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Effectiveness of Augmented Reality (AR) on Students' Achievement and Motivation in Learning Science

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Abstract

This study aimed to determine the impact of an augmented reality (AR) application, NutricARd, on students' achievement and motivation. The mixed-methods research seeks to ascertain the influence of AR-NutricARd learning cards on the motivation and achievement of form 2 science students. There were 50 participants in this study. The NutricARd applications, which had undergone rigorous design and development research, were employed for the treatment group. Each of the control and experimental groups had 25 participants. The control group used existing AR features in textbooks provided by the Malaysia Ministry of Education. The study revealed that there is a significant difference in achievement between the treatment and control groups. Pre-tests and post-tests, as well as a procedure for semi-structured interviews, were employed as research tools in this study. The paired t-test results showed that there was also a significant difference in students' motivation. The semi-structured interview showed that AR-NutricARd has the capabilities and intriguing aspects that encourage students to engage with the science subject. The findings of the study also showed that there is a significant relationship between motivation and achievement. Thus, a higher motivation implies increased student achievement.

Keywords: augmented reality, NutricARd, m-learning, achievement, motivation

INTRODUCTION

Technology is a powerful tool that enhances education in a variety of ways. For instance, technologies allow individuals to learn and collaborate uniquely. Also, the availability of smart gadgets that connects to the internet has ushered in a new era that permits learning at any time. It is high time for teachers to start harnessing their technological potentials for the betterment of classroom teaching and learning activities. The reason is that students of this era are inquisitive, and they prefer to explore while they learn. Hence, smartphones and other mobile gadgets are increasingly popular among students. Thus, teachers are expected to be innovative while conducting classes and they must transform learning into a pleasant activity for students by employing technology in teaching and learning. Incorporating technology into education is not new, especially in this 21st century teaching and learning environment. Science is an essential discipline that needs attention based on the level of criticality involved and the integration of technology into science education can assist in clarifying the concepts in this body of knowledge. Besides, it is believed that students can broaden their learning experiences while developing critical and creative thinking skills by optimizing the use of technology in learning. Using information and communication technology (ICT) in schools will help in expanding the possibilities for a more rewarding learning experience (Fitriyadi, 2015).

Augmented reality (AR) is the projection of virtual reality such as images, texts, videos, and sounds, on a screen to enhance the visual experience. This implies overlapping virtual information on digital devices to promote real-world experiences (Lo et al., 2021). It is one of the most recent technologies that can be introduced into teaching and learning activities since it makes use of various mobile devices (Yasak et al., 2010). Studies showed that teachers and ICT are important factors in implementing 21st century teaching and learning (Garba et al., 2015). Amran and Rosli (2015) suggested that technology can support student learning by combining

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Contribution to the literature

- The key contribution of this study is the use of Augmented Reality (AR) in learning science for secondary school students, whereby the learning process utilising AR offered students with improved learning experiences.
- The mixed-methods study demonstrated how AR improved students' motivation and achievement in science through mobile learning. Students utilised mobile devices to access AR content from textbooks and customize learning cards (NutricARrds).
- The findings revealed that studying using AR provides students with an engaging learning environment as well as enjoyable learning.

various media elements. The use of technology helps in learning in a more exciting and meaningful manner (Khalid & Wong, 2017). Besides, Abdullah et al. (2018) revealed that science teachers who had used virtual learning environments (VLE) such as Frog were inspired to teach more effectively. Technology is applied to the curriculum, which contains science. However, AR concepts are one of the most current technologies with the potential of being incorporated into education and used by educators in science instruction. Liu et al. (2017) suggested that AR enhances learning in this era of contemporary technology through tailored instruction.

The Malaysia Ministry of Education (MOE) has introduced AR into the national education system and embedded this concept in school textbooks within the country. This application of AR provides an opportunity for teachers and students to use the latest technological features for teaching and learning in the classroom. However, it is difficult to ascertain to what extent the features provided in these school textbooks are utilized by both teachers and students. AR is an emerging technology that has numerous potentials for education. Teaching and learning using AR help in arousing science students' interest. Also, AR is a technology that combines virtual reality with the natural world (Akcayir & Akcayir, 2016). Incorporating AR in learning can enhance collaborative learning (Martín-Gutiérrez et al., 2015).

