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Augmented Reality: The Effect in Students' Achievement, Satisfaction and Interest in Science Education

Norazilawati Abdullah
National Child-Development Research Centre
Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia

Vijaya Letchumy Baskaran
Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia

Zainun Mustafa
Southeast Asian Ministers of Education Organisation (SEAMEO)
Regional Centre for Education in Science and Mathematics (RECSAM)

Siti Rahaimah Ali, **Syaza Hazwani Zaini**
Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia

Abstract. The purpose of this study was to analyse the students' views and the effects of using Augmented Reality (AR) in learning Science. Given that Science education emphasizes the understanding of the physical and the natural world, the science lesson is basically received through systematic observation and experimentation. The introduction of abstract concepts in the science lesson is implemented gradually by scaffolding the concrete understanding during primary schooling. The potential use of AR, as a teaching tool in facilitating the process of understanding concrete facts, could be beneficial in science education. The introductory topic, "Senses," was chosen; since it is directly related to the students' anatomy; and it cultivates their interest in Science. A quasi-experimental methodology was utilized to examine the impact of AR on primary school students' academic achievement, interest, and science-process skills in this study. During the science lesson, the experimental group was exposed to AR stimulation, whereas the control group was not; and rather it learnt through the conventional method. A set of post-test questions was conducted, in order to collect the data on student achievement and science process skills, while a set of questionnaires was employed, in order to identify the students' interest. The data were analysed by using descriptive statistics and the t-test. In this study, the real world had been augmented by using virtual information, thereby providing new possibilities for science education to become more meaningful. The findings indicated that AR had a significant favourable effect on all three aspects of the experimental group's achievement, interest, and science-process skills.

Keywords: academic achievement; Augmented Reality; interest; Science-Process Skills; Science Education

1. Introduction

The emergence of Augmented Reality experience in technology assisted learning has become a key trend, with more than 3000 research documents that were indexed in WoS and Scopus by 2021. It is a significant finding; since it reflects researchers' interest in delving into the benefits, advantages, and potentials of Augmented Reality in education. The fast and widespread use of wireless communication networks have contributed to the surge in popularity associated with the use of AR users worldwide. Seamlessly combining the digital information with the real-world environment on screen alters how individuals interact with virtual objects and visual-graphic experiences. The use of AR, however, does not mean that the virtual environment completely replaces the real-world; rather, it integrates virtual items into the real world by having AR as the interaction among human-computer-physical world (Papadopoulos et al., 2021).Thus, the use of AR in much formal education avenue encourages the students to have exciting learning experience, while acknowledging their real-world physical surroundings: teachers, peers and educational tools. To address this concern, the past studies on AR in education are highly contextualized, according to the subject matter, the cognitive level, the socio-cultural and digital competency (i.e: Law & Heintz 2021; Karakus et al., 2019; Akçayır & Akçayır 2017; Fidan & Tuncel 2018).

In an educational environment, AR exists in different ways. In a study conducted by Diegmann, Schmidt-Kraepelin, Eynden, & Basten (2015), there were five types of AR directions used in educational environments. Firstly there is discovery-based learning, where the user is provided with information about a real-world place that has been of interest to them. For instance, AR is often used in museums, historical venues, and astronomical simulations, in order to exhibit information visually. Secondly, object modelling, which allows users to identify how a given item would look in a different setting, Thirdly, there are the AR Books, which offer 3D presentations and interactive learning experiences for the users. Fourthly, there is skills training, which requires visually composite simulations. Finally, AR gaming enhances the power of gaming in educational environments. The implementation of AR in educational environments will provide many new ways to indicate relationships and their connections. Students exposed to these types of applications should be able to provide interactive and visual forms of learning.

AR has also attracted a lot of interest in the research community; because it provides unique learning experiences for individual learners by offering a platform that enhances the interactivity with content and visualisations of scientific phenomena, which in turn, reduce the cognitive load of a learner. According to Cipresso et al. (2018) and Garzón & Acevedo (2019), AR applications have extended their use into the social sciences. For instance, research conducted by Akçayır & Akçayır (2017), Bernal et al. (2019), Cano et al. (2019) and Radu (2014) has shown that AR has a positive effect on students' academic achievement and learning outcomes. Meanwhile, in a study conducted by Arici et al. (2019), Bacca et al. (2018), Chiang et al. (2014), and Ibañez et al. (2020), it has been proven that AR also has positive effects on the students' motivation. In the same vein, Brown et al. (2020) have reported that AR is highly effective in augmenting traditional forms of pedagogy, whereas Tekedere and Göker (2016) and Garzón et al. (2020) indicated that the effectiveness is medium.

In the educational studies, the use of AR was predominant in science education when compared to other subjects (Fidan & Tuncel, 2018). In the context of science education, the use of AR could be engaged in problem-based learning (Daineko et al., 2018) laboratory settings (Kearney et al., 2020; Kumar & Mantri, 2021), the modelling of certain cause-and-effect studies (Ables, 2017), 3-dimensional objects (Hendajani et al., 2018; Xiao et al., 2020) and interactive digital text-books (Kelpšienė, 2020; Nordin & Daud, 2020). The advantages of AR among primary-school students in several countries has been documented (Beyoglu et al., 2020); as this technology facilitates in improving students' cognitive abilities to transform abstract ideas into a better perception when learning sciences.

