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Adopting Cognitive Theory of Multimedia Learning to develop an Augmented Reality learning kit in Topic of Gravitation in Physics High School

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ABSTRACT
Abstract concept which has been believed to be one of the problems in physics. This paper proposed an integration of Cognitive Theory of Multimedia Learning to develop a learning kit based on augmented reality. Cognitive Theory of Multimedia Learning is believed to guide researchers to develop a meaningful learning kit to help students increase their knowledge in Gravitation. The five principles involved in this theory are Coherence Principle, Signalling Principle, Redundancy Principle, Spatial Contiguity Principle and Temporal Contiguity Principle. Many technologies have been used in producing better learning environment. The study involves 15 students in a high school. The instruments used in this study are Pre test, Post test and Wilcoxon Signed-Ranks Test. Findings show there was increase in scores after the implementation. The inferential analysis of non -parametric test Wilcoxon Signed-Ranks Test also being done after the implementation of the AR learning kit. The study shows there are significant differences between the mean of the Pre Test scores and the Post Test scores in Gravitation Test ($z = -3.411$, $p=0.001$). The results show that AR learning kit have a significant difference in the scores of Pre and Post test of the students in topic Gravitation by integrating the CTML theory.

Keywords: Augmented Reality, Cognitive Theory of Multimedia Learning, Gravitation, Physics.

INTRODUCTION

Physics is one of the main branches in the discipline of Science, Technology, Engineering and Mathematics (STEM). Physics is being perceived as a challenging subject. One of the foundational disciplines in the science stream is physics, along with further mathematics, chemistry, and biology. Physics is being labelled as a boring subject [1], [2]. Physics has always been perceived as a difficult subject and not easy to understand and yet having difficulties in solving mathematical problems in physics.When the students have problems in mathematical equations, they might lose interest in Physics [3]. Physics also involves abstract concepts and students might encounter problems thus having misconceptions [4]. Students are also having difficulties in solving and doing application in problems in physics [5].

Study shows that integrating visualisation in teaching and learning has helped students in understanding abstract concepts [6]. The visualisation will help to concretize the abstract concepts [7], [8]. Digital simulation has helped students to visualise scientific phenomenon thus making better exploration of learning [9], [10]. The development of technologies has emerged. For smart and better learning experience, various digital technologies are being integrated into the learning and teaching process. Furthermore, using technologies in teaching and learning is in support of Goal 4 of Sustainable Development Goal (SDG) which is focusing on Quality of Education [11]AR is a type of immersive technology that allows things in both virtual and real-world environments to be fully immersed in real time [12].Many benefits have been showed by the usage of AR. Study shows that AR applications has reduce misconceptions and making comprehension of concepts better [13].Applying AR in teaching and learning has shown a great potential and

beneficial to students [14]. The aspect of visualisation and interactive learning will give bigger impact and attract the students in learning [15].

The research is being conducted in solving students' problems based on the Topic of Gravitation. It involved 15 students in a secondary school in an urban area in Peninsular Malaysia. Under a pedagogical context, gravitation is one of the more challenging topics in Physics form four. In this context, gravitation that is being focused only on Kepler's Law I, Kepler's Law II, Kepler's Law III, and a snippet of escape velocity. Moreover, when involving this topic of gravitation students do not have a chance of doing experiments in the real world as it is one of the ways to make students understand better. Furthermore, if there is lab equipment in this topic of Gravitation, the majority of which will require complicated lab tools and expensive. Findings from a study held in Perak state that a need in Gravitation topic is very crucial to help students in this topic in Physics [16]. Another study in Gravitation has also been done to pre-service teachers solely to assist the teachers to develop and understand the concept of Kepler's Law [17]. Research in the topic of Gravitation especially escape velocity is still lacking. Based on the need analysis that has been done shows that is a need in proposing a learning kit based on AR to assist the students.