RESEARCH SCOPE

Augmented Reality in Science Subject

Previous research showed that students struggle to understand science concepts such as biology, chemistry, and physics (Nordin & Ling, 2011). Most students have a negative attitude towards science (Nordin & Ling, 2011) as they view science as a tricky subject, complicated, and challenging to grasp (Nordin & Ling, 2011). Awang (2015) suggested that one of the reasons why science subjects are difficult for students is a lack of learning media that can provide illustrative images of real-world phenomena. Besides, students are weak in mastering integrated science process skills and have difficulty answering those skills (Anggara et al., 2021). Hence, students appear to have difficulty understanding the science process without being supported by other teaching and learning materials. According to Phang et al. (2014), students perceive science and mathematics topics to be difficult to study, contributing to low success in science and mathematics. Saidin et al. (2015) discussed the challenges that have developed in the teaching and learning of science and highlighted various issues from the literature including decreasing number of students interested in science. Ah-see (2011) study also showed that many students are not interested in science, based on their belief that it is a difficult subject. Noh et al. (2017) discovered that students' dependency on textbooks caused boredom. Besides, most students have an unfavorable opinion of science classes (Nordin & Ling, 2011). According to Phang et al. (2014), motivation has to do with student achievement in science subjects. Puteh (2012) indicated that many students face acute anxiety and fear of failure when learning science and mathematics. Nachiappan et al. (2017) stated that students were depressed and anxious when learning science concepts. Also, students' concerns and attitudes towards science subjects reflect their level of motivation. Previous studies presented science subjects as difficult. Notwithstanding, the study by Anggara et al. (2021) showed that the application of technology in education, such as AR technology, has a positive impact on students understanding and learning. The use of technology also helps to improve student achievement in learning regardless of its use at school or home (Yunos et al., 2014).

Previous research on AR in learning showed that it can help to improve students' motivation and performance (Martín-Gutiérrez et al., 2015). AR technology has assisted students in a more natural setting (Saidin et al., 2015). Khalid and Wong (2017) showed that students have a favorable view of the use of AR as part of the learning process. Kucuk et al. (2014) who used AR to see the impact of this technology in terms of students' achievement, and cognitive load for English subjects, concluded that students with low cognitive load showed a positive attitude. A positive attitude towards AR helps students achieve higher scores. Ibáñez et al. (2020) through their study showed that AR technology improves student motivation and achievement. The use of AR technology in Malaysian

education is still in its early stages. At the secondary school level, the application of AR in teaching and learning is relatively uncommon in Malaysian education. Although AR has been included in specific textbooks in schools, the application of the features is still unknown and has received little attention. Timur and Ozdemir (2018) suggested that AR has a great potential for being one of the innovative technologies to be used in education. According to Shelton and Hedley (2002), AR improves learning outcomes and comprehension of astronomical topics. The AR allows supportive learning. For example, an increased content understanding and memory preservation, as well as learning motivation (Cipresso et al., 2018).

Malaysian researchers such as Gopalan et al. (2015) also agreed that AR using markers on existing textbooks could enhance the performance of form 2 students. In Indonesia, Amir (2017), created the biology AR's system module for upper secondary students and it was revealed that using this technology in teaching and learning improves students' success. Cascales-Martínez et al. (2013) and Elliot and Mikulas (2011) stated that students that use AR show better science learning performances. Cascales-Martínez et al. (2013) also showed that AR is a good teaching aid that stimulates active learning and creates an exciting environment. There are several studies on the use of AR at the tertiary level in Malaysian education. For instance, Khalid and Wong (2017) employed AR to enhance motivation and solicit feedback on the experience of utilizing technology among second-year students in the educational technology course. Previous studies on AR showed that this technology can stimulate students' critical thinking through activities carried out collaboratively while improving communication skills. Chiang et al. (2014) revealed that the use of AR in inquiry activities of primary school science subjects significantly increased motivation for aspects of attention, confidence, relevance, and satisfaction compared to the conventional method of learning. Turel and Ozer Sanal (2018) study discovered that students' achievement increased after using the mathematics e-book prepared according to the ARCS motivation model strategy. Khan et al. (2019) also agree that the use of AR can increase student learning motivation.

AR technology is an innovative teaching medium in this 21st century. Also, there are still studies related to the use of AR at the secondary school level involving science subjects. The usage of AR in educational settings has a favorable impact on a variety of factors, which include improved student performance in science. However, past research has not identified which forms of AR add significantly to students' motivation in scientific learning. It is believed that the use of AR can lead to varying levels of academic success and student motivation depending on how it is used.

