

The Effectiveness of Using Augmented Reality Applications with 5E Inquiry-based Learning Model on Student Achievement and Motivation in the Moon Phases Topic

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Abstract

This study evaluated the effectiveness of the My Lunar AR application integrated with the 5E inquiry-based learning model in improving Year 5 students' achievement, motivations in learning of the Moon Phases topic. Using a quasi-experimental design with 60 students, data were collected through pre- and post-tests and motivation questionnaires. Results from paired sample t-tests showed that students using My Lunar AR within an inquiry-based environment achieved significantly higher scores than those taught through conventional methods. Motivation toward the AR application was also highly positive. However, correlation analysis showed no significant direct relationship between achievement and motivation, suggesting that each operates independently. The integration of AR with inquiry-based learning supported active exploration, critical thinking, and conceptual understanding, making the lesson more interactive and engaging. Overall, the findings highlight the promise of AR-enhanced inquiry-based learning for improving student outcomes and supporting innovative, student-centred science instruction. Future research should apply this approach to other science topics and broader student groups to further validate its effectiveness.

Keywords : augmented reality, model 5e, inquiry based learning, moon phases topic

1. Introduction

Recent literature consistently emphasises the growing role of educational technology in supporting student-centred learning and improving teaching quality, particularly through the integration of ICT and interactive digital tools (Bozkurt, 2020; Nazaretsky et al., 2022; Ministry of Education, 2012). Studies have shown that multimedia-based approaches, such as videos and animations, enhance student engagement and learning compared to traditional textbook methods (Mohd Rusli et al., 2021), prompting wider adoption of advanced technologies including Augmented Reality (AR) in Malaysian education (Baako & Abroampa, 2023). AR is widely recognised for its ability to create immersive, interactive learning environments that support collaboration, critical thinking, and problem-solving, while also facilitating the understanding of abstract concepts that are difficult to visualise through conventional instruction (AlNajdi, 2022; Adams Becker et al., 2017; Tuli et al., 2022). Empirical evidence further suggests that AR is particularly effective when aligned with inquiry-based learning approaches, enhancing motivation, visualisation, and conceptual understanding in science education (Chiang, Yang, Huang, et al., 2014; AlNajdi, 2022). However, despite strong support for inquiry-based frameworks such as the 5E model in promoting active learning and engagement (Attard et al., 2021; Nor Puteh & Nawastheen, 2013; Quintero et al., 2019), students continue to struggle with abstract scientific topics like Moon Phases, which negatively affects achievement and motivation (Jones, 2012). This highlights a critical gap in existing research regarding how emerging technologies such as AR can be systematically integrated with inquiry-based models to address persistent conceptual difficulties, particularly at the primary education level.

2. Literature Review

2.1 Augmented Reality Technology

Augmented Reality (AR) is a technology that overlays digital information onto the real world in real time, enriching users' perception of reality (Nikolaidis, 2022). Unlike Virtual Reality, which fully replaces the real environment, AR superimposes computer-generated visuals, audio, and information onto physical surroundings through smartphones,

tablets, or head-mounted displays, enabling interaction with virtual objects while maintaining real-world awareness (Angra et al., 2025). Its development has expanded from early aviation and military uses to education, healthcare, tourism, and engineering, driven by advances in tracking systems and hardware (Zhao et al., 2023). Modern AR relies on marker-based and markerless tracking and is increasingly accessible through low-cost mobile devices (Zhao et al., 2023). In education, AR is valued for creating immersive and interactive learning experiences, enhancing engagement, motivation, and collaboration by bridging real and virtual environments and supporting the visualisation of abstract concepts (Zhao et al., 2023). AR's compatibility with mainstream devices also lowers adoption barriers and promotes inclusivity through features such as text-to-speech and sign-language overlays (Zhao et al., 2023). Despite its advantages, AR faces challenges related to technical limitations, cost, and usability (Akinradewo et al., 2025). Issues such as tracking errors, lag, device constraints, and limited user training continue to affect adoption (Koumpouros, 2024; Akinradewo et al., 2025; Basumatary & Maity, 2023). Poorly designed AR content may cause cognitive overload, and concerns such as eye strain and privacy have been reported (Basumatary & Maity, 2023).

