent Monitoring
Unblock Me FREE	10+	Puzzle	×	✓	×	×	×
Kiko's Thinking Time	3 - 7	Education	×	×	✓	✓	✓
Think! Think!	5 - 10	Education	×	✓	×	×	✓
Peak – Brain Games & Training	N/A	Education, Brain Games	×	✓	✓	✓	×
Plants vs. Zombies FREE	N/A	Strategy	✓	×	✓	×	×
The Room	11+	Puzzle, Adventure	✓	✓	✓	×	×
Geostorm	7+	Puzzle	✓	✓	✓	×	×

Table 2. Executive Functions in Games and Activities.

Game	Type	WM	IC	CF	FA	EC	PO	SM	IN	GDP
Perilous Path (from Peak game)	Application	✓								
Must Sort (from Peak game)	Application				✓					
Path to Safety (from Brain Wars game)	Application	✓								
Flick Master (from Brain Wars game)	Application	✓			✓					
Spinning Block (from Brain Wars game)	Application	✓		✓						
Cross Out	Paper	✓								
Sudoku	Paper	✓								✓
Blurt	Activity		✓	✓						
Chess	Activity	✓		✓		✓	✓			
Daily planning	Activity						✓	✓		✓
Scrabble	Activity			✓		✓	✓			
Pictionary	Activity			✓			✓			
5 Second Rule	Activity					✓	✓		✓	

same except *Interpretation* and *Analysis*. Therefore, some of the 9 executive functions and the 6 core critical thinking skills could be mapped together through the relationship between the critical thinking components and the 7 executive functions. For example, *Initiation* could be related with *Inference* and *Self-Regulation* through the relationship of the *Motivation* and *Energization*. For another example, in correlation with *Explanation*, *Planning and Organizing* are correlated through the relationship of *Problem Solving and Planning*; meanwhile, *Goal-Directed Persistence* are correlated through the relationship of *Goal-Orientation* and *Task Fixing*.

Furthermore, there are the studies which explain the connection between some of the 9 executive functions and the 6 core critical thinking skills. For example, *Self-Monitoring*, *Working Memory*, and *Cognitive Flexibility* are required to operate with each other while *Self-Regulation* depends on them. In addition, some of 9 executive functions could be mapped to some of 6 core critical thinking skills with their explanation from the previously mentioned research. For instance, *Planning and Organizing* is necessary for *Interpretation* and *Analysis* skills as the planning skills could support the *Interpretation* of relevant and important issues, linking ideas together, and seeing the whole picture of problems and situations. All in all, the relationship between the 9 executive functions and 6 core critical thinking skills could be summarized as in Table 3.

After exploring how the skills are potentially related to each other, the occurrence of *EF* upon *CT* could further be a significant factor to identify the criteria of game's difficulty in term of arranging tasks inside Esc Challenge game. At this point, as it can be implied from the Table 3 that the *EF*'s occurrence on *CT* is related to the importance of skills development. Hence, for Esc Challenge project, the more mentioned occurrence it appears, the more priority of initial practicing that *EF* will be.

Moreover, since this project set an initial goal for designing tasks inside the game to help children practice at least half of the 6 *CT*, the occurrence rate of *EF* towards *CT* has been found to be a significant factor to determine the scope of designing the tasks. Therefore, with regards to mentioned prioritization, in order to scope down *EF* for covering 3 *CT*, the priority range appears to be up to 4 which consists of 5 *EF*; *Working Memory*, *Cognitive Flexibility*, *Focus or Attention*, *Planning and Organizing*, and *Goal-Directed Persistence*. Therefore, by applying those mentioned 5 *EF* as a concept of designing, it could help children further practice up to 5 important *EF* along with their 3 *CT* which are *Interpretation*, *Analysis*, and *Explanation*.

Table 3. Relations of Executive Functions and Critical Thinking Skills with their Difficulty Identification.

CT / EF	IT	AN	EX	EV	IF	SR	EF Occurrence	Skill Priority
Working Memory	✓	✓	✓	✓	✓	✓	6	1
Inhibitory Control				✓	✓	✓	3	4
Cognitive Flexibility			✓		✓	✓	3	4
Focus or Attention	✓	✓	✓	✓	✓	✓	6	1
Emotional Control				✓	✓		2	5
Planning and Organizing	✓	✓	✓		✓	✓	5	2
Self-Monitoring						✓	1	6
Initiating					✓	✓	2	5
Goal-Directed Persistence			✓	✓	✓	✓	4	3

** IT – Interpretation, AN – Analysis, EX – Explanation, EV – Evaluation, IF – Inference, SR – Self-Regulation*

Further from those analysis of *EF* prioritization and skills to be practiced, tasks inside Esc Challenge game are also ordered follow the same idea of prioritization along with making each room contains all 3 mentioned *CT*. However, the application of those analysis and design will further be explained in the next section.