Augmented Reality and Mobile Learning

Khalid et al. (2016) suggested that one of the potentials of smartphones is for mobile learning (m-learning). The use of m-learning in the teaching process is quickly changing the traditional forms of teaching from teacher-centered to learner-centered instruction (Saleh & Siraj, 2016). However, most of the use of smartphones among students is only for communication and socialization (Khalid et al., 2016). The Malaysia Ministry of Education (MOE) incorporated AR elements into form 2 science textbooks based on the secondary school standard curriculum. The AR features have been integrated into several textbooks, and students see the videos or 3D simulations of the material on their cell phones by scanning the photographs given in the textbook. Hence, the AR in textbooks permits the utilization of virtual reality for teaching and learning. However, integrating AR features in textbooks had not been optimized by instructors and students. Some students have optimized the use of ARs in the form 2 science textbook. As a result, this work presents a new learning method based on mobile AR to improve inquiry-based learning activities. The researchers created a learning card based on the AR application, which combined the AR textbook and Zappar software. The application is also called NutricARd. The AR-based applications were created for the topic human digestive system, and the study focused on the effect of NutricARd on student achievement.

The following research questions were explored to determine whether the suggested AR strategy using NutricARd is effective:

1. Is there a significant difference in the motivation of form 2 students when using AR textbook and NutricARd for science subjects?
2. Is there a significant difference in the learning achievement of form 2 students when using AR textbook and NutricARd apps for science subjects?
3. Is there a significant relationship between students' motivation and achievement when using AR textbook and NutricARd for science subjects?

NutricARd is an application used in this study, which contains a learning card with markers given for the human digestive system. This marker requires the usage of the AR applications, which consist of the AR textbook and the Zappar software. Students in the treatment group were expected to scan the NutricARd markers. However, the students in the control group scanned the AR textbook markers and then explored the resulting AR on their smartphones. Motivational aspects in this study were measured through IMMS questionnaire items using motivational factors from the ARCS motivation model (Keller, 1987). The learning design in this study was based on the aspects contained in this motivation

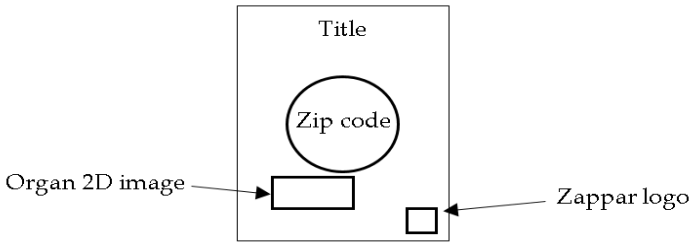
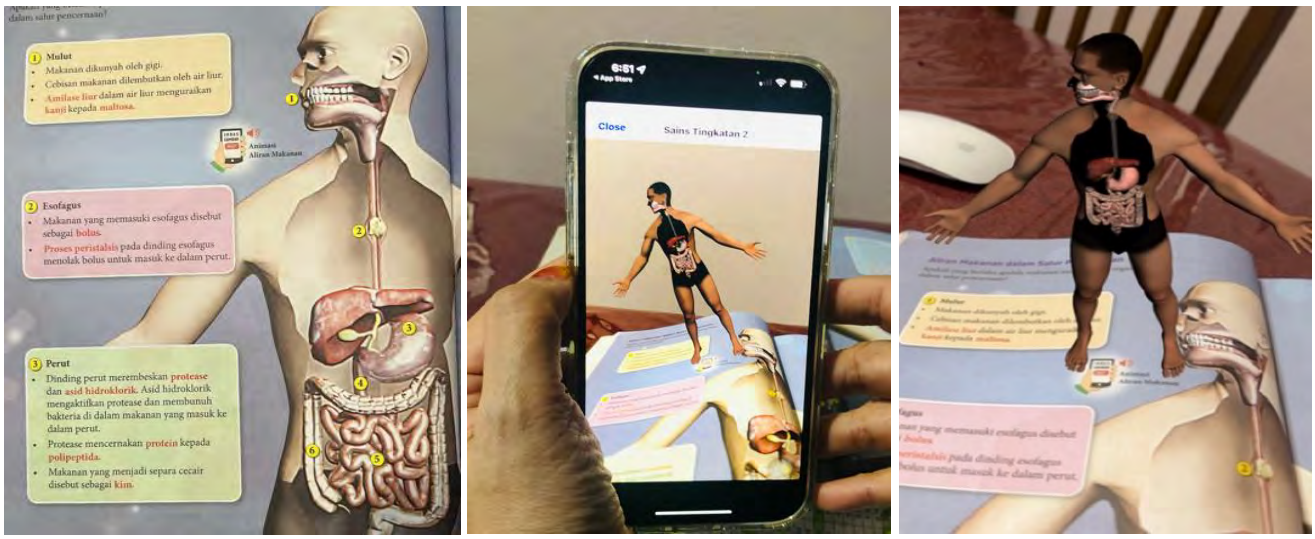


Figure 1. Layout of NutricARd prototype



a. Markers b. Scanning process c. Scanning output

Figure 2. AR Marker Scanning Process for NutricARd

model such as attention, relevance, confidence, and satisfaction (ARCS).