AR helps in facilitating primary school students to convey abstract-visual representation during the teaching and learning process to a much more concrete one. This shows that AR is aligned with constructivist theories. Learning science requires the acquisition of scientific knowledge that is not only limited to just comprehending the facts, but also to mastering the science-process skills, in order to improve the analytical thinking skills and to be more critical in decision-making and solving a problem (Curriculum Development Division, 2014; Kementerian Pendidikan Malaysia, 2019). Students should be able to combine scientific information, procedures, and Science-Process Skills, in order to comprehend a scientific topic by bringing about an insight whether by face-to-face, or through e-learning, when using AR. The use of AR provides students with exceptional learning experiences and to engage them in immersive, enriched, situated, and seamless learning (Bozkurt, 2018) by illustrating concepts and visualizing the content knowledge, skills and ideas explicitly, by using AR during the process of learning Science.

Since AR applications are able to provide diverse and meaningful learning experiences for students in the process of learning Science, this study was conducted to identify the students' views and perceptions on applying AR methods in science lessons in terms of their academic achievement, interest and the mastery of science-process skills in the national context. The findings from this research should provide baseline data in order to reflect the use of AR applications among primary-school students.

2. The Literature Review

2.1 Augmented reality in science education

Our modern world is undergoing an epistemological and technical revolution that is increasing quantitatively and qualitatively all the aspects of life, with education serving as the foundation for these areas. Other sectors are benefitting tremendously from its development. Furthermore, we are aware that technology-assisted learning, such as AR application is becoming more prominent in our world.

AR is an interactive environment that alters a person's ongoing perception of the physical world by computer-generated information. The information could be visual, aural, haptic, somatosensory, and olfactory that incorporates AR technology in real-time, interactively and manipulatively. In the same way, the AR also holds a huge potential for the collection and distribution of tacit information in the semantic context of environmental cues. Therefore, the use of AR enhances the natural environments or circumstances; and it provides perceptually enriched experiences, generally known as immersive perceptual experiences (Bozkurt, 2018).

The mention of AR in Mark Zuckerberg's speech has sparked more interest in the AR application in the daily lives of students. In the transcript of his speech about the future revolution of social media, the potential for AR application in the world of education is indefinite (Zuckerberg, 2021). For instance, he demonstrated the learning of astrophysics through interactive AR by 'bringing' those solar systems closer to the students. This futuristic way of learning is actively studied all over the world; but it seems to be favouring certain developed and developing nations (Fidan & Tuncel, 2018). To date, the use of AR are as supplementary to the traditional national curriculum with the emphasis on utilising various sensory modalities to enhance learning, whether it is physical, hybrid, remote (Bozkurt, 2018; Kelpšienė, 2020). For instance, several studies look into possibilities of graphic (Hendajani et al., 2018), video (Young-Yong Kim et al., 2015), and music (Ye Yang, 2020) to be integrated into the real-time experience of AR to be used as pedagogical tools in formal education.

Arici et al. (2019) found that the most favoured types of AR used in science education are; 1) marker- based material and 2) mobile applications; as these could be developed more easily. It is clear that both types of AR focus on cognitive, affective and psychomotor development in both- theoretical and practical classes. The fundamental application of AR is in displaying visual pictures in textbooks (Nordin & Daud, 2020; Wong Kung Teck, 2019), flashcards, and other instructional reading materials, which may have embedded "markers" or triggers that, when scanned by an augmented reality device, provide students with additional information in a multimedia format for theoretical session. Similarly, augmented-reality videos were incorporated into the mobile application, in order to demonstrate experimentation. The AR use in experiments basically relates to the ability to view specifically animated activity of cause and effect.

Several AR applications are specifically designed for science education. There are thousands of commercially developed learning apps that fundamentally work with AR technology; however, this literature review tries to look into several varieties of field-specific AR, which are reported publications. For instance, AR in chemistry subjects enables students to inspect the 3D structures of molecules and interact with a molecule's spatial structure (Patrick Maier et al., 2009). In the chemistry subjects as well, AR notecards were designed to understand mechanisms in organic chemistry and the AR video projections, onto laboratory instrumentation, in order enable the user to be guided through the equipment set-up and operation by a virtual expert (Plunkett, 2019). In an anatomy lesson, the use of AR enables the students to visualise the human body's various systems in 3D anatomy (Kuang & Bai, 2019; Ozdamli & Karagozlu, 2018). This has increased learners' understanding; and it provides intrinsic benefits, such as greater engagement and learner immersion.

AR can also be used to enrich the learning experiences in electromagnetism (Ibanez et al., 2019), analytical chemistries (Naese et al., 2019) and astronomies (Xiao et al., 2020) by increasing one's visual thinking (Ahmad, 2021) and visuo-spatial abilities (Ibanez et al., 2019).

In short, integrating augmented reality into education, especially in science education, allows students to engage and connect more authentically with content knowledge through technology-assisted learning. The majority of research found that students have positive impacts from AR, while becoming more active in the physical classroom when they interact with their computer-stimulated environment, while still being in a traditional classroom (Alizkan et al., 2021; Kuleto et al., 2021; Law & Heintz, 2021; Saadon et al., 2020).

