Effects of Digital Game-Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students

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ABSTRACT

The aim of this research is to study the effect of using Digital Game-based Learning apps based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for primary school students from the aspects of motivation, performance and problem-solving ability. A boring conventional learning affects pupil's motivation and can further effect pupil's problem- solving ability in mathematics. This in turn will affect their mathematics performance as well. Digital Game-based Learning apps based on Mayer's Cognitive Theory of Multimedia Learning could be one method of enhancing the students' motivation which lead them to have a better problem-solving ability and would improve students' performance. The research design was pre-experimental where one group would be studied without comparison with the control group while the sample were 25 year 3 students in a primary school. A questionnaire was used to test the impact of motivation and problem-solving ability meanwhile an achievement test was used to test students' performance. The mean comparison before and after intervention is measured by conducting a Wilcoxon Signed Rank-test to test the effect of motivation, performance and problem-solving ability. A semi-structured interview was conducted to identify pupil's perception towards Digital Game-Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning during intervention. As a conclusion, the intervention can increase pupil's motivation, enhance students' performance and problem-solving ability in primary school mathematics with significant mean differences which also supported by the findings from positive responses from the interview session.

Keywords
Digital game-based Learning Apps; primary school mathematics; technology

Introduction

Malaysia set foot to implement an instruction framework that would be used to scale up the quality of learning across the country. In 2013, the Ministry of Education set up the Malaysia Educational Blueprint (2013-2015) whose primary aim was the assessment of the country's current instruction framework. One of the operational shifts to be implemented suggested the introduction of ICT into learning. The implementation of ICT into teaching would enhance the student's learning experience and provide a wider scope of content that is more interactive and engaging (Malaysia, 2013). The digital game-based learning apps is a way of introducing ICT in learning owing that ICT has aided in the significant development of the learning process. Digital Game-Based Learning (DGBL) is an instruction method that includes the utilization of computerized recreations (Hussain et al., 2017). Lately, numerous educational digital games have been created for improving learning most especially in mathematics and this is also seen to increase the motivation of students (Hung, 2012). Mathematics is a basic and practical subject in our daily lives. It is vital to stimulate interest in Mathematics from an early age as it is plays a significant role in future development (Huang 2013). Conventional teaching methods are dull and boring hence decreasing student's interest (Jong et al., 2013).

Background of the Problem

Learning motivation for students has always been a primary challenge for teachers especially in Mathematics. This has triggered the creation of digital content for mathematics that best suits students who consider the subject as an obstacle. Naik (2015) demonstrated that the use of DGBL increases the learning attitudes of students as their

guidelines aid the students in creating constructive knowledge. The overlying problem in the educational environment is the lack of motivation (Hwang et al., 2013). Henceforth, the application of interactive media is highly essential for students as it attracts their enthusiasm and will to understand mathematics (Vansteenkiste, 2006). Despite the introduction of the digital methods of learning, research has still not been conducted in regards to whether technology reduces the rate of anxiety that students have towards Mathematics. Anxiety in this subject is one of the primary factors that leads to a lack of motivation by students (Bagaka, 2011). Mathematics remains a subject that has been a great obstacle to Malaysian students basing on the PISA assessment. PISA which is Programme for International Student Assessment is a project that evaluates reading literacy, mathematics and sciences of students to find out how they manipulate this knowledge to solve daily life problems. Embracing of the DGBL is essential for Malaysia as it also increases the problem solving skills of the students. The Mayer's cognitive theory of multimedia learning further suggests that the process of learning is enhanced by the use of pictures and words rather than just words. Mayer (2008) further argues that multimedia supports the manner in which the human brain learns.

