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Validating the Effectiveness of Game-based Learning Approach in the Form of Video Game for Assessing Computational Thinking

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Abstract

This research aims to validate the effectiveness of students' understanding in four aspects of computational thinking with the game-based learning assessment. The four aspects of computational thinking involved in this research are decomposition, pattern recognition, abstraction, and algorithm. This research will use a mixed method design approach with a quasi-experiment using a pre-test and post-test nonequivalent group design. The quasi-experiment will validate the effectiveness of students' understanding on the decomposition, pattern recognition, abstraction, and algorithm aspects of computational thinking with the game-based learning assessment. The qualitative data gathered will be analyzed using thematic analysis. It is expected that the students' understanding in four aspects of computational thinking with the game-based learning assessment will vary in terms of the effectiveness.

Keywords: game-based learning, computational thinking, learning assessment, video games

INTRODUCTION

This study shall investigate the effectiveness and usefulness of game-based learning approach towards higher education students' understanding and performance of computational thinking using a video game developed with game-based learning implementation. In this section, the background of the study, statements of problems, research objectives, research questions, research hypothesis, significance of the study, scope of the research as well as operational definition shall be discussed, and a summary of the study will be concluded at the end of this proposal.

For the time being, there are many game-based learning video games available in the market. However, most of them are hardly related to the aspects of computational thinking (Pho & Dinscore, 2015). Even for the ones that do, the majority of them exercise a proprietary design approach to assess the main aspects of computational thinking (Pho & Dinscore, 2015). Undeniably, game-based learning video games are gradually becoming popular, but the lack of reference models to the effectiveness of game-based learning towards the computational thinking aspects is a prevalent issue (Abdulmajed, Park, & Tekian, 2015).

On the other hand, the concept of game-based learning is also immensely broad and ranged to a great extent. Hence, it is difficult to evaluate the effectiveness and reliability of game-based learning towards the performance of learners (Hooshyar, Malva, Yang, Pedaste, Wang, & Lim, 2021). There is also the lack of a standardized framework to assess a learning outcome using the application of game-based learning, let alone the more specific aspect - computational thinking (Shute, Sun, & Asbell-Clarke, 2017). Subsequently, without a standard definition to operationalize computational thinking leads to research where results and measurement strategies vary significantly across studies, which ultimately makes the obtained results less convincing and difficult to compare (Shute, Sun, & Asbell-Clarke, 2017).

Furthermore, another major consideration is whether the game or technology is being used for its own sake or if it essentially brings improvement to the learning process (Trybus, 2012). Instructors should consider the learners' proficiency or expertise with technology such that the technology itself does not become a barrier to learning (Abdulmajed, Park, & Tekian, 2015). Additionally, for those who would like to create their own games, it is worth to notice that, even for experienced game designers or creators, developing a game is not easy. A greater challenge coming after that making of a good game is to make the one that effectively and successfully teaches and engages players (Pho & Dinscore, 2015). Thus, adding the feature of assessing computational thinking is something that increases the difficulty to another level.

RESEARCH AND THEORETICAL FRAMEWORK

A conceptual framework is constructed to support the research study and provide a better workflow throughout the research and development. Figure 1 displays the proposed conceptual framework for this research study. The constructed framework is designed and referenced from the literature reviews of the study, which consisted of computational thinking aspects, game-based learning elements, as well as the techniques assessing computational thinking.