2.2 Augmented Reality in Education

Recent studies highlight the strong potential of Augmented Reality (AR) to enhance learning in primary education by providing visual, interactive, and multisensory experiences that support understanding of abstract concepts and improve engagement and achievement (Basumatary & Maity, 2023). Evidence across subjects such as science, mathematics, and language shows that AR supported 3D visualisation promotes deeper understanding, retention, and learner motivation (Basumatary & Maity, 2023). However, these positive outcomes are not consistent across studies, as researchers caution that AR's effectiveness is highly dependent on pedagogical alignment, curriculum integration, and instructional design quality. Poorly designed AR applications may increase cognitive load and distract younger learners (Koumpouros, 2024; Basumatary & Maity, 2023). In addition, systemic challenges including limited teacher readiness, insufficient pedagogical training, and infrastructure constraints continue to hinder effective implementation (Koumpouros, 2024). Methodologically, many AR in education studies remain short term pilots with small samples and non validated instruments, limiting conclusions about long term learning impacts (Koumpouros, 2024). Consequently, while recent research affirms AR's educational promise, it also reveals a clear gap for more rigorous, pedagogically grounded, and longitudinal studies that examine sustainable learning outcomes in primary education contexts (Nevrelova et al., 2024).

2.3 5E Inquiry-based Learning Model

The 5E Inquiry-Based Learning Model is a constructivist framework that guides students through five phases: Engage, Explore, Explain, Elaborate, and Evaluate, progressing from initial curiosity to reflective understanding (Melgarejo et al., 2024). While the model was originally developed by the Biological Sciences Curriculum Study (BSCS) in the 1980s, it draws on earlier learning cycle theories and Dewey's experiential learning philosophy, emphasizing hands-on inquiry and active learning. This structure fosters an active learning environment where learners connect new information with prior experiences through questioning, investigation, and reasoning, which aligns closely with inquiry-based science education (Melgarejo et al., 2024). Beyond improving academic performance, studies consistently report that the 5E inquiry-based learning model enhances higher-order outcomes such as scientific reasoning, critical thinking, and process skills. For example, Melgarejo et al. (2024) demonstrated gains in creative thinking, collaboration, and student engagement among middle-school learners, attributing these outcomes to the model's student-centred and inquiry-driven phases. However, while these studies confirm the general effectiveness of the 5E model across contexts, they largely focus on conventional instructional settings. Limited research has examined how the model performs when integrated with emerging technologies, particularly in primary education. Addressing this gap, the present study extends existing findings by investigating the combined use of the 5E model and Augmented Reality to support conceptual understanding, motivation, and achievement in learning abstract science topics (Melgarejo et al., 2024; Polanin et al., 2024).

2.4 Problem Statement

Science achievement among primary school students has become a central focus of contemporary education. According to Yaakob et al. (2023) science is among the most challenging disciplines for young learners, as students often struggle to relate experimental outcomes to real-life contexts. This disconnect negatively impacts their academic performance and reduces overall motivation to learn science. The topic of Moon Phases is particularly challenging, with studies attributing low comprehension primarily to deficits in spatial and abstract reasoning skills (Cole et al., 2015; Kruse & Wilcox, 2009; Taşcan & Ünal, 2022). Additionally, previous research has shown that the effectiveness of teaching strategies significantly influences students' understanding of complex scientific phenomena (Barnett & Morran, 2002; Jones, 2012). In this context, Augmented Reality (AR) technology emerges as a promising tool to enhance students' conceptual understanding through interactive, visually engaging experiences. AR provides learners the opportunity to directly observe phenomena that are otherwise difficult or impossible to experience firsthand, effectively bridging abstract concepts with their everyday surroundings (Mustafa & Didem Alsancak, 2018). Nonetheless, the effectiveness

of AR-based interventions heavily relies on their thoughtful integration within the educational environment and alignment with sound pedagogical approaches (Talan et al., 2022).

3. Research Questions

1. Can the Augmented Reality application with the 5E inquiry-based learning model improve student achievement levels for the Moon Phases topic?
2. What is the level of student motivation after using the Augmented Reality application in learning the Moon Phases topic?
3. What is the relationship between the level of student achievement and the level of motivation after using the Augmented Reality application?

4. Conceptual Framework

This conceptual framework explains how science learning is supported through an Augmented Reality (AR) application integrated with the 5E inquiry-based learning model. The AR application uses 3D marker-based visualisation to show the movement of the Moon around the Earth, helping Year 5 students better understand the Moon Phases topic through interactive learning (Tian et al., 2014). The integration of AR within the 5E inquiry-based approach is designed to enhance both student achievement and motivation.