Problem Statement

The Mayer's cognitive theory explains that the use of the digital game-based learning apps is suitable due to the providence of animation and pictures that attracts the student as they further get to engage with audio visual materials. Teachers need to create interesting methods of teaching to capture the student's interest and to meet their needs (Zaliza & Zainon, 2014). The technique of teaching is therefore an essential part of learning that educators should look into. As they further look into their teaching techniques, teachers should also evaluate how the DGBL apps have impacted the performance and attitude of students so as to acquire information that will guide them into establishing how to increase learner experience. Lack of interest is one of the factors that lead to poor performance by students. Henceforth, teachers should capture their student's interest by incorporating both modern and traditional methods of teaching hence guaranteeing full comprehension of concepts (Woo, 2014). Use of digital assistants has been seen to improve learning outcomes both in class and outdoors (Sung et al., 2016). Furthermore, the use of DGBL has been seen to increase teacher-student interactions which is vital in education as the teachers are able to identify certain weaknesses in students and hence have better chances of approaching these problems. In addition to this is the inadequacy of students that possess problem solving ability. Problem-solving ability has been mentioned as one of the most complex abilities among students as it requires a lot of expertise and dedication. On that note, DGBL apps are manipulated in ways that evoke the student's ability to solve problems (Sung et al., 2016). The visual representations aid the students in overcoming problems related to learning motivation hence sharpening their problem-solving skills. Thus, the Mayer's cognitive theory is efficient and essential in that it offers teachers a wider range of instructions and guidelines that aid in increasing the student's learning achievements. In finality, the overlying issues that are a cause of poor mathematics performance among Malaysian students is the lack of motivation or otherwise interest, teaching strategies and lack of proper learning materials.

Research Objective

1. To develop and design DGBL apps based on Mayer's Cognitive Theory of Learning in Mathematics for primary school students.
2. To evaluate the effects of DGBL apps based on motivation, performance and problem-solving ability.
3. To identify student's perception towards DGBL apps based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students.

Research Questions

1. What are the effects of DGBL apps base on motivation, performance and problem-solving skills?
2. What is student's perception towards DGBL apps based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics For Primary School Students?

Research Hypothesis

This research has three hypothesis testings' that will try to uncover whether there has been any difference in using DGBL on the Mayer's Cognitive Theory.

1. H_0 There is no significant difference between the (motivation, performance and problem-solving skills) of the respondents before and after the intervention of DGBL on the theory.
2. H_1 There is a significant difference between the (motivation, performance and problem-solving skills) of the respondents before and after the intervention of DGBL on the theory.

Conceptual Framework

Multimedia learning is a cognitive theory of learning that builds mental representations from words and pictures. The theory has mainly been defined by Richard E. Mayer's cognitive theory. The components of the theory are summarized as having the following components; a dual-channel structure, limited processing capacity in memory, three memory stores, five cognitive processes of selecting, organizing and integrating and theory-grounded and evidenced-based multimedia instructional methods. In game system components, the first point of consideration is the challenge. In educational games, challenges must be encapsulated with teaching content. The mechanism of the game determines the player-computer interaction while the interactive interface influences the sensation of the game. Several factors could be implemented in a game to make it enticing to the player hence attracting some game values. This way students are able to learn while enjoying themselves at the same time.