2.2 Augmented reality for primary children

From the constructivist standpoint, the young children's cognitive development, from birth to seven years old progresses from innate sensorimotor co-ordination to concrete thinking, to abstract logical reasoning through the acquisition of continuous information from their environment. This means that, children will start to receive stimulus from their surroundings by using their sense of vision, touch, hearing, and smell. Having the innate sense and the environmental cues, a child would start to construct knowledge through meaningful forms that arise from their individual experiences and perceptions. Simply defined, perception is referring to one's interpretation of information garnered through multimodal senses. Generally, at the age of seven, children's early perceptions are established through formal or informal education, regardless of whether they attend preschool, or not. However, because these perceptions are primarily concrete, science teaching for primary school should be designed to be scaffolding gradually towards much abstract and logical thinking.

Therefore, the research in the use of AR is aligned with the theoretical foundation of constructivists, such as Piaget and Brunner. As in a conventional way of learning, young learners would be exposed to the use of concrete manipulatives and images in learning alongside with images, such as cubes, models, real organisms and clays for them to retain the knowledge taught and learned. These concrete objects should allow the children to utilize all their senses effectively during their lesson; and later, the object would be manipulated to learn more abstract ideas. For instance, the use of a single cube could be used to learn about shapes or building blocks. Later, these concrete objects could also be manipulated in order for the children to comprehend more complex ideas, such as how the concept of stability is linked with the height of stacked cubes. The cognitive ability for children to ease the transition of concrete towards abstract, and at the same time the psychomotor development during the interaction could be promoted with the use of AR. The idea of associating AR to concrete ideas (Trory, 2016), known as virtual manipulatives (Bouck et al., 2014; Petit, 2013; Siti et al., 2018) or virtual concrete.

The idea that the careful and effective use of AR in young learners could mimic the concrete manipulatives is backed by research evidence, with some constraints that need to be looked into (Barrett et al., 2015; Klahr et al., 2007).

2.3 Students' satisfaction, interest and science-process skills

Studies at Romania and Serbia show that the millennial and post-millennial children have more acceptance in the use of digital technology in education (Kuleto et al., 2021) as compared to the teachers (Alalwan et al., 2020). Consequently, most of the research concluded that the use of AR among the young learners had caused them to garner their attention in the learning process (Ozdamli & Karagozlu, 2018) and to enjoying their learning sessions (Alizkan et al., 2021). Other studies found that AR has contributed to the intrinsic motivation among these young learners by exposing them to authentic scientific inquiries (Saadon et al., 2020). This further decreases the level of anxiety among the learners, when learning Science (Beyoglu et al., 2020).

Previous studies found that students were still unable to implement Science-Process Skills during practical activities in the laboratory; and subsequently, they do not gain a meaningful learning experience (Lue, 2020). In the Malaysian context, Irene Lue (2020) found that students in Malaysia have difficulty in mastering Science-Process Skills, such as defining operationally, interpreting data, stating inferences and making predictions. This situation occurs probably because these skills were applied among students indirectly; while the students were carrying out their activities; and it is not planned implicitly. Activities in the laboratory are mainly carried out by students, based on a list of instructions from teachers or textbooks and students' understanding of Science Process Skills, which are not emphasized by teachers (Sembak & Abdullah, 2017).

Science teachers need to plan a lot of practical activities, so that scientific skills can be applied when students plan, handle, and analyse data using a variety of tools. However, many constraints faced by teachers in administering practical activities, such as a lack of science laboratories, a lack of apparatus (Gultepe, 2016) and the inability of teachers to control students in the laboratory (Rauf et al., 2013), in addition to not having sufficient knowledge to apply Science-Process Skills in their teaching and learning activities (Hikmah et al., 2018).

3. The Problem Statement

The development of science and technology has changed the world from the use of human energy (IR 1.0) to the use of supercomputers, smart robots, driverless vehicles, genetic modification and the development of neurotechnology that allows humans to better optimize their brain function (Reischauer, 2018; Guangli, 2018; Ciolacu, 2018).These scenarios have greatly impacted the world of education, in which students are seen to be more comfortable in learning when using pedagogy and cybergogy methods (Ismail et al., 2019), blended learning (Ahmad, 2018), WhatsApp (Chear, 2017), functional diversity of gadgets and modern application tools (Shatto, & Erwin 2016), learning through gamification (Ding, 2017), Skype, Face-Time and Hang Out, as well as learning by using heutagogical methods. The recent ones include the Augmented-Reality application in the learning process.

Yusoff, Jamaludin & Abda (2015) presumed that, there must be a cohesive relationship between current wants and needs in the world in which technology-assisted education has become a preferred method of learning. They further denote that the modernity of Information and Communication Technology (ICT) and the advent of Industrial Revolution 4.0 (IR 4.0) has opened up opportunities for students to explore information a click-away. This revolution makes an important impact on the learning process at the school level (Yusof & Tahir, 2017), including in Science Education.