The 5E model consists of five phases Engagement, Exploration, Explanation, Elaboration, and Evaluation which encourage active learning and reflection. This framework is guided by Mayer's Cognitive Theory of Multimedia Learning (2002) and the 5E model (Bybee et al., 2006). Student outcomes are evaluated through achievement tests and motivation questionnaires. Overall, this combined approach aims to improve students' conceptual understanding and increase their interest in learning science.

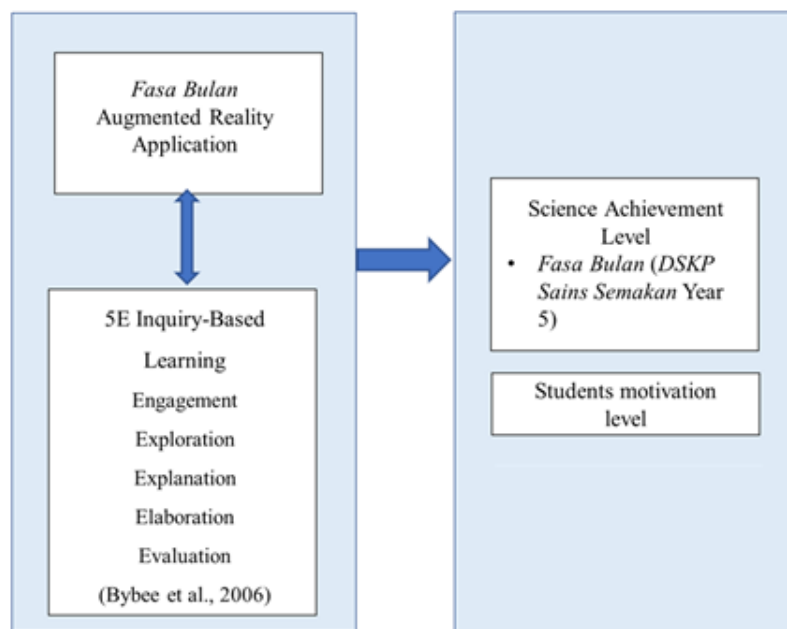


Figure 1. Conceptual Framework of the Study

5. Development and Validity

The My Lunar AR application was developed using the ADDIE instructional design model as shown in Table 1, which provides a structured approach for mobile learning development and is supported by the Cognitive Theory of Multimedia Learning to enhance understanding through audio visual integration (Dawi, 2012). The application was created using Unity and Vuforia for marker-based AR and designed for Android devices, aligning with Malaysian students' smartphone usage. Its design applies key AR learning principles, including cognitive load reduction, 3D interaction, and effective user-environment interaction (Shukri et al., 2017; Kourouthanassis et al., 2013; Liang, 2016). To ensure quality, three educational technology experts evaluated the application based on multimedia learning principles, with results indicating high clarity, usability, and accurate scientific representation, confirming its suitability for classroom use.

Table 1. ADDIE Phase

Phase	Description
Analysis	Conducts preliminary analysis to assess appropriateness, including syllabus content, learning process, user needs, and software implementation.
Design	Implements the 5E inquiry-based learning model and applies Mayer's Cognitive Theory of Multimedia Learning principles, such as multimedia, coherence, redundancy, and voice principles.
Development	Uses Unity software for AR material development, with Vuforia for marker-based imaging and virtual content integration.
Implementation	Applied in the exploratory and explanatory phases of the 5E model. Students visualise moon phases through simulation, and teachers explain moon phase concepts, including celestial movements.
Evaluation	Conducted in two parts: before implementation (expert and pilot study evaluation) and during implementation (4-week trial, effectiveness assessed via pre- and post-tests).