METHODOLOGY

NutricARd Design and Development

NutricARd was designed and developed before the data collection process (Figure 1). NutricARd is a learning card that contains AR markers for the topic human digestive system in the treatment group (Figure 2). NutricARd contains markers for the AR textbook and Zappar applications. The NutricARd design involved research into themes, approaches, specific topics, and the teaching and learning methodologies. The NutricARd uses a learning card method. The content of each learning card is selected and placed on a storyboard. Also, the aspects of AR to be employed were investigated to meet the demands of the target group and the time of the study. The NutricARd prototype comprises eleven learning cards that contain user instructions. Experts were allowed to evaluate NutricARd and the results were used to develop the prototype.

Research Method

This study involved two schools in the eastern part of Malaysia. Also, the participants were 14-year-old students from two different schools. The treatment group involved 25 students from school A and the control group contained 25 students from school B. Due to the constraints imposed by COVID-19, the participants were subjected to AR-based education using mobile learning. Hence, this study did not introduce face-to-face activities with the participants. The participants were required to have smartphones with internet access to participate in mobile learning. 25 students from school A were assigned to the control group after the download of the AR textbook application on their smartphones. Also, 25 students from school B download the Zappar applications and were ready for the treatment group. The form 2 students were assumed to have identical academic achievement, which implies that both the treatment and control groups had virtually similar features. According to the current Ministry of Education policy, which states that there must be no class screening based on student achievement. Hence, the form 2 students were assumed to have nearly identical academic achievements. Nevertheless, different degrees of achievement in a class meant that both groups, namely treatment, and control, had almost similar features. Four respondents were chosen for the semi-structured interviews based on their post-test ratings. Five questions were asked during the semi-structured interview. The interview analysis results

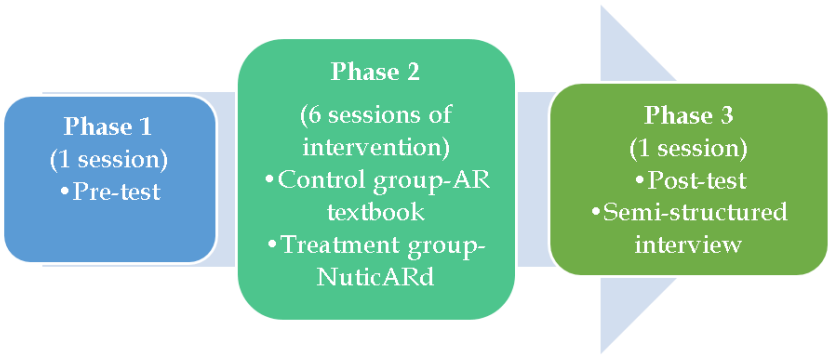


Figure 3. Research procedure

highlighted the respondents' perspectives about the AR application called NutricARd.

Research Procedure and Instruments

Pre-tests and post-tests, as well as a procedure for semi-structured interviews, were employed as research tools in this study. Before the intervention, respondents were required to complete a pre-test. The intervention was then carried out for six weeks using Telegram applications to integrate AR into teaching and learning sessions. Telegraphic reality applications were used to distribute videos and resources. The material of the NutricARd was identical to that of the textbook, as a new approach to AR. After completing the interventions, all participants were required to complete an online post-test. The two tests were compared to determine the intervention for both groups. Semi-structured interviews with randomly selected students were based on their post-test scores that were conducted to ascertain their overall experience with the NutricARd learning process (Figure 3). The process of assessing students' motivation involved the teaching and learning design based on the ARCS motivation model, which was included in the daily lesson plan and delivered through m-learning.

Questionnaires were also used in this inquiry for data gathering in each group. The questionnaire was designed to elicit comments on the usage of AR NutricARd in the learning process from a motivational standpoint. The questionnaire format was adapted from the questionnaire used in the instructional materials motivation survey (IMMS) (Keller, 1987; Khan et al., 2019). Questionnaires were distributed before and after the intervention. The questionnaire was divided into two sections: part A (demographics) and part B, which contains 32 items that used the Likert scale to assess various characteristics of motivation. Also, the questionnaire was distributed to respondents before and after providing the NutricARd AR intervention. The IMMS questionnaire concept, which comprised of 36 questions, came from (Keller, 1987). It used the ARCS motivation model as a guide. The study data gathering procedure included six intervention sessions for over six weeks and a three-phase data collection process.