2.2 Systems Design

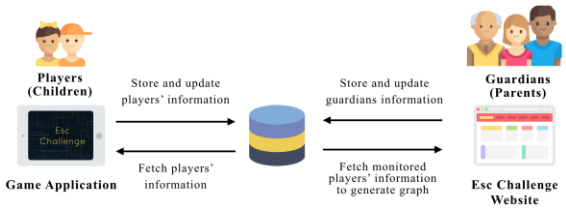

Figure 1. Esc Challenge System Architecture.

As mentioned that Esc Challenge generally divided into 2 platforms, game application, and monitoring website. Therefore, the occurred scenarios from system integration can be found as is Figure 1, which the results after players finish playing a game task will be fetched and represented on monitoring website for their parents as guardian to track on players' practicing progress.

1) Game Application

Figure 2. Initial Game Page.

Figure 3. Main Map.

Escape scenario has been applied together with a storyline to find a lost dog which run into a mystery building of numerous rooms. In the game, there are 3 rooms initially designed in different environments that the players are required to complete every task inside the current room to unlock the next room. Furthermore, players will get to practice and develop their *EF* through each task in different levels; easy, medium, and hard. Also, in each level, it has 3 rounds for letting children practice their skills better. Therefore, tasks inside the game will further be explained in details in this section in order to provide more understanding of each task's background.

Room 1 - Laboratory

- *Cross Me Out*: Initially, the player needs to cross out the elements from the table follow the defined rule that each of them composed of one number and one alphabet. Both amount of the element and rule(s) for table pattern differ by the difficulty in each level. Gained skills are WM and FA.

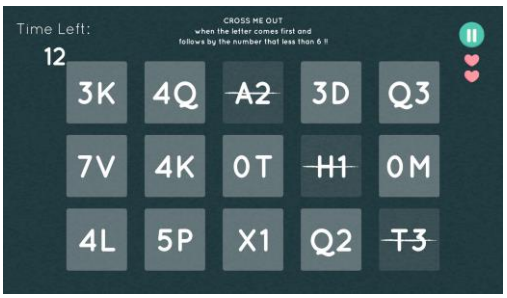

Figure 4. Cross Me Out Game Tasks.

- *Turn Me*: There will be a doodle appeared on separated spinning wheels in randomized direction. Each separated wheel needs to be rotated for the correct position in order to fix the doodle. Gained skills are WM, PO, CF, and GDP.

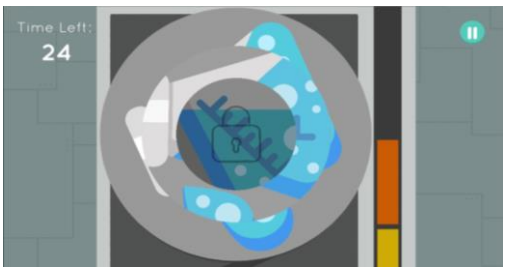

Figure 5. Turn Me Game Tasks.

Room 2 - Winter Forest

- *Catch Me*: There will be a sequence of number which is required the player to remember and then recall by tapping each number in sequence from a pool of moving numbers. The task becomes more challenge according to the speed of movement triggered towards those numbers. Gained skills are WM and FA.

Figure 6. Catch Me Game Tasks.

- *Fix Me*: Players have to fix the matchstick equation by removing some of them according to the defined rule in each level. The stick to be removed could be a part of each number or sign in order to make the game be more challenge for the player. Gained skills are PO, CF, and GDP.

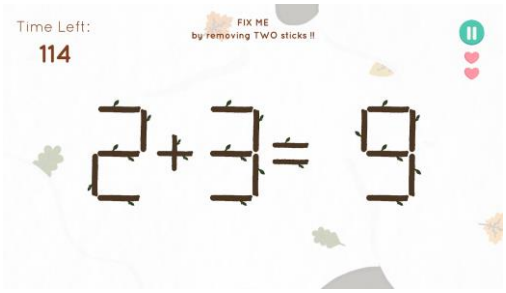

Figure 7. Fix Me Game Tasks.