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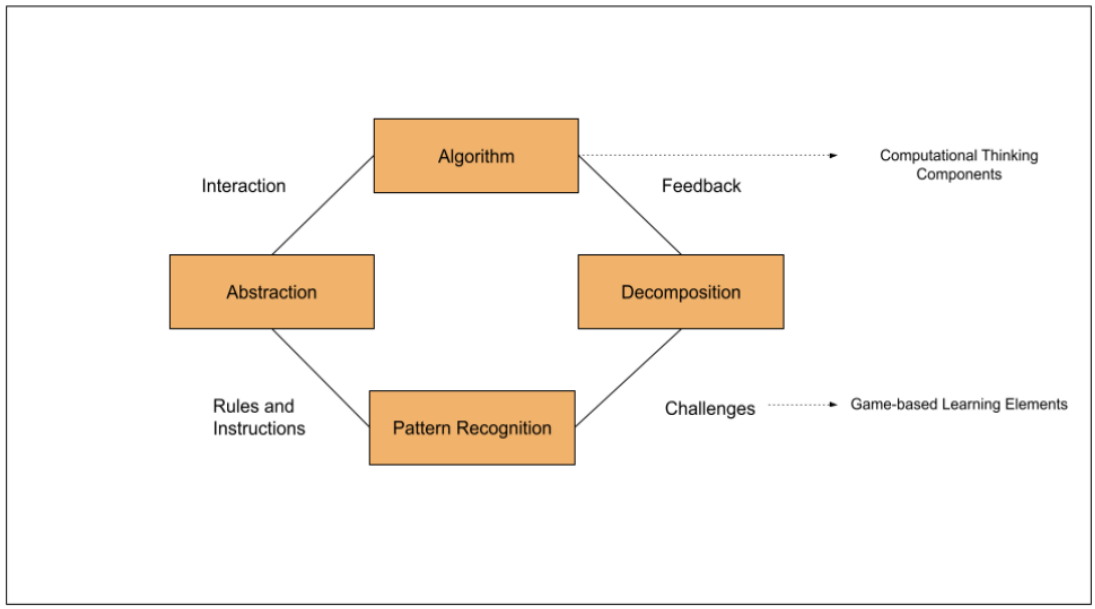

Figure 1: Research and Theoretical Framework

The four main aspects of computational thinking shown in Figure 1 are:

1) *Decomposition*

Decomposition is the concept of breaking down the complexity of a subject into smaller and more manageable parts. Being able to identify and decompose the smaller parts of a task is significant in solving it as an entity. For example, making a cake can be recognized as a complex task that requires many small steps combined, such as mixing up the ingredient, shaping the mixture, and setting up for the baking process. Thus, and so, a clearer outline for the procedures can be constructed assuming that we have all the steps figured out. Ultimately, we can begin to solve the complex task.

2) *Pattern Recognition*

Pattern recognition can be seen as the skill to observe for similarities and patterns in the subject for further analytical process. Pattern recognition is a fundamental ability that we apply throughout our everyday tasks. Examples of the everyday application are such as differentiating foreign languages, and identifying what food one is allergic to. Curriculum wise, the applications are such as recognizing the correct formulas used for certain calculations, and classifying different species by their traits and characteristics.

3) *Abstraction*

While decomposition and pattern recognition enable one to break down the complex problem, abstraction allows one to figure out how the broken-down parts connect and work with each other accurately. It also helps to filter out irrelevant and less useful components in the problem. One of the daily applications is the ability to identify the most important details in a long article and create a summary.

4) Algorithm

Algorithm thinking is the essential skill to construct a systematic and logical process to solve the problem. It allows the automation of the problem-solving process by building a replicable and sequential system that compiles the inputs to produce reliable outputs. One of the most relevant applications is coming up with recipes for food by figuring out the ideal portion of each ingredient, the time taken for each process, and the pairing of different dishes that suits together. As the name suggests, algorithms also allow the programmers to construct a defined set of algorithms that are useful and replicable in code development

Whilst, the game-based learning elements are as follows:

1) Challenges

Challenges are the obstacles that the player encounters during the process of tackling the game objective. Challenges allow the player to figure out the actions needed to overcome the problem in order to progress through the gameplay. They are the core element for excitement and immersiveness that makes the player want to progress.

2) Rules and Instructions

Rules and instructions are the statements and directions the player must follow in order to properly play the game. Rules can also be viewed as a defined set of principles that add limitations to the player's actions so that the actions made are meaningful. It can be also considered as a protection mechanism made by the game designers to protect the players from violating the game systems that may potentially ruin the game experience, whether intentionally or unintentionally.

3) Interaction

Interactions are the reciprocal influences made by the actions and reactions of both the player and the game systems. In short, any action made by the player to the game systems should have a corresponding reaction, and vice versa. By properly interacting with the game mechanics, a gaming experience is created since the actions done are no longer mono-directional.

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4) Feedback

Feedback is produced whenever an interaction occurs. For example, clicking the arrow keys will allow players to move their selected in-game characters. Feedbacks provide real-time information on the player's progress towards the objective. Examples of game feedback are such as, the amount of lives available, time remaining for the task, and the current location of the player character.