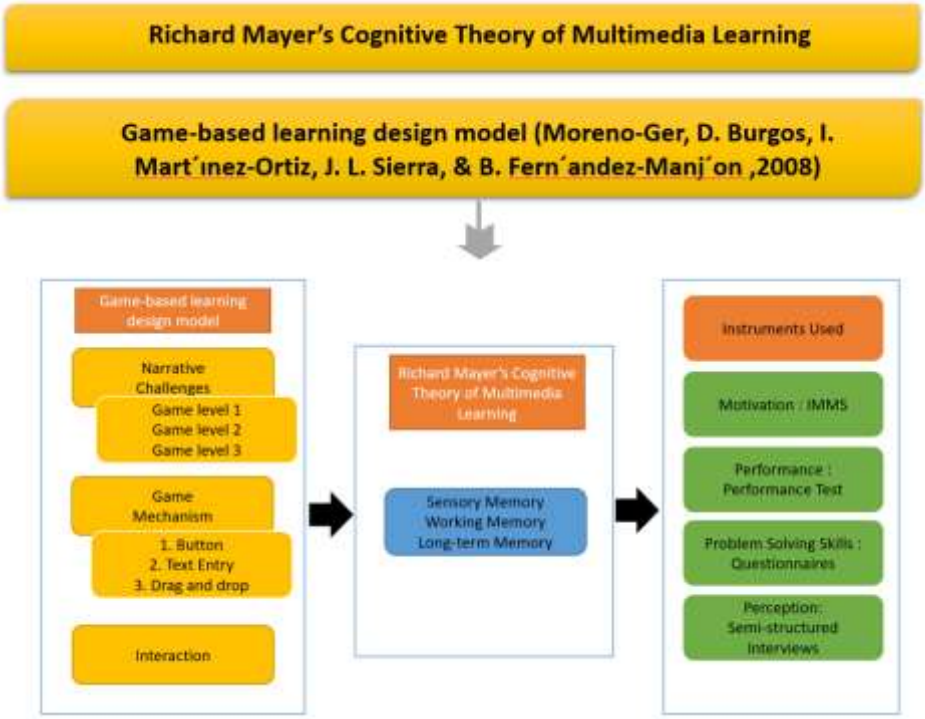

Figure 1. Research Conceptual Framework

Literature Review

The use of digital game-based learning as a powerful teaching approach has dominated today's educational system. This is primarily because of the increased development and adoption of educational technologies in classroom settings. There are a few researches that indicates positive views on using Digital Game Based Learning for learning Mathematics, such as it exerts positive attitudes in teaching and learning for students (Noraddin & Kian ,2013 ; Abdullah et al. 2012). Moreover, researches conducted by (Hussain, Tan & Idris, 2014) and (Hung, Huang & Hwang ,2014) concluded digital game-based learning able to have positive results on students' learning motivation and achievement. Digital game based learning also showed to able to enhances student's learning of concepts based on the research conducted by Mei et al. (2014). Rabu & Talib manage to come into conclusion that digital games have the potential to resolve low performance and mastery among rural primary school students in Malaysia.

Emergence of Digital Game Based Learning

Hussain, Tan & Idris (2014) state that digital games have traditionally been considered as a form of entertainment. However, in recent years, this tool has been proposed as an effective tool for enhancing student engagement and participation in learning activities/tasks within the classroom. According to Noraddin & Kian (2013), digital game-based learning has emerged as a powerful learning tool since its developed as a practice with the potential to provide solutions to learning difficulties in the modern classroom setting. As part of development and integration of technology-based learning methods in the classroom, digital games have been proposed as one of the most powerful and effective resources for learning when combined with education to enhance student engagement in learning activities (Hussain, Tan & Idris, 2014; Rabu & Talib, 2017).

Young People and Digital Game Based Learning

Existing literature demonstrates that digital game-based learning is an important phenomenon in the educational field, especially in relation to education technology. The significance of this phenomenon is attributable to the fact that playing digital games has become a common practice in the everyday lives of many young people (Gabriel, 2016). According to Cheema (2014), digital game based learning provides a suitable approach for engaging and motivating children and teenagers in the classroom. Through a study on how to engage young learners through adopting educational technology in the classroom, Cheema (2014) found that one of the major benefits of DGBL is that it enhances student engagement and motivation in the classroom. In relation to teachers, Oakman (2016) suggests that digital game-based learning provides teachers with instant feedback and analytics. As compared to conventional teaching and learning methods, digital game based learning is a suitable framework with which teachers obtain instant feedback or information regarding their teaching techniques and learning processes. , Oakman (2016) suggests that digital game based learning contributes to improvement in the classroom environment and learning processes that are aligned with the needs of individual students.

Digital Game Based Learning Apps

Digital game-based learning is defined as a teaching approach in which digital games that work in a virtual platform are utilized for academic purposes (Su, C. H. and Cheng, C. H., 2014). A DGBL apps engages students in the process of problem solving or knowledge acquisition when facing the challenges presented by the application and game. Liu, X., and Li, Q. (2015) define digital game-based learning apps as the use of mobile-based video games for academic purposes. In this case, the games are developed as computer-assisted instruction programs that stimulate students' curiosity and imagination as they interact with learning materials/content. These programs also provide exciting challenges to students, which help to enhance their mastery of various issues relating to the subject area. During this process, students enhance their imagination skills as they are exposed to an exciting learning environment. (DaCosta, B. Seok, S. and Kinsell, C. 2018).