Room 3 - Clouds

- *Execute Me*: In this game, couples of numbers in set will be needed to consider whether the recent appeared couple of numbers can be executed by the allowed signs or not. The difficulty between each level will depend on the pattern of each number. Gained skills are WM and CF.

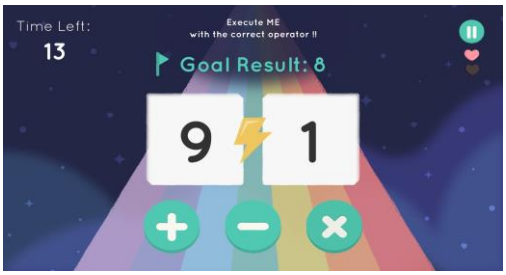

Figure 8. Execute Me Game Tasks.

- *Collect Me*: The player has to collect a crystal in each time in each level by firstly memorizing the pattern of obstacles before they become invisible, and later moving the crystal to the treasure box on the screen to complete each round. The increase in a number of obstacles and pattern size result in letting the player has more playing time to deal with the task. Gained skills are WM, FA, PO, and GDP.

Figure 9. Collect Me Game Tasks.

According to details of each task, the following Table 4 will specify what EF each task contains and how many stars in maximum that players will be received after playing it.

Table 4. Game Tasks and Its Executive Functions.

Task	Executive Functions				
	WM	FA	PO	CF	GDP
Cross Me Out	✓	✓			
Turn Me	✓		✓	✓	✓
Catch Me	✓	✓			
Fix Me			✓	✓	✓
Execute Me	✓			✓	
Collect Me	✓	✓	✓		✓

Further on from the task design, after players complete each level in the game, they will receive an achievement in form of stars. However, in order to complete the task and receive stars, players need to use given lives and time less than what are given or else the game will be over. Therefore, the *Stars Calculation* comes from player's *Remained Lives* and *Remained Time* (except for one task named Turn Me which the stars will come from the remained time only). In addition, there will be 2 lives given in each round, meanwhile, the given time might be different in some task and some level. However, the general calculation for stars will use the mentioned origin factors to further calculate for 2 aspects which are *Life Scores* and *Time Scores*. Then, the mean of those 2 aspects will be the given stars as the end. Thus, the method of finding aspects will be illustrated further details as follows.

- Life Scores

  Life Scores depended on the total *Remained Lives* of 3 rounds playing. If players did not lose any life from playing, they will receive 3 Life Scores. However, once the players lost 1 life, they will receive decreasing Life Scores follows the increasing number of round occurrence. For instance, if they lost 1 life for 1 round, they will receive 3 Life Scores; meanwhile, if they lost 1 life for 2 rounds, they will gain 2 Life Scores.

Table 5. Time Scores Scale.

Time Given	Task	Remained Time	Time Scores
20 Seconds per Round	- Cross Me Out - Turn Me - Execute Me - Collect Me (Easy)	40 – 60	3
		20 – 39	2
		1 – 19	1
30 Seconds per Round	- Catch Me - Collect Me (Medium)	60 – 90	3
		30 – 59	2
		1 – 29	1
40 Seconds per Round	- Collect Me (Hard)	80 – 120	3
		40 – 79	2
		1 – 39	1
120 Seconds per Round	- Fix Me	240 – 360	3
		120 – 239	2
		1 – 119	1

- Time Scores

  In order to identify the Time Scores, the total *Remained Time* from players is needed to be compared with the total given time from 3 rounds for determining the falling range of the Time Scores. However, in each task or even in its level, there might be some differences in the given time; thus, the Table 5 will propose the possible given time in Esc Challenge game.

Furthermore, the given stars, which appears in form of *Executive Functions Scores* for players through the profile page on the game application, can be calculated further for the *Critical Thinking Skill Practicing Percentage* that will be shown on the monitoring website as a radar chart. However, the calculation can be done if and only if players finish every task inside the room. Hence, the process of calculating each focused *Critical Thinking Practicing Percentage* comes from the following formula in Figure 10.

$$\text{Interpretation Practicing \%} = \frac{\sum Gained\ Stars\ of\ (WM, FA, PO)}{\sum Total\ Stars\ of\ (WM, FA, PO)} \times CT\ Progress\ \%$$

$$\text{Analysis Practicing \%} = \frac{\sum Gained\ Stars\ of\ (WM, FA, PO)}{\sum Total\ Stars\ of\ (WM, FA, PO)} \times CT\ Progress\ \%$$

$$\text{Explanation Practicing \%} = \frac{\sum Gained\ Stars\ of\ (WM, FA, PO, CF, GDP)}{\sum Total\ Stars\ of\ (WM, FA, PO, CF, GDP)} \times CT\ Progress\ \%$$

Figure 10. Critical Thinking Practicing Percentage Formula.