LITERATURE REVIEW

The aim of the literature review is to understand the current literature on the research topics, outline the existing issues encountered by students and provide the latest information regarding the current situation and research results on game-based learning as an assessment to computational thinking. Therefore, systematic review shall be done on the research area and within the context of the proposed study.

Game-based Learning

Game-based learning can be defined as an active learning approach with the embedment of game components and principles. Application of game-based learning can be adapted as an educational technique that promotes learners' engagement and motivation to the learning materials, ultimately enhancing the learning process (Pho & Dinscore, 2015). In recent years, digital game-based learning has attracted substantial attention in academia and has become one of the popular research topics (Chen, Zou, Cheng, & Xie, 2020). Numerous studies have shown that digital game-based learning give positive effects on the learning attitude and motivation of students or learners (Yang, Chang, Hwang, & Zou, 2020; Taub et al., 2020; Tapingkae, Panjaburee, Hwang, & Srisawasdi, 2020).

Game-based learning provides opportunities for instructors to embed active learning into their teaching sessions, promote students' engagement and interest, and provide instant feedback on performance. There are a substantial amount of research works that suggests that game-based learning can intensify student learning (Pho & Dinscore, 2015).

In the classroom settings, the traditional teaching approach is monotonous based and does not provide sufficient interaction for students. This ultimately makes the students lose the inquisitiveness to understand the purpose of studying certain subjects and educational topics (Priyaadharshini, NathaMayil, Dakshina, Sandhya, & Bettina, 2019). In another way, game-based learning provides the students with interesting interaction and feedback using the game design elements. For example, the students are provided with points earned and scoreboard system to know how well they are doing and how far is their progress to achieve a certain learning outcome (Kapp, 2014).

Computational Thinking

Computational thinking can be defined as a cognitive skill that allows people to apply computational solutions for a contemporary problem by adapting computer sciences' reasoning processes (Wing, 2014). The four main aspects of computational thinking are classified as pattern, decomposition abstraction, recognition and algorithm.

Several research works have reported that adaptively and personalization in educational based on computer games can facilitate students or learners reaching their full educational or academic potential. However, little efforts have been made targeting to develop adaptive computer games education for the purpose of promoting and developing students' computational thinking (Hooshyar, Malva, Yang, Pedaste, Wang, & Lim, 2020).

Although the technical definition of CT varies among researchers, the most used and cited definition is given by Cuny, Snyder, & Wing (2010) which describes CT as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent." It emphasizes on the conceptualization and fundamental thought processes of solving a problem not syntactically but rather computationally.

The participation of students in learning based on gamification activities for the development of computational thinking skills can be achieved and can positively impact on students' learning (Kotini & Tzelepi, 2015). Computational thinking holds crucial key as mental tools and practices in computing field but it is also addressed in other areas far beyond the scope of computer science. It is a very crucial and useful thinking approach in almost all disciplines and school subjects as an intuition of what can and cannot be computed (Kalelioglu, Gulbahar, & Kukul, 2016).

Over the recent years, interest in the development of computational thinking has shown some drastic increment, especially across the professionals such as the researchers, educators, and policymakers. (Zhao & Shute, 2019). In the noteworthy publication of the article titled "Computational Thinking" by the influential researcher Jeannette Wing. In the article, computational thinking can be defined as an essential skill set that can be applied during almost any learning process. It is also pointed out that computational thinking is significant in most of the basic skills such as writing, reading and arithmetic.

Educational games, or any equivalent with game-based learning approaches, have gained the attention of many researchers, educators and relevant developers, as studied have shown they are effective learning tools that provide engagement and motivation for the learners, which subsequently improve their learning outcomes (Zumbach, Rammerstorfer, & Deibl, 2020; Pontes, Duarte, & Pinheiro, 2020; Hooshyar, Yousefi, Wang, & Lim, 2018).

Despite the existence of these game-based learning games with the purpose of promoting computational thinking, to a certain degree, they ignore nurturing computational thinking skills.

Instead, most of these game-based learning approaches revolve around the reinforcement of computational thinking's conceptual knowledge and the students' motivation to learn (Hooshyar et al., 2019; Zhao & Shute, 2019; Kazimoglu, Kiernan, Bacon, & Mackinnon, 2012; Kazimoglu, Kiernan, Bacon, & Mackinnon, 2012; Kuruvada, Asamoah, Dalal, & Kak, 2010).