Science education is an essential component of 21st-century education; therefore, a few challenges must be addressed. One of the most pressing issues in scientific education is the generation of unpleasant emotions and experiences. The learners struggle to grasp scientific courses, which leads to an increase in rejection and drop-out rates (Mellado et al., 2014; Vidakis et al., 2019). Furthermore, the teachers' lack of motivation, knowledge of relative subjects, methodology connected to teaching science, and overall unpleasant experience could well be transferred to their students (Kalogiannakis et al., 2021). Therefore, the students must always be introduced to new ways to investigate and understand scientific concepts, while promoting active and critical thinking. Unlike learning in a traditional setting, the application of AR should be able to encourage students to become more proactive, and to try new ways of learning, as indicated by Al-Azawi et al. (2016). Furthermore, AR is often linked to a socially interactive and constructive learning environment, in which it helps students to become more open to learning (Chan et al., 2017); and it provides a safe environment for students to learn (Kim, et al., 2018).

Therefore, a significant effort must be carried out to improve the students' scientific inquiry, while learning the subject. Innovative teaching practices must be implemented, in order to engage students in science education (Loganathan et al., 2019). The AR technology may also be used to complement other teaching techniques, such as inquiry-based learning, project-based learning, or experiential learning (Khazanchi et al., 2019). Scientific inquiry has long been regarded as an important component in obtaining science literacy and developing a scientifically literate workforce, which is the primary goal of science education. since science is an enquiry process, inquiry-based learning has been widely applied, assisting students in learning science by acting as scientists, actively designing, engaging in, and carrying out enquiry activities, rather than merely obtaining passive knowledge from teachers.

AR is a technology that has the potential to be used in education. Due to the sheer efficacy of this technology in recent years, the number of studies on AR is increasing in a variety of educational settings. AR, in particular, is a good technique to represent a model that has to be visualised. AR also enables seamless interaction between the real and virtual worlds, as well as the utilisation of a tactile interface metaphor for object handling. AR integration in school produces beneficial learning and teaching results (Alkhattabi, 2017). Le and Nguyen (2020) claimed that the use of augmented reality (AR) in education provides portable, low-cost, stress-free, and promising alternatives for application in a wide range of academic situations. The implementation of AR in the teaching and learning process was inspired by the realisation that the traditional chalk-and-talk instruction, and the usage of static textbooks fails to interest students; and it results in poor learning outcomes.

On the other hand, in order to produce a society, especially of science-literate students, reasoning skills and scientific skills are essential. Science process skills are components of scientific skills that are needed to find answers to a problem or to make decisions systematically (Rauf et al., 2013; Turiman et al., 2012). According to a research conducted by Azmah et al. (2014), a teaching approach that is more oriented to the science process and more interactive, requires a high level of knowledge and visualisation skills. To meet the demand of visualisation, AR works with a strategy that enables teachers to increase three-dimensional (3-D) shape learning – Instead of the old method of using wooden manipulatives by teachers. Not limited to the static 3-Ds, AR also enables rich visualisation and object motion, which could reduce misconceptions that occur from students' inability to visualise abstract concepts, such as chemical bonding. Henceforth, the AR also offers the benefit of providing macro- and micro-visualisation of objects and concepts that are not visible to the human eye. At the same time, AR shows things and concepts in a variety of ways and from various perspectives, thereby allowing students to have a deeper understanding of the subjects (Cerqueira & Kirner, 2012). The way AR is planned, implemented, and integrated into formal and informal learning environments has a direct impact on its educational value. How AR technologies enable and afford effective learning is a key consideration. Educators might benefit from viewing AR as a tool for the facilitation of skills and knowledge, rather than a specific sort of technology.

4. The Research Questions

The research questions of this study are:

1. What is the effect of AR on students' satisfaction?
2. What is the effect of AR on students' ability to obtain information?
3. What is the effect of AR on students' learning ability?
4. What is the effect of AR on students' attitude?

5. What are the effects of AR on students' learnability level in learning Science?
6. What are the students' interest levels towards Science education?
7. What are the students' interest levels towards Augmented-Reality application?
8. What are the differences in students' achievement in Science subject before and after using the AR application?

5. The Methodology

Population and Sampling

The data were collected from 60 Year-1 students from a school in Putrajaya, Malaysia. The school is located in a suburban area where the majority of students have moderate academic achievements. The teachers also have been exposed to the use of digital technology, in order to facilitate the teaching and learning process.

The Research Design

This study was carried out using quasi-experimental methods. Two group of student with similar academic achievements were chosen. One class was made into a treatment group that was taught using AR; while another class was a control group that was taught by using conventional methods.

The development of AR applications

The development of AR teaching materials was based on the ADDIE model. The phases are stated below:

Phase 1 (Analysis)	Phase 1 was carried out when the Year 1 Science Curriculum was analysed. This is for the researcher to identify the suitable topic, the students; their requirements, and any previous knowledge.
Phase 2 (Design)	Phase 2 involves designing the apps by referring to the learning objectives, delivery format, activities and also exercises.
Phase 3 (Develop)	Phase 3 will be developing the teaching materials, the creating prototypes, developing course materials, the review and the planning of a pilot session.
Phase 4 (Implement)	Phase 4 involves implementing the prototype in selected schools.
Phase 5 (Evaluation)	Phase 5 will be on evaluating the effect of teaching by using AR on academic achievement, interest and science-process skills.

However, the AR developed must be suitable for local students; and for example, the language used in the AR application should be available in both Malay and English (For DLP schools). Teaching methods that allows student to be comfortable, while learning, will be impactful towards students' interests, and their achievements in science from an early stage. The control group was taught by using the traditional teaching method, and non-AR strategies.