Before the intervention, the pre-test involved 25 participants in the treatment and control groups. The treatment group involved a pre-questionnaire that was distributed before the intervention. The items in the questionnaire were focused on NutricARd and only the participant in the treatment group was expected to fill in their answers. Also, the teacher informed students about the Telegram channel link that was designed for this study. Students were expected to download the Zappar and AR textbook applications for the treatment group. However, the control group participants were only exposed to AR textbook. The teachers upload the NutricARd usage manual and video tutorial on NutricARd to the treatment group. Each intervention session took place according to schedule and it ended with a quiz (Telegram). Upon completion of the six phases of the intervention, students from both groups were required to answer the post-test questions.

A week before the intervention, pre-tests were conducted. The pre-test was used to ascertain students' knowledge and to compare the students' level of achievement. Students were evaluated on one subjective question involving eight fraction questions on the nutrition chapter, more specifically the digestive system, and five multiple-choice questions. The pre-test was validated by experts in terms of phrase structure, language, and question format. It considered the weighting of the marks and the appropriateness of the time provided. One week after the intervention was completed, post-tests were administered. Topic-related test questions were produced and distributed to students. Each student must respond individually to the post-test questions, which are like those on the pre-test. The goal of the post-test was to determine the effect of the intervention on student learning achievement. Since this study employs m-learning teaching and learning strategies, the post-test was conducted using the Google form.

Semi-structured interviews were used to obtain qualitative data and feedback from respondents. Questions were asked by following the current situation

Table 1. Paired sample t-test

	Mean	SD	SE	Lower	Upper	T	df	Sig. (2-tailed)
Pair 1 post-pre	.10960	.20043	.04009	.02687	.19233	2.734	24	.012

Note. SD: Standard deviation; SE: Standard error

and allowing for honest answers. Face-to-face interviews were not conducted due to the COVID-19 pandemic. Hence, the Telegram voice chat was used to interview four selected respondents based on their post-test scores. The semi-structured interview involved five questions. Also, the interview was analyzed to know the participants' views about NutricARd.

Data Analysis

The data for this study was gathered by using a pre-test, post-test, and questionnaire. There were no significant mean score differences between the pre-test and post-test. Also, four students were chosen for the semi-structured interview with two of them receiving the highest and most satisfying results. The statistical package for social science (SPSS v 24.0) was used to analyze the data, which was done by employing both descriptive and inferential statistics. The standard deviation, mode, and percentage relied on the data gathered from the respondents as discussed under descriptive analysis. The paired t-test, ANCOVA, and Spearman-rho correlation were all used to test the study hypotheses under inferential analysis. The outcome of the study focused on the NutricARd and students' accomplishments.

The demographic data analysis showed that the participants spent around two to three hours with a smartphone. The duration of using the second-highest smartphone was one hour. This result showed that only 60% of the respondents own smartphones, and 40% did not have a smartphone. According to the results of the survey, all the respondents had no prior knowledge of the Zappar application, and only 12% of the respondents had used AR textbooks. This low percentage was due to the inability of participants to have prior exposure to AR textbook application at school.

RESULTS

Preliminary Findings on Students

The IMMS questionnaire used in this study involved 11 items for the aspect of attention, seven items for the aspect of relevance, nine items for the element of confidence, and five items for the component of satisfaction. The researchers employed descriptive and inferential analysis to examine the IMMS questionnaire that was delivered to the respondents in this study. Mean, standard deviation, mode, and percentage were used in descriptive analysis. A paired t-test was used for inferential analysis. Before the intervention, the questionnaire had a Cronbach's alpha reliability rating of 0.16.

The questionnaire's Cronbach's alpha reliability value after the intervention on the treatment group was 0.68. After the intervention, the reliability value of the questionnaire data was satisfactory. Frequency analysis according to the Likert scale showed that the highest frequency for each aspect was on the agree scale (S) and 117 was recorded for attention aspect, 102 for relevance aspect, 83 for satisfaction aspect, and 73 for confidence aspect. In general, through the analysis of the frequency of responses to this questionnaire, the respondents agreed that AR NutricARd was engaging, relevant to learning, confident to use, and satisfying.

In terms of percentage, among the four aspects, the satisfaction aspect recorded the highest rate with a percentage value of 66.4%, followed by the relevance aspect 58.3%. The attention aspect had 42.5% and the confidence aspect had a percentage value of 32.4%. This low result was based on the background of most students from the demographic factor who had never used the AR application (Zappar) before. However, the attention received the highest frequency even though students' confidence was low.