Motivation and Engagement

Students motivation is heavily impacted based on teachers' teaching method. Most of the Mathematics lesson in primary school still use conventional methods and by Ibrahim, B. (2017), in a conventional classroom, not all students come to class to learn. This is due to some of it's not even interested in a particular subject or frustrated by the current educational system. The gap is much time for each student to master a learning unit in a conventional classroom learning also lead to less effective and boring. According to McLaran et al. (2017), a conventional approach in teaching mathematics also leads to students' easily lost focus and decrease its engagement in learning mathematics. Bressler, D. M., Bodzin, A. M., Tutwiler, M.S. (2018) provide a different perspective on the impact of digital game-based learning apps in teaching and learning primary school Mathematics. These researchers contend that this learning tool and strategy enhances student motivation and engagement through changing their attitudes towards different subjects like Mathematics.

Students' Performance

According to Chen et al. (2014), digital game-based learning has been found to generate better learning impacts and achievement among students in Mathematics classrooms. These researchers attribute the improved student

achievement in this subject area to higher learning motivation and enhanced engagement in the learning process and activities. In comparison to traditional classroom instruction, digital game based learning generates better learning effects in elementary and primary school Mathematics. Mahardhika (2016) concurs by stating that DGBL improves students' mathematical skills, which in turn improves their performance and achievements in this subject area. Similar to Chen et al. (2014), Mahardhika (2016) states that the improved student achievement following integration of DGBL in teaching and learning Mathematics is attributable to the subsequent attractive learning process and enhanced interest in this subject area.

Problem-Solving Ability

According to Kenna (2016), problem-solving is a highly imperative skill, which is mandatory to be learned by the students. This is because they must be able to adapt to the developmental changes along with the advancements that are taking place in the recent scenario. Hence, it was suggested that 'interactive math games' can be used in order to support the problem-solving strategies of children (Kenna, 2016). In this context, Katmada, Mavridis, and Tsiatsos (2014) have highlighted several benefits of DGBL, which can be optimally used for teaching the students in an effective way. To be specific, Al-Mashaqbeh and Al Dweri (2014) affirmed that it can help students to develop memorizing and problem-solving skills. In this regard, it was also affirmed that using technology as a tool to teach math can be highly effective. It has further been suggested by Brezovszky et al (2019) that in order to apply problem-solving procedures in teaching, flexibility is highly required. This will not only help the students, but also the teachers to enrich their teaching methods. Hence, this can ultimately assist in developing adaptability, as well as, flexibility regarding arithmetic problem-solving.

Richard Mayer's Cognitive Theories of Multimedia Learning

Cognitive Theories of Multimedia Learning has been popularized by Richard E. Mayer. Based on his interpretation of Cognitive Theories of Multimedia Learning, multimedia learning occurs when words and pictures are constructed from us to build mental representation. In general, the theory seeks to address the issue of how to structure multimedia teaching practices and use more effective cognitive strategies to help people learn more effectively. (Mayer, 2005). According to Mayer (2001), information is divided into two channels which are verbal and visual. Mayer's theory states that the use of multimedia will go through three cognitive processes that are important for a student to use. The first cognitive process is the selection of text or words for processing in verbal working memory and selection of images for processing in visual working memory. The second cognitive process involve organize texts or words into working memory and organize pictures into visual memory. The third cognitive process involve combine the working memory and visual memory. The table below shows the meta-analysis for studies about Mayer's Cognitive Theory of Multimedia.

Table 1. Meta-analysis of Richard Mayer's Cognitive Theories of Multimedia Learning

Study	Objective	Population	Outcome
Baharudin, S. N., & Zulkiflei, K. (2019)	Using Multimedia to Promote Students' Learning andUnderstanding of English Literature in Secondary School.	25 Form Five students(aged 17) from a local secondary school in Selangor district	Powtoon videos encourages active participation among learners in class. Teaching literature using Powtoon videos indeed gives noticeable result improvement asdiscussed in the findings earlier.
(Gegenfurtner, Quesada-Pallarès, & Knogler, 2014)	To examine the manner in which design behaviors in learning environments that are based on digital simulation facilitate self-efficacy and	15 studies comprising a sample size pf 2274 students.	The results obtained suggested that a high level of user control leads to higher approximates of transfer and self-efficacy and increased levels of transfer and efficacy beliefs. However, the impacts of social, narrative, as well as multimedia behaviors were reported to have little significance.