The school selected for this study is in Putrajaya; and it involved only first-year students. This school was chosen; because it has a large number of students; and the majority of them are with moderate achievement. The Science teachers at that school have been constantly exposed to technology-assisted teaching methods and materials. In total, this study involves only 60 students. The instruments used in this study are pre-test and post-test questionnaires, as well as a questionnaire identifying the students' interest in science, while using AR applications. The instruments had been simplified by the researcher for the Year 1 students for them to understand and give feedback.

6. The Research Findings

Augmented Reality-usability effects on students' satisfaction

Descriptive analysis was conducted to identify the level of Augmented Reality's Usability among primary-school students.

Table 1: Item analysis

Number of Items	Items
5	Students' satisfaction on AR
7	Students' ability to obtain information through AR
5	Ability of AR in assisting the students to learn.
3	Ability of AR in controlling the students.
5	Students' learnability using Augmented Reality, while learning Science.

The data were analysed to determine the mean value, the mean score, the standard deviation and the overall mean value for each item of the Augmented-Reality Usability-Measurement Questionnaire among primary school students. The analysis of this study was analysed by using the Statistical Package for The Social Sciences (SPSS) version 23. The mean values were interpreted, based on the mean-score table, as shown in Table 2.

Table 2: The Mean-score Interpretive Table

Min score	Interpretation
1.00- 1.66	Low
1.67 - 2.33	Average
2.34 - 3.00	High

Students' Satisfaction on AR

Based on Table 3, the overall mean of students' satisfaction on Augmented Reality is at a high level with a high mean score of M = 2.85.

Table 3. Mean, Mean Score, and Standard Deviation of Students' Satisfaction on Augmented Reality

No	Statement	Mean	Mean Score	Standard Deviation
1	I love this AR video	2.91	High	0.38
2	I want to watch this AR video to the end	2.87	High	0.41
3	I want to use this AR video with my friend	2.90	High	0.38
4	I want to use this AR video again	2.78	High	0.59
5	I love Science after watching this AR video	2.81	High	0.52
	Total mean value	**2.85**	High	

Augmented Reality usability effects in students obtaining information.
Based on Table 4, the overall mean to identify students' ability to obtain information from Augmented Reality application is at a high level, with a mean score of M = 2.51. The analysis had shown that Augmented Reality can effectively assist students to obtain information on their learning.

Table 4: Mean, Mean Score, and Standard Deviation of Students' Ability to Obtain Information From Augmented Reality Application

No	Statement	Mean	Mean Score	Standard Deviation
1	I understand the description in this AR video.	2.81	High	0.39
2	I got to know about Science after using this AR.	2.93	High	0.24
3	I can recognize 5 senses in this AR video	2.84	High	0.36
4	I became so good at Science after using this AR video.	2.81	High	0.39
5	I love Science after watching this AR video.	2.81	High	0.52
6	I love this video in AR.	2.12	Moderate	0.85
7	I was scared after seeing the video in this AR.	1.30	Low	0.46
	Total mean value	**2.51**	**High**	

Augmented Reality's effects in assisting the students to learn.
Based on Table 5, the overall mean of the extent to which this Augmented Reality assists students is at a high level with Mean Score of (M = 2.84). The analysis had shown that Augmented Reality can assist students to learn more effectively.

Table 5: Mean, Mean Score, and Standard Deviation of the extent to which this Augmented Reality assists students

No	Statement	Mean	Mean Score	Standard Deviation
1	I can retell what is in this AR video.	2.96	High	0.17
2	I enjoyed learning Science after watching this AR video.	2.87	High	0.48
3	I can study Science on my own after using this AR video.	2.72	High	0.57
4	I understand the kind of senses after watching this AR video.	2.93	High	0.24
5	I love the girlish character in this AR video.	2.72	High	0.57
	Total Mean Value	**2.84**	High	

Augmented Reality's effects on students' attitude.
Based on Table 6, the overall mean to identify the extent to which this Augmented Reality controls students is moderate with the mean score of M = 2.27. The analysis had shown that Augmented Reality moderately affects students' attitude.

Table 6: Mean, mean score, and standard deviation of control the extent to which this Augmented Reality controls students.

No	Statement	Mean	Score mean	Standard deviation
1	I'm not tired of watching this AR video	2.72	High	0.45
2	I don't like watching this AR video	1.21	Low	0.41
3	I can do Science activities after watching this AR video.	2.90	High	0.38
	Total Mean Value	**2.27**	**Moderate**	

Augmented Reality effects on students' learnability level.
Based on Table 7, the overall mean of the extent to which this Augmented Reality facilitates students to learn is at a high level, with a mean score of M = 2.82. The analysis has shown that it can facilitate students' learning at a high level, and very effectively.

Table 7: Mean, Mean Score, and Standard Deviation of the extent to which this Augmented Reality enables students to learn.

No	Statement	Mean	Mean score	Standard deviation
1	I learned new things after watching this AR video.	2.87	High	0.33
2	This AR video gives me the knowledge I want to know.	2.78	High	0.41
3	Love this AR video because it's easy to download.	2.87	High	0.33
4	I feel good after learning to watch this AR video.	2.66	High	0.64
5	This AR video is interesting.	2.96	High	0.17
	Total mean value	2.82	High	

Students' interest level towards Augmented Reality application.
Descriptive analysis had been carried out to identify the students' interest level towards science, while using Augmented-Reality application.