Test of Normality

To test the normal distribution, the Shapiro-Wilk was performed. It was postulated that, if the value of $p>.05$, then the data were distributed normally. However, if the value is $p<.05$, then the scattered data is not normal. The control group recorded a value of $p=.312$. The p-value of the control group was greater than .05 ($p>.05$). This implies that the data was normally distributed. The treatment group recorded a value of $p=.100$. The p-value of treatment group was greater than .05 ($p>.05$). Hence, data distribution for the treatment group was normal.

Hypothesis 1

HO_1: There is no significant difference in the motivation of form 2 students when using AR textbook and NutricARd for science subjects.

This research question one was answered by employing paired t-test statistics (Table 1). The result showed that there were significant differences in the motivation of the respondents when using AR NutricARd for science subjects.

Table 1 shows the results of the paired t-test performed in the study, which showed that $t=2.734$, $p=.012$. According to Crawford and Howell (2010), if the value of sig. $p<.05$, the null hypothesis is rejected. Hence, HO_1 was rejected.

Table 2. Tests of between subjects' effects

Dependent variable: Post-test						
Source	Type III sum of squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected model	1,568.000	1	1,568.000	13.181	.001	.215
Intercept	29,0322.000	1	29,0322.000	2,440.535	.000	.981
Class	1,568.000	1	1,568.000	13.181	.001	.215
Error	5,710.000	48	118.958			
Total	29,7600.000	50				
Corrected total	7,278.000	49				
R squared=.215 (Adjusted R squared=.199)						

Descriptive statistics			
Dependent variable: Post-test			
Group	Mean	Standard deviation	N
Control	70.60	9.278	25
Treatment	81.80	12.322	25
Total	76.20	12.187	50

Table 3. Correlations

			Motivation	Post-test scores
Spearman's rho	Motivation	Correlation coefficient	1.000	.895**
		Sig. (2-tailed)	.	.000
		N	25	25
	Post-test scores	Correlation coefficient	.895**	1.000
		Sig. (2-tailed)	.000	.000
		N	25	25

Note. **Correlation is significant at the 0.01 level (2-tailed)

Hypothesis 2

HO_2: There is no significant difference in the learning achievement of form 2 students when using AR textbooks and NutricARd for the topic of nutrition in the science subject?

This research question two was analyzed by using descriptive statistics and analysis of co-variance (ANCOVA) (Table 2). This study also analyzed the pre-test and post-test scores to assess student's achievement in science after using the NutricARd.

The ANCOVA analysis showed that there was a significant difference between the mean of pre-test scores and the mean of post-test scores as F (1,50)=13.18 p<.001. Hence, there were significant differences in the learning achievement of form 2 students when using AR textbooks and NutricARd for science subjects. The study reveals that there is a significant difference in student achievement between the treatment and control groups. NutricARd, which incorporates AR intervention, aids students in their learning process. The treatment had a significant impact on the students. The R squared value indicated the value of 0.215 (.215×100) or 21.5% independent variable, which implies a pre-test contributed to the dependent variable, post-test.

The study is looking at significant differences in the learning achievement of form 2 students when using AR textbooks and NutricARd for the topic of nutrition in the science subject. Pre-test and post-test were conducted in the control and treatment groups. The participants for each group were 25 students (N=25). Descriptive data analysis was conducted to identify the mean post-test achievement for the control and treatment groups. Based on Table 2, the results showed that the mean post-test achievement for the control group is 70.60 with a standard deviation of 9.28 (M=70.60, SD=9.28, N=25).

The mean post-test achievement for the treatment group was 81.80, with a standard deviation of 12.32 (M=81.8, SD=12.32, N=25). Significant mean differences indicate that the treatment given to the respondents had a significant effect. Hence, hypothesis two was rejected.

Hypothesis 3

HO_3: There is no significant relationship between motivation and student achievement when using AR textbook and NutricARd for science subjects.

Spearman-rho correlation analysis was conducted to answer research question three (Table 3). The selection of correlation coefficient with Spearman-rho was suitable since this study sample in each group was less than 30 (N=25) (Darusalam & Hussin, 2016). In Table 3, the results of Spearman-rho correlation coefficient showed that r=.895 and p=.00.

The value of significance is shown in Table 3 as .000 and this value is less than .05 (p<.05). This indicates that there is a significant relationship between motivation and achievement of form 2 students when using AR textbook and NutricARd for science subjects.