Components of Computational Thinking

Despite the great extent of studies and research of computational thinking, there is no fixed consensus among the researchers for the definition of computational thinking and what are the components and competencies of this skill (Angeli & Giannakos, 2020; Angeli & Valanides, 2020; Guzdial, 2008).

During the early period of studies made on computational thinking, Wing (2006) has argued the six primary components for computational thinking, such as problem formulation, problem decomposition, automation, systematic testing, abstraction and problem reformulation. Few years from there, Denning (2009) has made the statement that computational thinking does not only apply to the computer science principles and comprises seven components. They are computing, coordination, communication, recollection, design, assessment and automation.

Throughout research and studies for over a decade since the defined establishment by Wing (2006), there is still a lack of fixed consensus on the components. However, there are four core components that are generally accepted and overlapped among the numerous studies made globally. The four core components are decomposition, pattern recognition, algorithm, and abstraction (El Mawas, Hooshyar, & Yang, 2020; Zhao & Shute, 2019; Tsaravaet al., 2017; Brennan & Resnick, 2012; Kazimoglu, Kiernan, Bacon, & MacKinnon, 2012; Wing, 2006).

The application of computational thinking is component-based, hence there is a sequence of which of the components is accessed by the learner first during the thinking process (Kazimoglu, Kiernan, Bacon, & MacKinnon, 2012). In this case, the most common initiating component that most studies have in common is decomposition (McVeigh-Murphy, 2019). Decomposition handles the process of breaking down complex problems into smaller and more controllable parts, which makes problems that seem overwhelming at first become something more achievable (McVeigh-Murphy, 2019; Zhao & Shute, 2019; Denning, 2009; Wing, 2006).

Valenzuela (2018) has stated that decomposition is an ability that can be seen both academically and throughout the daily life of most people. Everyday examples are such as making cookies, which may seem like a complex task, but is actually reducible into smaller and simpler tasks such as forming the dough, shaping the cookies with cutters and baking them. Academic examples are such as composing an essay by collecting facts and evidence, developing a thesis and creating a bibliography page.

Research Methodology

This section presents the proposed methodology that will be implemented in detail. The details of the

research methodology are research design, research sampling methods, research instrumentation, procedure of data collection and data analysis which will be used in this study for the purpose of creating a game-based learning assessment for the students' understanding and performance towards ubiquitous computational thinking.

Research Design

The chosen research design for the study shall be mixed research method along with quasi experiment. With the quasi-experiment approach, the research design will be constructed by a pre-test and post-test non-equivalent group design.

The proposed research conceptual framework illustrated by Figure 1 is adapted by systematically reviewing papers from other authors and researchers and then concluded by combining and modifying all elements and concepts used by the researchers.

Research Sampling

The chosen sampling to be used in this proposed study is known as a purposive sampling. It is a non-probability sampling method which is frequently achieved by implementing expert knowledge of the population to select a sample of elements in a non-random way that represents a cross-section of the targeted population. Due to limited time, resources and purpose of the study, it has been chosen as the proposed technique.

The sample population targeted for this study shall be participants who are in computer science or game development fields. The participants are the students and experts, such as lecturer, developer and designer. These sample populations are categorized into two parts:

a) Student Group

The participating computer science students will be categorized into two groups, which are focus group and control group. There will be an estimated 25 - 30 people in each group. The expected minimum results in conducting this research will be minimum 50 participants or maximum 60 participants.

b) Expert Validation

The experts are required to have a minimum of five years' experience that involve in Game Based Learning related development. Minimum of three will be chosen in conducting this research study.

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Phases of Data Collection

a) Phase 1: Literature Review & Expert Validation

As the beginning phase of the research, literature review will continuously be conducted to keep the researcher updated with the newest knowledge and findings related to the game-based learning assessment framework considering the computational thinking. Such extensive review will help to comprise numerous assessment frameworks for the computational thinking. For the time being, the conducted literature review has showed that the game-based learning assessment framework comprising computational thinking has not been well explained and researched extensively. The recent approach has not been improvised nor reported in literature, hence further conforming the originality and novelty of the proposed research study.

With the literature review carried out, an initial framework design for the assessment will be drafted. Subsequently, expert validation will be commenced as consultation and acknowledgement from the relevant experts. The selection of experts will be narrowed down to designers, developers and lecturers with relevant game-based learning expertise and minimum of five years of experience in the field.