Table 8: Item Analysis

Number of Item	Items
5	Interest in Science Education
5	Interest in using Augmented Reality application.

The data were analysed to determine the mean value, the mean score, the standard deviation and the overall mean value for each item of the Students' Interest Level towards the Science-Education Questionnaire among primary school students**.** The analysis of this study was analysed by using the Statistcal Package for the Social Sciences (SPSS) version 23. Mean values were interpreted, based on the mean score table, as shown in Table 9.

Table 9: Mean Interpretative Table

Mean Score	Interpretative level
1.00 -1.66	Low
1.67 - 2.33	Average
2.34 - 3.00	High

Students' Interest in Science Education

Table 10 below shows the overall mean value of students' interest in Science Education. It shows that students have a high level of interest in science education with a mean score of M=2.69.

Table 10: Mean, Mean Score, and Standard Deviation of Students' Interest in Science Education.

No	Statement	Mean	Mean Score	Standard Deviation
1	I like to learn Science subjects.	2.93	High	0.24
2	I have fun while learning Science.	2.72	High	0.51
3	Learning Science is not difficult.	2.66	High	0.73
4	I want to read books on Science every day.	2.69	High	0.68
5	I can read Science books for a long period of time.	2.48	High	0.79
	Total Mean Value	**2.69**	**High**	

Students' Interest in using Augmented Reality applications.

Table 11 below shows the overall mean value of students' interest in using Augmented Reality applications. It shows that students have high levels of interest towards using Augmented Reality application in their learning process with a mean value of M=2.77.

Table 11: Mean, Mean Score, and Standard Deviation of Students' Interest in using Augmented Reality applications.

No	Statement	Mean	Mean Score	Standard deviation
1	After using AR application, I like to learn Science.	2.69	High	0.64
2	After using AR application, I think learning Science is easier.	2.72	High	0.51
3	After using AR application, I want to learn Science every day.	2.81	High	0.52
4	When teacher is using AR, while teaching, I have fun in learning Science.	2.78	High	0.54
5	After using AR application, I am not afraid to learn Science.	2.87	High	0.41
	Total Mean Value	**2.77**	**High**	

Differences in students' achievement in Science subjects before and after using the AR application.

Inferential Statistics: Paired Sample t-Test of Pre- and Post-Test Evaluation for the topic of Senses when using the Augmented-Reality application.

Empirical data were analysed following the methods used by Chiang et al. (2014) and Di Serio et al. (2013). The overall mean values of the pre-test and post-test questionnaire were used to compare students' achievement and determining whether there was any statistically significant difference in motivation.

Table 12 shows the values of paired sample t-test carried out between the Pre- and Post-Tests for the topic of Senses using Augmented Reality. The report showed that t (32) = -.35.310, p <0.0005. It showed that the mean value of the test and the t values, had significant improvement after using Augmented Reality application from 9.48 ±1.77 to 21.36 ± 2.40 (p<0.0005)

Table 12: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test	9.4848	33	1.66060	.28907
	Post-test	21.3636	33	2.40855	.41928

Table 13: Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test – Post-test	-11.87879	1.93258	.33642	-12.56405	-11.19353	-35.310	32	.000

7. Discussion

Based on the data obtained from this study, the research questions have been discussed and answered as follows:

1. ***What is the effect of AR on students' satisfaction?***

From Table 3, it can be concluded that the satisfaction level of students using the AR application is high ((M = 2.85, SD = 0.456). The satisfaction obtained after learning is a type of reward because it brings a sense of achievement, praise and entertainment. According to S. Malik (2014), students should be provided the opportunity to practise (or apply) their newly learnt skills, as soon as feasible in a relevant situation, in order to maintain their satisfaction. The finding from this study is similar to a study that was carried out by Pipattanasuk & Songsriwittaya (2020). Pipattanasuk and Songsriwittaya explained that students' satisfaction with the AR instructional model is very high because the instructional package is a modern technology popular among the students. This technology allows the student to interact via various senses, including textual, graphic images, colours ques, dynamic motions, soundtrack, and audio, all of which enrich their learning experiences. The students were given the ability to tailor their lesson, according to their needs and time. This findings also resonate with those of the Chien et al., (2010) report. Chien was exploring the satisfaction of medical students who learned and interacted with a computer-generated 3D skill by using AR. The result had supported that AR improved students' motivation to learn anatomy and their retention of knowledge, while also promoting an interactive environment for the medical students to learn more effectively.

2. *What is the effect of AR on students' ability to obtain information?*

AR provides a realistic learning experiences, while learning Science Education. The findings from this study showed that he overall mean for identifying students' ability to obtain information from Augmented Reality application is at a high level, with a mean score of M = 2.51. The analysis had shown that Augmented Reality can effectively assist students to obtain information on their learning. It is more clear in Item 2: *I got to know about Science after using this AR*. This item has the highest item in the domain.