The data obtained for the aspect of student motivation recorded a mean of .110. There were significant differences in student motivation after the

intervention was conducted. In terms of achievement, there were significant differences in the achievement of students in the treatment and the control groups. The mean for students in the treatment group was higher (M=81.80) than students in the control group (M=70.60). The value of the correlation coefficient, r=.895 indicates a strong relationship between motivational factors and student achievement. In conclusion, there were significant differences in student motivation and achievement after using AR textbook and NutricARd. Motivation and student achievement were also interrelated, which implies that motivation influences student achievement. The higher the student motivation indicates an increment in the student achievement. Hence, hypothesis three was rejected.

Findings from Students' Interview

Thematic analysis was performed on semi-structured interview data. The semi-structured interviews were done through Telegram voice chat, with interviews conducted on four respondents. Two of the participants in the pre-test and post-test received the highest and lowest scores respectively. The students that received high results were excited to study with AR and had no problems during the m-learning. However, students with low test scores love learning through AR. However, there were some limitations, with regards to having their mobile phone and printing of the Zip code. These elements disrupted the participant's concentration. Also, three themes emerged from the interviews which are: interactive, motivating, and enjoyable learning. The four participants clearly stated in their interview responses that they considered the NutricARd as fascinating.

Interactive

The interview questions led to the interactive subject. Also, students thought the NutricARd AR application was fascinating since it provided an interactive platform based on the multimedia elements available in the application. All four respondents stated that they had never used any form of AR software. Besides, the capabilities in Zappar applications convinced them to adopt it in their study. Furthermore, they stated that there was no previous exposure to the AR features incorporated in the science textbook. The AR NutricARd is appealing to all pupils due to the interactive components in the application. The 3D output for the digestive system topic encourages students to be more interested in studying. One of the students highlighted that the AR features allowed him to understand the procedure even though it was in a hardcopy textbook. Another student stated that she was able to scan the photo several times to ensure that she understood the digestive system procedure.

Fun Learning

The semi-structured interview contained the themes of fun learning. The NutricARd, according to the students, presented them with a fascinating way to learn about human digestive systems. They all expressed happiness while utilizing the NutricARd. During the interviews, it was mentioned that memorizing scientific material was complex with NutricARd. They voiced their joy at this unique learning technique. Also, students observed that having animated videos for each subtopic in the NutricARd helped them learn better, making them feel more satisfied with their learning experience.

Motivating

The students who participated in the interviews discussed their feelings about the science classes. Three of them stated that they were having the poor motivation to learn the material. According to the interview, the NutricARd boosted all the student's motivation to learn additional topics based on the following question: Do you intend to use AR for a variety of topics or subjects in reality? The topic generated from the thematic analysis was motivating.

Challenges in Using NutricARd

The researchers also asked the students about the primary issue they encountered when using the NutricARd. The biggest concern raised by the students is the requirement to first download and print the AR marker for this study, namely Zip code, or to scan the Zip code with a smartphone or other laptop. This issue interrupts pupils' concentration at the start of the learning process. However, while the problem only arose at the beginning of using the NutricARd, they were still inspired to utilize the application due to its innovative nature.

DISCUSSION

This research focuses on the motivation and achievement of form 2 students in the topic of digestive system after using AR, through a developed application called NutricARd. The study findings also revealed a relationship between motivation and student achievement after learning with AR NutricARd. In general, the findings of this study discovered that the use of AR through m-learning had a positive impact on students. Chang et al. (2018) discovered that using the ARCS motivation model in conjunction with project-based learning activities allowed flipped classroom method to have a positive impact on students. According to Asiksoy and Ozdamli (2016), the flipped classroom approach adapted from the ARCS motivation model had a significant impact on students.

Augmented Reality Impact on Student Achievement

This study's findings revealed that the factors of AR use through the medium of m-learning influences student achievement. The findings of this study support the findings of Hwang et al. (2016), who studied AR in ecology, as well as Kucuk et al. (2014) and Solak and Cakir (2015), who studied AR in English. Their research also discovered that AR promotes student achievement in their disciplines. The findings of this study are also consistent with the findings of Akcayir and Akcayir (2016), who discovered that using AR increased student achievement in science skills. The m-learning approach allows students to go through the learning process by scaffolding. The exploration of learning occurs with the teacher acting as a facilitator. According to Dunleavy et al. (2009), AR learning occurs in a constructivist and student-centered manner by allowing students to learn according to their ability. The use of AR in learning influences students' cognitive load, which in turn influences student achievement. Rosli (2013) discovered that incorporating AR into science learning through the topic of muscle systems for preschool students can improve cognitive development and learning abilities. Kucuk et al. (2016) integrated AR in anatomy and discovered that AR improves students' achievement by reducing the cognitive load.