According to 3 formula of *Critical Thinking Skill Practicing Percentage*, the possible total stars for each executive function in each task is 9 stars since 3 stars in the maximum amount that players could get from each level. In addition, the mentioned *CT Progress %* is a weighting factor that will be increased follows the accruing room number as shown in Table 6.

Table 6. Critical Thinking Progress Percentage Weighting Factor.

Room	CT Progress %
1	20 %
2	30 %
3	50 %

2) Monitoring Website

With the monitoring website, parents as guardians could trace their children's practicing progress during the gameplay through a radar chart which contains *Critical Thinking Practicing Percentage* from each room. Also, parents could learn concepts of *EF* and critical thinking for a better understanding about the game tasks. Moreover, parents could apply and plan how to enhance their children development.

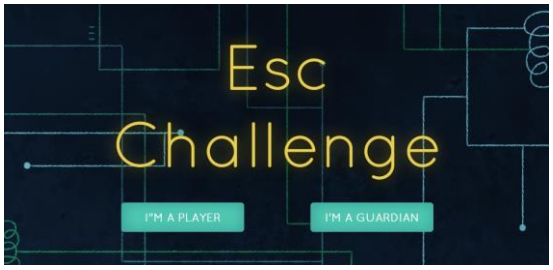

Figure 11. Monitoring Website Home Page.

Figure 12. Monitoring Website Tips Page.

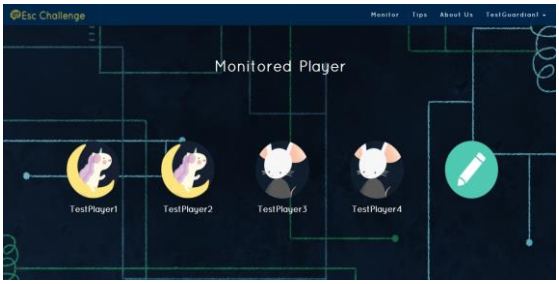

Figure 13. Monitoring Player(s) Management Page.

Figure 14. Monitoring Player's Progress Page.

3. Experiment and Evaluation

In order to ascertain if implemented systems serve users both convenience and ease of use, the experiment has been conducted to inspect user's behavior with respect to the given scenario. Therefore, the developers could find out what works and what needs an improvement.

According to limited availability of time to be conducted for the experiment, there were 9 volunteered participants joined at Chindapong school; 3 Grade 1 students and 3 Grade 5 students joined as players, while other 3 parents joined the experiment as guardians. The time given for each participant was at most 30 minutes.

For players, they were assessed on several significant aspects for the game application including usability, satisfaction, and engagement. However, there were only Grade 5 students participated in engagement testing. On the other hand, guardians participated for usability testing and satisfaction assessment towards the monitoring website. In the following section, there will be a description for each testing delivered during the experiment.

- Usability Testing

  Players will be initially described the storyline of the game, while guardians also get to know primary details about the monitoring website. Afterward, all of them will individually try using the systems according to the test scenarios During the experiment, they will be evaluated in a range of 1 - 4 rating scale whether there is any guidance given or not. To illustrate, if the participant can complete the task without any guidance, that task usability will be scored as 4, if the task is completed with 1 guidance given, the score will be 3 and continue to lessen according to the demand of guidance respectively.

- Satisfaction Assessment

  Once both types of participants finished the given scenarios on usability testing. They have to assess their satisfaction towards the system. The participated children could rate their satisfaction through using smileys which represent scores of 1 - 3 or poor, average, and excellent. Differently, parents as guardians could directly rate their satisfactions through the rating scale of 1 - 5 that indicates from poor to excellent.

- Engagement Testing

  Participated students get to play games in 2 different types; the implemented application and the paper-based one. Then, they will have to decide and explain which one of them they prefer to play more.

4. Results and Discussion

According to the experiment conducted towards students in Grade 1 and 5 students, there were 3 types of user testing provided, which are usability testing, satisfaction assessment, and engagement testing. The outcome results will be shown as following.

1) Game Application Experimental Results

a. Usability Testing

For the graph of Application Usability Testing in Figure 15, the statistic shown that the lowest average score is the profile management usability which is 1.3 out of 4. On the other hand, the highest average score of 3.8 is going through the game step by follows by setting management and the access and general usage in the application in sequence.