After gathering enough information from the expert validation, the framework will go through a design integration and adjustment to modify and enhance the assessment game in a better approach. Then, an enhanced framework will be proposed to the experts again to get approval and finalize the design.

b) Phase 2: Implementation & Game Development

The information and data gathered from phase 1 will be implemented as part of the game design integration. The development of the game-based learning computer game responsible for this research study will begin. All the relevant assessment framework considerations obtained from phase one will act as the reference and guidelines for the development. The developed game will then be validated again by the subject experts accordingly. A series of quasi-experiment will be conducted upon the development completion. Targeted students (minimum 50 students from participating schools or educational institutions) will be selected to participate in this quasi-experiment. They are divided into a control group and a focus group with pre-test and post-test respectively. Students assigned to the focus group will be given the developed game to playtest. The game will not be assigned to students in the Control Group.

c) Phase 3: Analytical & Assessment Framework Modelling

After compiling all the results obtained from both groups in pre-test and post-test of phase 2, an analytical result with comprehensive comparisons will be documented. The data obtained will also be further investigated to establish a novel game-based learning assessment framework of pervasive computational thinking. This will act as the assessment of the students' understanding and performance toward ubiquitous computational thinking. The newly proposed and developed assessment framework will after that be validated by quasi-experiment to validate its effectiveness of assessing the students' understanding and performance toward ubiquitous computational thinking.

d) Phase 4: Data Analysis & Documentation

Documentation of the finalized result and data will be done in this final phase of research. The documented data will also be reported and published as a journal. Lastly, a final report for concluding the research work will also be compiled.

Research Process

The chosen research design for the study shall be mixed research method along with quasi experiment. with the quasi-experiment approach, the research design will be constructed by a pre-test and post-test non-equivalent group design. The process structure is shown in Figure 2 below.

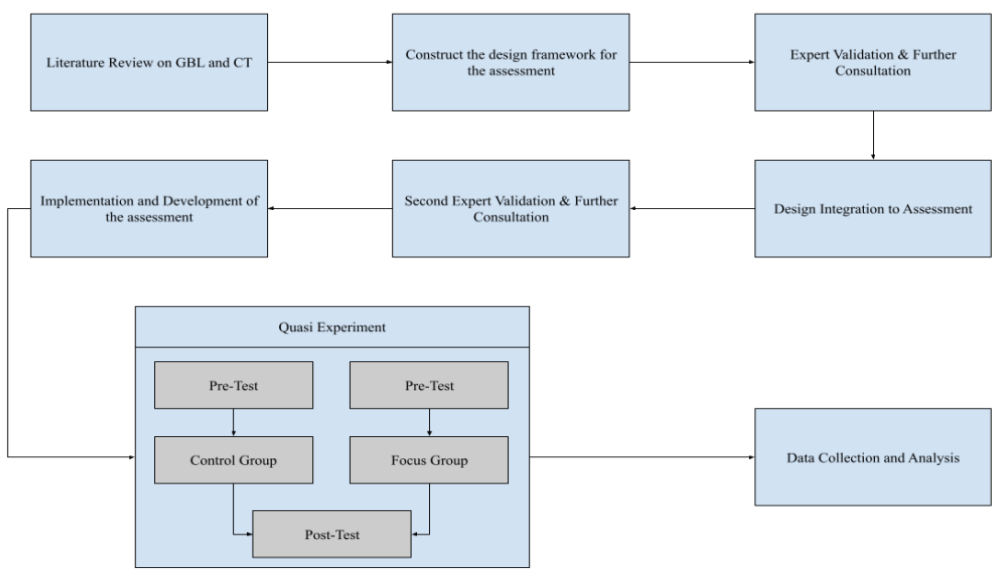

Figure 2: Research Process

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CONCLUSION

The objective of the research is to develop an assessment tool for validating the effectiveness of game-based learning approach in assessing the components of computational thinking. The assessment is constructed using a designated framework in combination with the game-based learning elements, and ultimately conducting it in the form of a quasi-experiment. By constructing an effective assessment tool as such, the understanding of computational thinking correlated to the game-based learning elements will be further enhanced. Moreover, the tool can be potentially utilized in parallel to the modern educational approach, significantly solidifying the fundamentals of computational thinking skills of the learners.

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