Relationship Between Motivation & Academic Achievement

The obtained correlation coefficients revealed a strong relationship between motivation and achievement. Based on the results of the correlation test, it is possible to conclude that as students' motivation increases, so does their achievement. Although previous studies investigated the effectiveness of AR in various branches of education, as well as involving different respondents and demographics, the findings of this study significantly support the idea that motivation has a significant relationship with student achievement (Akcayir & Akcayir, 2016; Gopalan et al., 2015; Ibáez et al., 2017; Khan et al., 2019).

One of the factors that boost student motivation is satisfaction and enjoyment. According to the interviews, students had fun learning when using AR. According to Akcayir and Akcayir (2016), the use of AR provides satisfaction and enjoyment in learning. Gopalan et al. (2015) discovered that satisfaction and enjoyment of learning through AR had the highest mean when compared to other aspects. Students can shift their perceptions of science as a difficult subject and individual behavior is influenced by thoughts. According to Bal-Tastan et al. (2018), motivation will direct students to act towards the target since motivation allows energetic behavior. All the quizzes given at the end of each intervention session yielded positive results. This implies that students comprehend the information being presented to them. However, the findings of this study contradict the findings by Garon-Carrier et al. (2016), which stated that increased motivation does not affect student achievement since other factors influence achievement more. However, much of the data from previous studies showed a significant relationship between student motivation and achievement.

Augmented Reality Through M-Learning

In this study, 10 demographic variables were evaluated with 25 participants in each group. The researchers were able to acquire information about smartphone use among form 2 students by conducting a demographic analysis. AR Zappar application had never been used by any of the students. Only three out of 25 pupils have used the free AR textbook. Both data findings show that students had never been exposed to AR technology for instructional purposes before the study. Students were unaware of AR texts as a free material that covers several fundamental concepts. This high percentage result in this study could be attributed to several factors, including teachers' ignorance of the existence of AR textbooks. Also, some teachers were aware and had limited time to integrate them into the classroom teaching and learning context. Since 2018, Malaysian day-secondary schools have been using AR-enabled science textbooks. The technical aspect in this textbook demonstrates that education in Malaysia is growing in tandem with technological advancements. Although, the adoption of AR applications was minimal. Notwithstanding, the percentage of students who own and use smartphones is relatively high. The interviews conducted reflected the demographic that 80% of students were ready to study through m-learning. This strategy was deemed more acceptable by students. Also, students appreciated it when teachers and learning materials were accessible through Telegram channels. They also indicated that the usage of AR was very useful in understanding the scientific process. However, additional time was required at the beginning of the intervention session to become acquainted with the AR program. Finally, teachers were encouraged to use these data to diversify their teaching and learning approaches using the m-learning strategy. Students should also be encouraged to use their smartphones to look for learning opportunities.

This study also discovered that students were more motivated to learn science since the 3D display provided by the NutricARd AR scan helped them understand difficult science subjects. AR created a more authentic learning environment, and it was like real scenarios.

FUTURE RESEARCH

This study employed the m-learning approach to delivering AR learning content. Students were drawn to the m-learning method, which encouraged them to

participate in the learning sessions. However, according to the interviews, some students had difficulty accessing the AR markers due to their inability to print the Zip code. Some students used two mobile devices to access AR. In the future, researchers must employ alternative teaching approaches and learning theories. Future researchers must endeavor to print Zip code ahead of time to make it easier for students to scan AR markers. Due to the epidemic, the number of samples used for this investigation was limited to only 25 people in each group. Hence, it was proposed that future studies must include additional samples so that the data becomes more accurate. The scope of this study must be broadened to include different schools from both urban and rural areas to obtain more comprehensive data on the usefulness of AR in learning science.

CONCLUSION

In conclusion, the use of AR helps in attaining an effective learning process. Also, there were significant differences in student motivation and achievement when using AR NutricARd. Besides, students' motivation increased by up to 9% when exposed to NutricARd. Even the achievement after undergoing treatment was higher before the treatment was given. Motivation and achievement also had a significantly strong relationship. Hence, this study showed that a higher motivation enhances an increment in the students' achievement. AR is not a new technology in Malaysia, and the use of AR especially the one provided in the textbooks by MOE at the school level needs to be improved. Based on the findings of demographic data, only 12% of students had ever utilized AR textbook. It is suggested that teachers must optimize the existing features to better facilitate students learning.

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