Furthermore, the need analysis from the interviews shows that there were problems involving understanding the concepts in Gravitation among students. At attempt to support the teaching and learning of the chosen students at that school, the research will therefore offer guidelines for creating an augmented reality learning kit on the topic of gravity by integrating the Cognitive Theory of Multimedia Learning.

2) LITERATURE REVIEW

Richard E. Mayer was the one that introduced Cognitive Theory of Multimedia Learning (CTML) as an aspect to assist in developing meaningful multimedia learning [18]. Multimedia learning is an ability for an individual to have meaningful learning in text with diagram rather than in text only [19]. The three primary components of the cognitive theory of multimedia learning are generative processing, necessary processing, and superfluous processing [20]. This theory helps in shaping meaningful and effective learning development integrating technologies. Study shows a development of media integrating CTML has helped in increasing engagement and interest in students [21].

Key concept in shaping development of learning tool involving cognitive process is being divided into three components. First, in selecting appropriate source of learning. Selecting appropriate sources involves students being engaged and paying attention to words and images according to learning material [22]. Second, the process involves compiling appropriate material. Compiling material is crucial in structuring learning material with memorizing cognitive components in students. The third process involves connecting learning material media with students' prior knowledge. This is to activate the long-term memorizing memory in students.

Figure 1 shows the guidelines of Cognitive Theory of Multimedia Learning. Multimedia presentation, sensory memory, working memory, and long-term memory are the four phases of the theory [22].

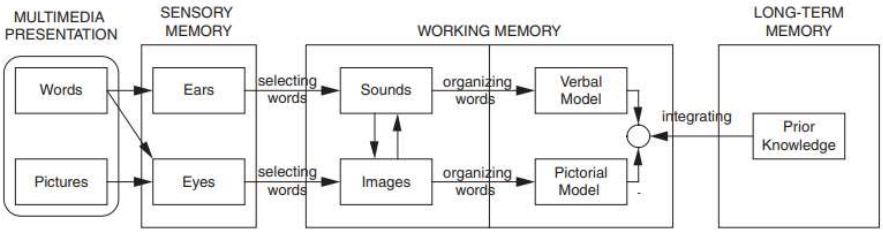

Figure 1 Diagram shows Cognitive Theory of Multimedia Learning [22].

Developing effective and suitable material of media and resources is integrating the five processes involved in cognitive theory of multimedia learning. This has considered that certain topics, certain subjects, and certain level of students is being taken into consideration in selecting appropriate media to make meaningful learning kit.

Table 1 Five Multimedia Principle involved in designing FizaAR

Principles	Description
Coherence Principle	People learn better when unnecessary words, images, and noises are removed rather than included.
Signalling Principle	People learn better when cues that highlight the key material's organization are supplied.
Redundancy Principle	People learn better from narrative and visuals as opposed to from narration, visuals, and on-screen text.
Spatial Contiguity Principle	People learn better When cues are incorporated that emphasize how the key information is arranged,
Temporal Contiguity Principle	People learn best when words and images that match are displayed near together on a page, screen, or in real time.

Table 1 shows five multimedia principles [22]. It has been employed in the planning, designing, and developing of successful multimedia learning [22]. This study only highlighted the five principles apart from many principles that have been mentioned [22], [23], [24], [25] as the effectiveness of integrating such principles has shown greater outcome. The study also involves designing and developing AR learning kit in the topic of Gravitation using multimedia tool especially to overcome the abstract concepts. To develop visualisation learning AR kit, different approaches and strategies needed in different subject.

3) The principle involves in FizaAR adopting CTML

Table 2 The description of the principles to be applied in developing FizaAR

Description	**How the principle applied in developing FizaAR**
Coherence principle	
People learn better when unnecessary words, images, and noises are removed rather than included.	Using the coherence principle, the visual exhibited objects with labels and no unnecessary text, images, or sounds.
	