This study finding further supports the Vázqtuez et al., (2018) report. Vázquez et al., (2018) showed that AR supports kinaesthetic learning, where it allows students to understand and memorize content through 3D visualizations. For him, the students will be able to learn faster and more effectively, even in complex learning situations. In the related development, Bitter & Corral (2014) and Deng et al. (2019) had evaluated the present status of AR application in mobile learning situations, notably for fixed and mobile wearable devices. In their article, the researcher has chosen educational topic areas that have been positively influenced by AR and made recommendations for AR applications in these areas. In an example given by Bitter & Corral (2014), they found that the museum tour applications might be used to reconstruct objects in the field of history. They further denoted that, AR reimagines the original structure, if its structures have deteriorated over time.

3. What is the effect of AR on students' learning ability?

Based on the findings, the ability of AR in assisting the students to learn is high, with a mean score (M: 2.84, SD: 0.406). Augmented reality works by superimposing sounds, videos and graphics onto an existing environment. In this way, educational institutions can incorporate interactive classrooms in their curriculum, thereby helping the teachers to create interactive classrooms to increase student engagement. A study conducted by Jessup et al. (2019) had discussed the various aspects of education in which AR has a huge impact. The findings from this study go hand-in-hand with a study conducted by Constan (2017) which had proved that AR has the ability to enhance education with immersive and interactive experiences in disciplines ranging from Science and Engineering to foreign languages and social sciences.

AR works well in improving empty gaps in certain activities, which require a high level of immersion that a conventional teaching and learning method could not achieve (Dalim et al., 2017). Item 1: *I can retell what is in this AR video,* explains very well how AR is helping the students to learn; since it has the highest mean level among all the other items. Students love studying subjects that they would not have learned otherwise during ordinary teacher-centred learning. When AR technology is used, students are seen to enjoy browsing library catalogues and solving mathematics and science problems. Using a manual or systematic technique of doing such chores, on the other hand, increases irritation. Increased concentration refers to learners' increased attentiveness while utilising AR technologies throughout the learning process, according to the findings of Diegman et al., (2015); since using AR in learning scenarios enhances students' physical interactions, which leads to a deeper focus.

4. What is the effect of AR on students' attitudes?

The findings of this study have shown that AR has moderately affected students; attitude in learning Science. Item 2: *I don't like watching this AR video,* had recorded the lowest mean value, which explains students having a positive attitude towards AR application, while learning Science. Meanwhile, Item 3: *I can do Science activities after watching this AR video*, had the highest mean value. Therefore, it has clearly been proven that students are positively inclined to participate in Science activities after watching the AR video. This is similar to a study by Delello (2014), Tomi and Rambli (2013) had shown that AR application has the ability to attract students' attention in the classroom.

Learning with AR had made the interactions more similar to natural face-to-face collaborations than were screen-based collaborations, as claimed by Giraudeau et al. (2019) and Martín-Gutiérrez et al. (2015). They had stated that AR promoted the collaborative and autonomous learning of Science practices without the assistance of a teacher; and students have described AR as "nice". Another study by Chu et al. (2019) and Pellas et al. (2019) had stated that AR in academic settings improved students' motivation and engagement. With realistic images, an effective and authentic interface, and engaging information, AR applications set themselves apart from traditional paper learning and computer-assisted learning (Wang et al., 2016; Nurul Ain Hidayah et al., 2022).

5. What is the effect of AR on students' learnability level in learning Science?

The findings from this study have shown that AR is helping in students' learnability level. This had been proven by the mean score (M: 2.82, SD: 0.376). AR can be defined as a series of computer programs that can visualize abstract or complex phenomena carried out in the field, to improve learning activities, in order to develop the skills needed in problem-solving. AR is able to help in students' learnability level by providing tools and the surrounding media that allow them to solve problems through experiments with animation or video. This scenario will enable affective and active learning to be promoted. For instance, AR can be enriching the learning experiences; and later motivate students to conduct experiments with inter-actively and to develop experimental skills.

Fundamentally, AR is built by replicating the real world with digital images (Constan, 2017). As compared to the traditional textbook that just employs a 2D model to explain an abstract concept. Means that, the students might find challenges to imagine a picture or view of something they might never be able to experience (Kumar et al., 2015; Norazilawati et al., 2021). Therefore using AR could open many possibilities that they had not previously encountered.

6. What are the students' interest level towards Science education?

Science is one of the important subjects to be studied and given exposure at an early stage. The objective of early science education for children is to shape and encourage the development of knowledge and skills that can be done at the primary school level. Knowledge in science education provides a conceptual framework to enable children to understand the environment. Children's exposure to early science education would emphasize the concept of active learning. The activities and learning methods applied will involve children in activities to become active through the interactions that take place. This can be evidenced when children well understand the learning conveyed through observation methods, tactile methods, taste methods and manipulating of learning materials, used to build more complex understandings.

This study had proven that the students' interest level towards Science education is high with a mean value of (M: 2.69, SD: 0.59). Item 1: *I like to learn Science subjects*; obviously has the highest mean value. It has proven that these students are very much motivated to learn Science at schools. The term "augmented reality" refers to a three-dimensional technology that allows students to acknowledge and perceive the actual world, while being surrounded by virtual items (Leung & Bsauw, 2020; Nor Hasnida et al., 2020).