Another usability testing as shown in Figure 16 which tested of on 4 tasks inside the game (Cross Me Out, Turn Me, Catch Me, and Fix Me), Grade 1 children have the highest average score of 2.3 in Turn Me then follows by Cross Me Out, Catch Me, and Fix Me.

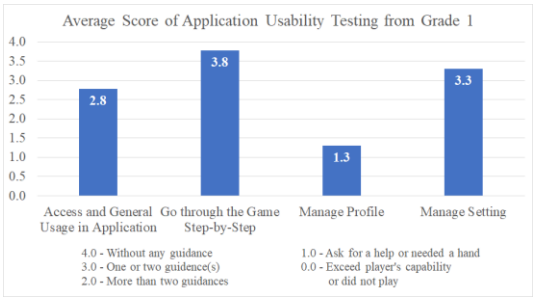

Figure 15. Grade 1 Students Results on General Usability Testing.

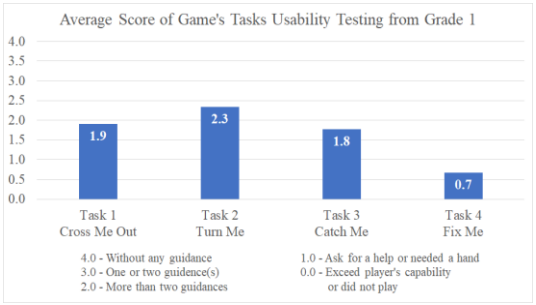

Figure 16. Grade 1 Students Results on Game Tasks Usability Testing.

On the other hand, most of the results from children in Grade 5 appeared to have a higher mean in every case of usability test as shown in Figure 17. For instance, from the graph of Application Usability Testing, the result shows that every average score of the children in Grade 5 is more than 3 which means most of the children in Grade 5 can use the application without any guidance or at least they were given one or two guidance(s) to achieve the test scenario.

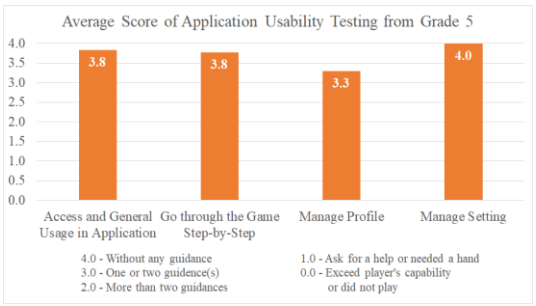

Figure 17. Grade 5 Students Results on General Usability Testing.

In addition, for the graph of Game's Tasks Usability result as shown in Figure 18, there is one task that children in Grade 5 have a lower result than

2 which is Fix Me Task. Meanwhile, other average scores are higher than 3.0 in other tasks where the highest average score is 3.9 from Catch Me Task, then follows by Collect Me, Cross Me Out, Execute Me, and Turn Me Tasks in order.

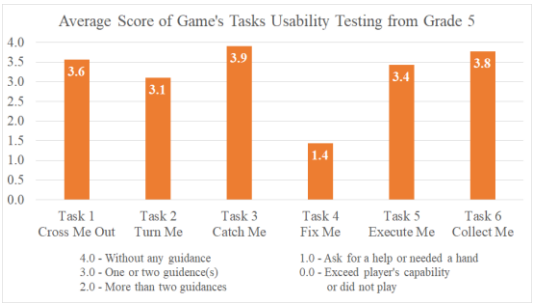

Figure 18. Grade 5 Students Results on Game Tasks Usability Testing.

b. Satisfaction Assessment

Furthermore, two bar charts in Figure 19 and 20 which present the satisfaction of children in Grade 1 and 5. For the graph of Satisfaction from the Grade 1 children, the children gave excellent or 4 score to the content, learn, and overall usage parts. For the rest one, the design part got lower average score than 3. For the satisfaction graph of the Grade 5 children, Learn and Overall usage of the game application also got excellent. However, there are 2 parts of satisfaction in Design and Content which got lesser than 3 score.

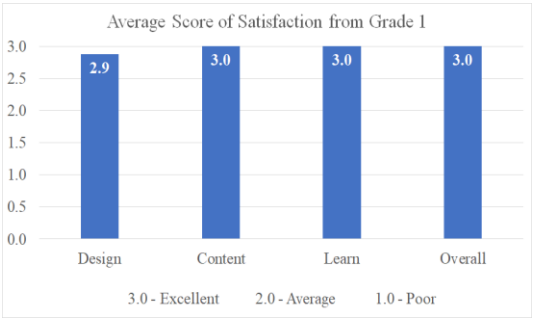

Figure 19. Satisfaction Assessed by Grade 1 Students.