	learning transfer.		
Peter Schrader (2017)	Examine the influence of multimedia presentations that leverage motion (present or absent) in conjunction with signaling cues (present or absent) on high school students' ability to learn science concepts.	2x2 experimental design, 99 high school participants were randomly assigned.	Statistical significance all participants over time for a knowledge measure and quality of concepts from a concept mapping task.
(Shamim, 2018)	To establish the effectiveness that video-technology has in teaching undergraduate medical students how to carry out operations for general surgery.	125 students in 4 batches that were used. All male Complete responses were 93.	The overall response rate was above average at 74.4%. 66 students which translates to 71% of the population were satisfied with the effectiveness of the video technology while 27 students (29%) were not satisfied. The video-sessions delivery was effective.
(Wang, Xie, & Li, 2016)	To examine the impact of text modality on tests for both transfer and retention.	91 empirical studies.94 independent effect size comprising 8088 participants analyzing retention.83 independent effect sizes comprising 6664 participants analyzing transfer.	The strong modality effect that was replicated indicated that performance on comprehension and recall tasks is better when words and images are presented in a modality that is dual as opposed to one that is single. These results were in support of the Cognitive theory of Multimedia Learning (CTML).
(Xie, et al., 2017)	To examine the issues regarding the direct relation that exist between cognitive load that is cue-related and learning outcomes.	32 articles with 3,597 participants. 25 articles containing 2,910 participants, and 29 articles with 3,204 participants.	Participants have a lower viewpoint regarding cognitive load compared to participants that did not have the no-cueing condition. Consequently, this evidenced that cues can minimize subjective cognitive load.Further addition of cues in materials for multimedia was evidenced to significantly facilitate transfer and retention.

Methods

Game components is a great contributor to the cognitive processing of the learning content. The methodology of the research involves the instruments and methods that would be used in the research. The validity and reliability of the instruments will also be weighed.

Research Design

The research will utilize both quantitative and qualitative approaches. This approach further tests out the effects of the Digital game-based apps based on the five-point Likert scale which represents the degree of agreement from strongly agree to strongly disagree. The qualitative approach on the other hand was relevant in this research as the study needed to be conducted in the natural setting in the field. In addition to that, it allows the researcher to participate in the field study and collect first-hand information (Bourgonjon et al., 2010). This study contains realities that will enable the researcher to collect data. A case in point is through observation which will aid him in witnessing the effects the applications has on the student and how they interact with teachers while making use of the digitized methods. The qualitative approach also allows the respondents to share their perceptions on the digital apps.

Research Location

A school in Johor State was chosen based on the adequacy in ICT equipment and good internet connection. The school was also a willing participant in the research as they provided the time and space for the researcher.

Population and Research Sample

The population to be used for the study consists of 25 students from year 3. The method of sampling to be used is the purposive method because the lessons are taught out of the Year 3 syllabus hence year 3 students are chosen for the research. Furthermore, this method of sampling enables the researcher to explore the student's views and perceptions towards DGBL apps.

Data Collection

Data from this research will be conducted using semi-structured interviews along with questionnaires. The processes of collection will be done in both Chinese and English to avoid any issues on language barrier which may compromise the credibility of the concluding results.

Research Instruments

The three instruments to be used in this research include the Adopted Instructional Materials Motivation Survey (IMMS) questionnaires whose main purpose is to evaluate the effect of DGBL apps in terms of motivation. The performance test will be used to evaluate the performance aspect of the research. Problem Solving Ability Questionnaires which will be used to evaluate the problem- solving ability. Lastly is interviews which will be used to address respondent's usage when conducting the intervention. The validity of all the instruments used has been approved by experts and the reliability of all the instruments was tested with Cronbach' Coefficient.