7. What are the students' interest levels towards Augmented-Reality application?

AR is responsible in the interactivity between the physical and virtual worlds and the after- effects would be enhancing the user's perceptions of the real world. AR facilitates students' manipulation of scientific hands-on experiments in authentic contexts. In this study, students' interest towards AR application is high, with a mean score of (M:2.77, SD : 0.524). Item 5: *After using AR application, I am not afraid to learn Science which,* had shown the highest mean value among all the other items. It clearly explained that learning Science using the AR application is highly interesting for these students.

Positive outcomes from these students are similar to the findings by Karagozlu et al.(2019). where it has the same result of students being satisfied with AR in learning, which Science, According to Şahbin & Yıl2020), AR-based applications can assist students to have a more positive attitude about the course. In today's educational system, it has been seen that augmented reality-based applications have quickly earned a position in science classes, as well as in many other courses, in which they help students to achieve academic achievement and develop a positive attitude towards the course.

8. What is the differences in students' achievement in Science subjects, before and after using the AR application?

Inferential statistics have indicated that students' achievement among the experimental group has more significantly improved results compared to the control group. Therefore, it can be proven that AR application plays an important part in improving the students' achievement, while learning Science. AR technology can be said to be suitable to science structure due to its advantages, such as realistic structure, making experiments easier, concretizing topics, being re-search and investigation-based and other characteristics (Yoon et al., 2017). This is especially crucial when Science subjects commonly have abstract and complex contents (Dünser et al., 2012). As a result, providing students at this level with technology-based environments will ensure that their interest and motivation remain high and that they achieve academic achievement. In fact, studies show that AR-based applications improve academic progress in primary schools (Contero & Lopez, 2013; Hwang et al., 2015; Tosik & Atasoy, 2017; Petrov & Atanasova, 2020) and maintain interest and motivation (Di Serio et al., 2013; Chen et al., 2017; Bistaman et al., 2018). AR has been found to be beneficial in academic settings where it allows more efficient visualization of abstract concepts that would help in students' engagement and learning intentions. A study carried out by Quintero et al., (2015) has reported the benefits of better visualizations in complex academic situations by using AR in educational settings. These advantages of AR in teaching and learning methods are directly proportional to the student's achievement levels, nonetheless.

8. Conclusion

The findings from this study would be able to provide research-based evidence to encourage the interest and collaboration among education specialists with the computer science expert to develop the effective AR-based pedagogy based on student-centric survey. 'A study conducted by Huang et al., (2019) had indicated that students who learned using AR have the tendencies to score higher on tests when compared to those who learned through traditional teaching methods. By focusing on the studied factor, all the findings suggest that AR could be an imparted as an important learning tool for improving students' knowledge retention. Having that, AR plays a significant role in improving the absorption of new knowledge while solving problems in a settings that were more realistic, AR is no longer perceived as a novel concept, and is expanding in tandem with the expansion of e-learning platforms. This research discovered that AR combines current technology with real-world situations to give learners with an engaging e-learning experience the advantages of using this approach in e-learning contexts that include, but are not limited to, improving kinaesthetic and collaborative learning, enabling high-risk e-learning in real-time, as well as visualisations, supporting real-world simulations with interactive objects, and increasing learners' motivation, satisfaction, attention, and content retention.

However, hurdles to AR acceptance and implementation have been identified, notably learning, pedagogical, and technological concerns. Regardless of the obstacle, training and continuing education were considered as potential answers to the primary difficulties in AR adoption in e-learning contexts, despite the fact that the industry remains dependent on technology improvements in this area. The primary drawback of this study is that it recognised the benefits and problems of employing AR in e-learning environments based on empirical study findings, which may have limits in terms of research design and evidential validity. This constraint is exacerbated by the fact that the use of AR in education is still in its early stages, and additional study is required. Given this, new research directions are recommended. Firstly, while using AR in the classroom has academic benefits, further study on how successful this strategy is for distant and remote learning is still needed. Since learners' attentiveness and ability in the use of technology vary greatly, measuring its efficacy is critical for education.

Secondly, in connection to the first future path, further study on the drawbacks of employing AR and how to reduce them in educational contexts is required. For example, several research have found that adopting AR in teaching might cause cognitive overload in children. Learners may get overwhelmed by the platform's intricacy or the volume of information offered. Future study should look at how such learning barriers might be addressed or minimised, in order to improve the effectiveness of AR in enhancing academic achievements.

Student and teacher training on how to utilise the programme is required to boost the adoption and utilisation of AR in e-learning situations. This requirement was identified, with the argument that a lack of training is a primary source of deployment and implementation issues. On-the-job training for instructors would not only help with the deployment of AR in e-learning contexts, but it could also help to overcome opposition to AR and speed up its adoption. AR's applicability and usage should be included into teacher training courses and student curricula, in order to provide future instructors and students with an essential understanding of AR technology, and to assure their continued use thereof.

The effectiveness of AR application in science learning has been looked into by using six main domains: Students' Satisfaction, Obtaining Information, Assistance in Learning, Attitude, Learnability Level and Interest. All of the domains except for attitude have shown high level of effectiveness in implementing AR application while learning. These findings are consistent with many other research projects being carried out before implementing AR to enable teachers to educate students without alienating them from classroom reality and form natural interactions with virtual objects and the physical environments surrounding them (Matcha & Rambli, 2013; Sin & Zaman, 2010).

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