Figure 2(a)	**Figure2 (b)**
Figure 2 (a)(b) Words explaining visual information are located in FizaAR involving Keplers' Law.	
Signaling Principle	How the principle applied in developing FizaAR
When cues that show how the key information is organized are provided, people learn more effectively.	FizaAR offered cues or visual cues that emphasized the elipse's minor axis.
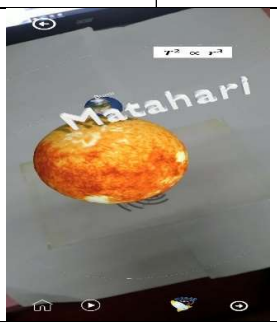	
Figure 3 The highlight of the information and essential material are added.	
Figure 3 shows that cues that highlight the main information added The cues of the relationship involved in Kepler's Law III. It shows that the cube of radius and the square values of the orbiting period are directly proportional.	
Redundancy principle	How the principle applied in developing FizaAR
When images and narrative are combined with on-screen text, people learn more effectively.	Regarding on-screen text and visuals, the redundancy concept is implemented. Should students require a more thorough explanation, the narration is provided.
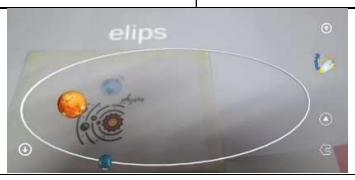	
Figure 4 The on-screen text appears on the Kepler's Law I.	
Figure 4 shows that the on-screen text appears on the Kepler's Law I are added. If students require a more thorough explanation, the narrative is offered.	

Spatial contiguity principle	How the principle applied in developing FizaAR
People learn better when matching words and images are positioned close together on a page or screen, as opposed to far apart.	The created FizaAR uses words and visual that are close to one another to implement the spatial contiguity principle.
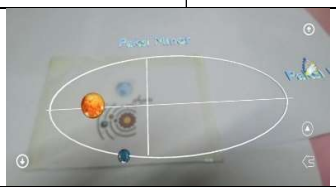	
Figure 5 The principle states that the words and visual objects are closed to one another.	
Figure 5 shows that the words and visual objects are closed to one another..	
Temporal contiguity principle	How the principle applied in developing FizaAR
When matching words and images are presented concurrently, people learn more effectively.	When the related words are shown concurrently in the developed FizaAR, the temporal contiguity principle is implemented. When the correct answer is typed, the indicator of the rocket will fly away from the planet. When wrong answer is type, the wrong indicator will appear simultaneously.
	
Figure 6(a)	**Figure 6(b)**
Figure 6 (a)(b) The corresponding text and images are displayed concurrently according to the principle.	
Figure 6 (a) shows that instead of being shown one after the other, corresponding text and images are displayed concurrently. The rocket flew as indicator of the correct answered of escape velocity. **Figure 6 (b)** Instead of being shown one after the other, corresponding text and images are displayed concurrently.The incorrect indication indicates that the escape velocity calculation is incorrect and should not be filled in.	

Table 2 shows the description of the principles to be applied in developing FizaAR. The principles involved are being followed to design FizaAR with each of its characteristics to make the desired learning kit.

4) METHODOLOGY

This study makes use of the Richey and Klein-developed Design and Development Research (DDR) [26]. The DDR technique is applied exceedingly methodically, encompassing the design, development, and assessment processes. This study is focusing on investigating the effect of integrating CTML theory to produce AR learning kit named FizaAR on students' scores on the topics of Gravitation in Physics. The findings of the pre- and post-gravitation tests are being examined. The topics of Gravitation will only involve Kepler's Law I, Kepler's Law II, Kepler's Law III and the escape velocity as the research has limitation and time constrain. The implementation was held for four weeks in a school in Seremban District. After four weeks of implementation, the Post test is conducted on the students. The samples are 15 students since this study involves students studying physics. There were students at the age of 16 years old studying in secondary school in Peninsular Malaysia. The students involved are volunteers and those being selected were at an intermediate level of knowledge in Physics and those who can use the latest learning technologies such as mobile learning. The students already have permission from their respective parents, principal, and Ministry of Education.