Research Procedure

The first step of the researcher will be to obtain the consent from the institutions which are participating in the research. The researcher approached the head of the schools that will participate. The researcher explained the reason for the research, explain background information of the study and give the processes that will be followed. The relevant information about the sample population was stated. The researcher sent the email to the heads of the school and explain the aim of the study. The participants were given enough information that they require to help make informed decision making. The research will ensure that all the participants are comfortable will participate on voluntary basis where they will be allowed to take part or leave the interview when they feel. They also had the right to refuse the questions that would make them not to be comfortable

Data Analysis

Quantitative data obtained from IMMS Questionnaires, Performance test and PSA Questionnaires will be used for descriptive and inferential analysis. descriptive analysis involved calculate the minimum value, maximum value, mean and standard deviation and median. After descriptive analysis, the data was analyzed inferentially to see whether there is a significant difference between before and after intervention.

Table 2. Data Analysis Methods

Research Question	Instruments	Data Analysis
1) What is the effect of Digital Game-Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students by the following aspects: i) Motivation ii) Performance iii) Problem Solving Skills	i) IMMS Instruments ii) Performance Test iii) Problem Solving Ability Questionnaires	**Descriptive** Minimum Value, Maximum Value, Mean, Standard Deviation. **Inferential** Wilcoxon Signed Rank Test
2) What is student's perception in Digital Game-Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Student?	Semi-structured Interview	Thematic and Coding analysis based on the method developed by Vaismoradi, M., Jones, J., Turunen, H., and Snelgrove, S., (2016)

The thematic and coding analysis was based on the method developed by Vaismoradi, M., Jones, J., Turunen, H., and Snelgrove, S., (2016). In their research, it was proposed that there are four phases of theme development, which will be showed in the following table.

Table 3. Four phases of theme development

Phases	Stages
Initialization	-Reading transcriptions and highlighting meaning units; -Coding and looking for abstractions in participants' accounts; -Writing reflective notes.
Construction	-Classifying; -Comparing; -Labelling; -Translating & transliterating; -Defining & describing.
Rectification	-Immersion and distancing; -Relating themes to established knowledge; -Stabilizing
Finalization	-Developing the story line

Results

Motivation

The findings of this quantitative analysis are used to answer research question 1 which is to find the effects of Digital Game-Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students on Motivation aspects. IMMS questionnaire has been used as the instrument to collect data to answer this research question. Data gathered was analysed using descriptive statistic and inferential statistic.

Table 4. Descriptive Statistic for Pre and Post IMMS Questionnaire

IMMS Questionnaires	N	Min	Max	Mean	Std. Deviation
PreIMMS	25	2.39	3.25	2.8078	0.20848
PostIMMS	25	2.81	3.61	3.1811	0.19791

Non-parametric test (Wilcoxon Signed Ranks Test) is used as inferential statistics to prove there is a significant difference between before and after intervention.
The hypothesis for this test is as follows:

H0 = There is no significant difference between the motivation of the respondents before and after the intervention of Digital-Game Based Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Mathematics.

H1 = The is a significant difference between the motivation of the respondents before and after the intervention of Digital-Game Based Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Mathematics.

Table 5. Ranks Statistic for Pre and Post IMMS Questionnaire

		N	Mean Rank	Sum of Ranks
PostIMMS - PreIMMS	Negative Ranks	3[a]	4.67	14.00
	Positive Ranks	22[b]	14.14	311.00
	Ties	0[c]		
	Total	25		

a. Post-IMMS Questionnaires < Pre-IMMS Questionnaires
b. Post-IMMS Questionnaires > Pre-IMMS Questionnaires
c. Post-IMMS Questionnaires = Pre-IMMS Questionnaires

Table 6. Wilcoxon Signed Ranks Test Based on Respondent's Motivation.

	Post - Pre
Z	-3.997[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.
c. Based on positive ranks.

The statistical results derived from the IMMS questionnaire revealed that there exists a strong and a direct correlation amidst the effects of using DGBL apps based on Mayer's Cognitive Theory of Multimedia Learning and the motivation level of the students learning the courses or the subject of mathematics. For instance, signifying huge differences persisting amidst the effects of implementing DGBL apps based on Mayer's theory and the students' motivation level.

Performance

The findings of this analysis are used to answer research question 1 which is to find the effects of Digital Game-Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students on Performance aspects. Performance test has been used as the instrument to collect data to answer this research question. Data gathered was analysed using descriptive statistic and inferential statistic.