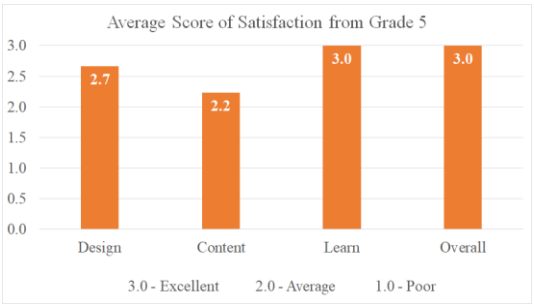

Figure 20. Satisfaction Assessed by Grade 5 Students.

c. Engagement Testing

Apart from the Usability Testing, the children in Grade 5 also have been tested the engagement of using game application upon paper-based game. The result from the test shown that one children prefers playing games through paper-based. However, two out of three children prefer using application to play games.

2) Monitoring Website Experimental Results

a. Usability Testing

According to Average Score of Usability Testing graph shown in Figure 21, all participants had done the tasks without any guidance in the Accessibility part such as register, log in, and page accessing, and also in the part of View the player's result. However, there are some parents, need a guidance in the Page Accessing part, so the average score of this part falls to 3.5. For the part of Monitored Player Management, there were parents who needed more than 2 times guidance, therefore this part has the lowest average score of 2.67 out of 4.

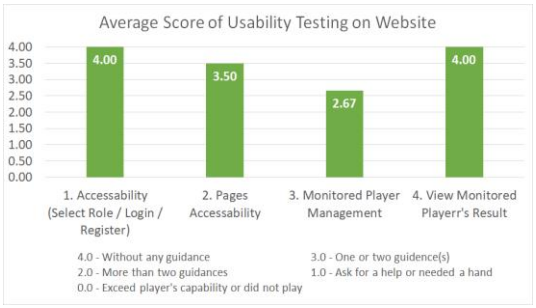

Figure 21. Parents Results on Usability Testing.

b. Satisfaction Assessment

The graph from Figure 22 presents the average score of parents' satisfaction on the monitoring website. The Content and Overall parts got 4.5 scores or in between good and excellent from all parents. However, there are some of the parents gave an average satisfaction or 3 scores for the part of Design, therefore the average score of this part is the lowest average satisfaction score of 4.1 out of 5.

Figure 22. Satisfaction Assessed by Parents.

3) Discussion

Firstly, from the *game tasks usability testing result*, there is a similarity between playing either on the application or the paper that participated students were unable to complete the task called Fix Me, which points out the lowest average score. This might be because the children have to use plenty of their Cognitive Flexibility [25] in seeing and shifting their perception over their general paradigm, also basic academic knowledge to complete the task. This indicates that difficulty levels and child development in focused age range should be aligned together with more concern.

The second point, the *game engagement result* from children in Grade 5 showed that the participant preferred perform the immediate or free action on paper-based game upon the game application Therefore, it can be presumed that not all children choose game application. However, this discussion might not finalize that which type of the game is better due to the small amount of the participants.

For the last point, as the *result of usability and satisfaction of the participants*, it was found that the barrier of both game application and monitoring website is the design of their components which might not represents understandable meaning for users by comparing with their familiarity on the design of game application and monitoring website. This indicates that the design of components on both platforms should be improved to be more simple and understandable based on their generations.

5. Conclusion

To summarize, Esc Challenge provides two subsystems for the game application and monitoring website. In order to encourage the players to practice their *EF*, the game application is combined with several approaches to attract them like escape room scenario with the storyline. For guardians, the systems provide the user-friendly website interface to let them trace their children practicing progress through the gameplay and further details about the game and applied theories, therefore, they can help and support their children to enhance the skills.

6. Limitations and Future Work

Based on the results, the age range of participants could be narrower for generating more specific design implications including task difficulties for a specific age group of children. Furthermore, the number of participants could increase for gathering more data and ensuring more reliability of the analysis. Moreover, the symbols or icons that appear on both game application and monitoring website could be modified for helping users precisely interpret their meanings. In addition, 'Daily Mission' along with more rooms and tasks could further be designed and added in order to cover all executive functions development and encourage the players to practice and achieve the tasks for receiving rewards in each day.

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