5) DATA ANALYSIS

In the research's analytical section, a descriptive analysis was carried out. Analysis and calculation were done on the pre- and post-test results. Each score of the students' achievement was compared within the pre test and post test.

Table 3 Descriptive statistics.

Type of test	N	Min	Max	Mean	Standard deviation
Pre Gravitation Test	15	16.7	58.3	31.62	10.83
Post Gravitation Test	15	62.5	95.8	84.7	10.40

Table 3 shows the pre- and post-test descriptive statistics.. The difference between the highest and lowest marks on the Pre test is 41.6 (58.3- 16.7), while in the Post test is 33.3 (95.8- 62.5). The Pre-Test's standard deviation is 10.83 and its mean score is 31.62. The Post Test's standard deviation is 10.40 and its mean score is 84.7. This indicates that the average scores of the students after the implementation have a higher value than the scores before the implementation.

The inferential analysis is done after the descriptive analysis. The Pre-Gravitation Test and Post Gravitation Test means for the two groups are compared in the inferential analysis. The sample size is small, hence a non-parametric test is being run as an alternative. This study employed the non-parametric Wilcoxon Signed-Ranks Test. The study's null hypothesis is that there are no statistically significant differences in the Gravitation Test mean scores.

Table 4 Ranks for the Pre and Post Test

Ranks				
		N	Mean Rank	Sum of Ranks
Pre Gravitation Test- Post Gravitation Test	Negative Ranks	0[a]	.00	.00
	Positive Ranks	15[b]	8.00	120.00
	Ties	0[c]		
	Total	15		

Table 4 shows Wilcoxon Signed-Ranks Test Statistics. In comparison to the Pre Gravitation Test, all of the students Post Gravitation Test results are higher.

Table 5 Wilcoxon Signed-Ranks Test

Test Statistics	
	Pre Gravitation Test- Post Gravitation Test
Z	-3.411[b]
Asymp.Sig.(2-tailed)	0.001

Table 5 shows the value of Wilcoxon Signed-Ranks Test. The alpha value of 0.05 is more than the significant value of 0.001. Consequently, the value for the Gravitation Test is used to reject the Ho. ($z = -3.411$, $p=0.001$). According to the findings, the AR learning kit significantly raises students' academic performance in the Gravitation topic.

6) DISCUSSION AND CONCLUSION

The most common problems in teaching and learning, particularly in science education, are abstract concepts. [27]. The aspect of visualisation is being proposed to help students in learning as to concretize the abstract aspects [28]. The AR learning kit also offers scaffolding aspects to make learning in smaller chunks and help to minimize the cognitive load of the students. The aspects of scaffolding on the enrichment exercises in FizaAR are being applied. The questions in the exercises are questions from low level, intermediate and to a higher level of questions. The findings are in line with research showing the benefit of scaffolding that helps to increase in the self-learning aspects of the students [29].

The aspects of scaffolding will help in guiding the students in solving escape velocity problems involving mathematical equations in physics. Therefore,to meet the goal of this study, a framework for FizaAR development was created that integrates scaffolding with the cognitive theory of multimedia learning to reduce students' cognitive load. The AR learning kit is also designed in the aspect of cultivating interactivity in solving problems in physics. This might be as an approach to make the learning more fun and joyful. It shows that AR has the ability to not just visualize 3D animation but also with interactivity components in solving physics problems. The results indicate that there was an increase in the students' pre- and post-test scores. Finding from the Wilcoxon Signed-Ranks Test shows that the mean Post Test scores are higher in Gravitation Test. It shows that principles that has been used in guiding the development of AR learning kit shows that the implementation on the students have an increase in scores among students

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9) DATA AVAILABILITY

This study does not generate or analyze any new data. This article does not apply to data sharing.

10) CONFLICT OF INTEREST

There is no conflict of interest, according to the authors.

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