Table 7. Descriptive Statistic for Pre and Post Performance Test

Performance Test	N	Min	Max	Mean	Std. Deviation
Pre	25	10	50	21.20	12.689
Post	25	40	100	66.80	20.761

Non-parametric test (Wilcoxon Signed Ranks Test) is used as inferential statistics to prove there is a significant difference between before and after intervention.
The hypothesis for this test is as follows:

H0 = There is no significant difference between the performance of the respondents before and after the intervention of Digital-Game Based Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Mathematics.

H1 = The is a significant difference between the performance of the respondents before and after the intervention of Digital-Game Based Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Mathematics.

Table 8. Ranks Statistics for Pre and Post Performance Test.

		N	Mean Rank	Sum of Ranks
PostPerf - PrePerf	Negative Ranks	0[a]	.00	.00
	Positive Ranks	25[b]	13.00	325.00
	Ties	0[c]		
	Total	25		

a. Post Performance Test < Pre Performance Test
b. Post Performance Test > Pre Performance Test
c. Post Performance Test = Pre Performance Test

Table 9. Wilcoxon Signed Ranks Test Based on Respondent's Performance.

	Post - Pre
Z	-4.412[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.
c. Based on positive ranks.

These results can eventually depict the positive correlation existing amid the effects of DGBL apps based on Mayer's theory and the motivation as well as the problem-solving abilities of the students learning mathematics. These values indicate strong and direct association persisting amidst the effects of implementing DGBL apps based on Mayer's theory further prove that Digital Game-Based Learning apps are able to increase pupil's performance and provide positive effect on students.

Problem-solving Ability

The findings of this analysis are used to answer research question 1 which is to find the effects of Digital Game-Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students on Problem-solving Ability aspects. Problem-solving ability questionnaire has been used as the instrument to collect data to answer this research question. Data gathered was analysed using descriptive statistic and inferential statistic.

Table 10. Descriptive Statistic for Pre and Post PSA Questionnaires

PSA Questionnaires	N	Min	Max	Mean	Std. Deviation
PrePSAQ	25	2.13	3.19	2.7040	0.31377
PostPSAQ	25	2.38	3.81	3.3424	0.39855

Non-parametric test (Wilcoxon Signed Ranks Test) is used as inferential statistics to prove there is a significant difference between before and after intervention.
The hypothesis for this test is as follows:

H0 = There is no significant difference between the problem-solving ability of the respondents before and after the intervention of Digital-Game Based Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Mathematics.

H1 = The is a significant difference between the problem solving ability of the respondents before and after the intervention of Digital-Game Based Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Mathematics.

Table 11. Ranks Statistics for Pre and Post PSA Questionnaires.

		N	Mean Rank	Sum of Ranks
PostPSAQ - PrePSAQ	Negative Ranks	2[a]	3.50	7.00
	Positive Ranks	21[b]	12.81	269.00
	Ties	2[c]		
	Total	25		

a. Post-PSA Questionnaires < Pre-PSA Questionnaires
b. Post-PSA Questionnaires > Pre-PSA Questionnaires
c. Post-PSA Questionnaires = Pre-PSA Questionnaires

Table 12. Wilcoxon Signed Ranks Test Based on Respondent's Problem- Solving Ability.

	Post - Pre
Z	-3.985[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.
c. Based on positive ranks.

This data above further indicated that a huge distinction lies between the effects of using DGBL apps and the students' problem-solving abilities towards learning the courses or the subject of mathematics.

Student's Perception towards DGBL Apps based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students.

The findings of this qualitative research are to are used to answer research question 2 which is "What is students' perception towards Digital Game Based Learning Apps Based on Mayer's Cognitive Theory of Multimedia Learning in Mathematics for Primary School Students." The respondents for this interview consist of 6 students among the respondents that participate in quantitative research. The respondents of this research are based on the score achieved in the post test that shows on table 5.12. Data Collection through interview were analyzed based on the themes and were recorded in transcript. Although the interview does not include questions that require respondents to express their impact on motivation, performance and problem-solving ability, but the respondents ' answers and statements are taken into account to support the findings obtained from quantitative analysis. Based on the interview data, there are 7 subthemes from the Weakness and Problem faced when conducting interview and there are 12

subthemes from the Strengths and Benefits of the intervention. The main themes, sub themes and code of the interview of both Weakness/Problem faced and Strength/Benefits are showed as below:

Table 13. Main Themes, Sub themes and code of interview data

Main Themes	Code	Sub-Themes
Weakness / Problems faced	W1	Not familiar with mobile devices and mobile apps before
	W2	Tablet not functioning smooth
	W3	Not really understand on one go
	W4	Button quite small
	W5	Typing numbers is difficult
	W6	Didn't like to find answers
	W7	Need to use with guidance
Strengths / Benefits	S1	Able to learn thoroughly
	S2	Try hardest to achieve learning objective
	S3	Do better than others
	S4	Don't want to feel left out
	S5	Feels like having fun in class
	S6	Solve harder question
	S7	Come out with multiple solution
	S8	Come out with a plan
	S9	Easier to understand and score improve
	S10	Easy and able to remember more
	S11	Fun, interactive and attractive
	S12	Suitable Audio

Discussions

Based on the overall interview results gathered for this particular research, it is evident that the learning mathematics in distinct primary schools had clear and positive perceptions towards using DGBL app based on Mayer's theoy. For instance, the relevant learning materials or contents of mathematics are largely available in the DGBL app. This app can be accessed either by listening to the audios or by visualizing the videos. Since the app supports them to learn more about the courses and/or the subject of mathematics successfully, the interviewees mentioned that they want to use this app in the future as well. The perceptions of the students towards implementing the DGBL app were so clear that they suggested certain ways through which this app could be improved in the most efficient way. In this context, some of the interviewees stated that the app can be developed by introducing more applications related to the courses and/or the subject of mathematics. It can thus, be critically commented that the DGBL app is regarded as one of those learning applications, which improvises the learning procedure of the students by an extensive level.

Based on the quantitative date analysis approach, it is quite evident that there are quite a number of differences between pre intervention and post intervention in terms of motivation, performance and problem-solving aspects. However, the qualitative results show that there are more positive aspects to the DGBL apps compared to the negative aspects. This shows that the respondents can receive intervention in learning and excelling in mathematics. The overall conclusions shows that the effect of DGBL on motivation has had a drastic increase after the intervention of the digital game-based learning. In terms of performance aspects, the pre-performance tests conducted on the respondents is seen to have risen after intervention of the DGLB apps. A case in point is the results if students which came out after the intervention. 88 percent of them were classified under excellent, good and satisfactory which makes it a positive effect. This percentage further caters for 22 students out of the 25. The same results are witnessed in the problem-solving ability.

Conclusions

From the above discussion, it had been quite apparent that learning achievement in any of the subjects or the courses, whether it is mathematics or others, is deeply influenced by certain significant aspects. These aspects typically encompass the teaching tactics, learning materials, developing performance, enhancing problem-solving capabilities and raising the motivational level by an extensive degree. Therefore, based on these notions, it can be critically commented that proper and timely execution of DGBL apps is likely to affect the learning of the students in relation to the subject or the course of mathematics. Since mathematics is duly considered to be a tedious as well as a forbidding subject by many of the students, the utilization of DGBL apps in the most effective way can have a positive impact on the learning achievement of the students. To conclude, the educational technology being affected by the use of DGBL apps based on Mayer's Cognitive Theory of Multimedia Learning is immense for the students learning mathematics, thereby influencing their future learning development at large.

Limitations and Future Studies

The respondents of the study were 25 of year 3 students who were fully equipped with mobile tablets and a computer laboratory with adequate internet. The limitation however is that the data collected in this study only represented a small sample size from one type of population. Thus, these results may not be a reflection of surrounding primary schools. This research was also done over a period of two weeks. Based on the weaknesses or otherwise the negative aspects that have been observed with the DGBL apps, there are recommendations that will aid in future improvement of the project. Some of the students in the class were not familiar with the gadgets hence making it difficult for usage. This problem is a result of the convectional way of teaching and as method of improvement, the educators should embrace the use of the digital methods as a means of exposure to these students. Furthermore, I recommend the use of the slight altercation of the size of font owing to the problem some of the students have when it comes to making errors in typing.

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