Figure 2. Application Development in Unity Software

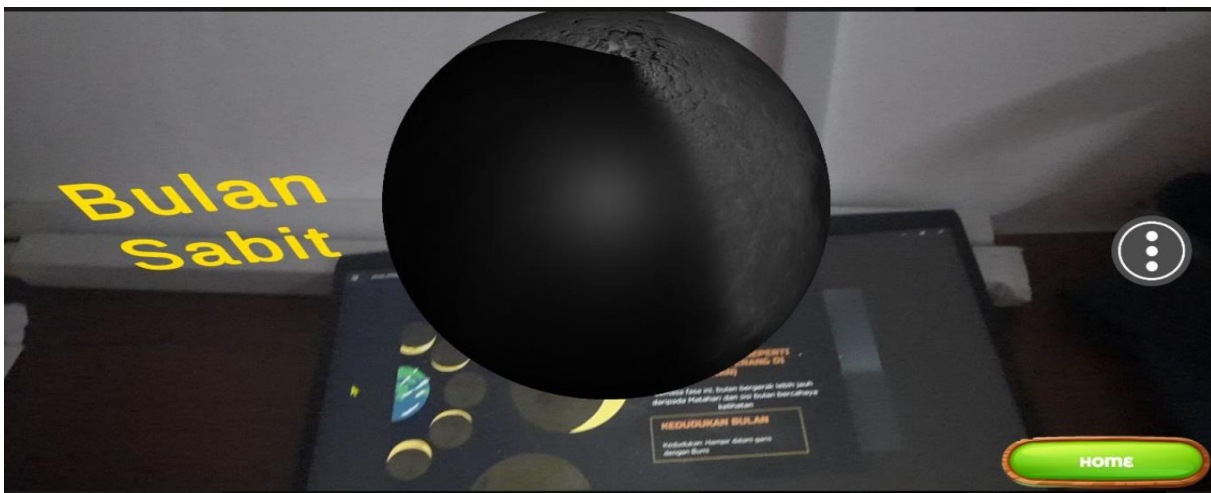


Figure 3. View of the My Lunar AR app

Table 2 shows the evaluation of the My Lunar AR application in terms of design and usability by three experts:

Table 2. Educational Technology Expert's assessment of the My Lunar AR application

No.	Part 1: Design	Mean
1	The interface display is convenient and easy to understand.	4.00
2	The background color used is appropriate.	4.00
3	The text provided is clear and readable.	4.00
4	The writing size is appropriate and easy to read.	4.00
5	The application navigation is easy to use.	4.00
6	Appropriate use of colors.	4.00
7	Audio is clear and understandable.	4.00
Total Mean		4.00
No.	Part 2: Application suitability based on Mayer's Cognitive Theory of Multimedia Learning	Mean
1	The reality 3D display is clear and accurate.	4.00
2	The purpose of the built application has been clearly stated.	4.00
3	The concept of science in the application is conveyed with the use of various colors in the AR application.	4.00
Total Mean		4.00

6. Methodology

This study uses quantitative data to evaluate the effectiveness of the AR application by comparing student achievement before and after the 5E inquiry-based learning model about the phases of the moon. Data is also used to measure students' motivation. There is a control group that receives conventional learning sessions without technology, while the treatment group uses AR technology in the learning process. The overall study design, including control and treatment groups, is summarised in Table 3. This study uses a quasi-experimental quantitative design involving quantitative data. This design was chosen because sampling could not be done at random (Cook & Campbell, 1979) and involved at least one control group and one treatment group. In Education research, obtaining a random sample is challenging due to several factors, making purposive sampling more commonly used (Ya-ling, 2002). According to Dreyhaupt et al. (2017), the implementation of randomized studies in education is complicated by the need for effective communication between researchers and different potential samples.

Table 3. Study design

Group	Pre Test	T&L Method	Post-Test
Control	P ₁	X ₁	P ₂
Treatment		X ₂	

P₁: The pre-test is a Science test to measure mastery of the Moon Phases concept given to Year 5 students in the control and treatment groups before the study.

P₂: The post-test is the same Science test to measure mastery of the Moon Phases concept, given after the implementation of learning using the AR application in the 5E model.

X₁: The control group followed conventional learning methods based on the 5E inquiry-based learning model without Augmented Reality application, using 3D model activities, textbooks, worksheets, and posters.

X₂: Treatment group using AR application in 5E inquiry-based learning model.

6.1 Research Procedure

The research process is a systematic and orderly series of procedures that the researcher takes to conduct the study and collect data for analysis. The step-by-step procedure of this study, beginning with instrument development, followed by a pilot study, application development, pre-tests, teaching and learning sessions, post-tests, motivation measurement, and final data analysis, is illustrated in Figure 4. This structured sequence ensured that the research design was implemented systematically and that data collection was aligned with the study objectives.

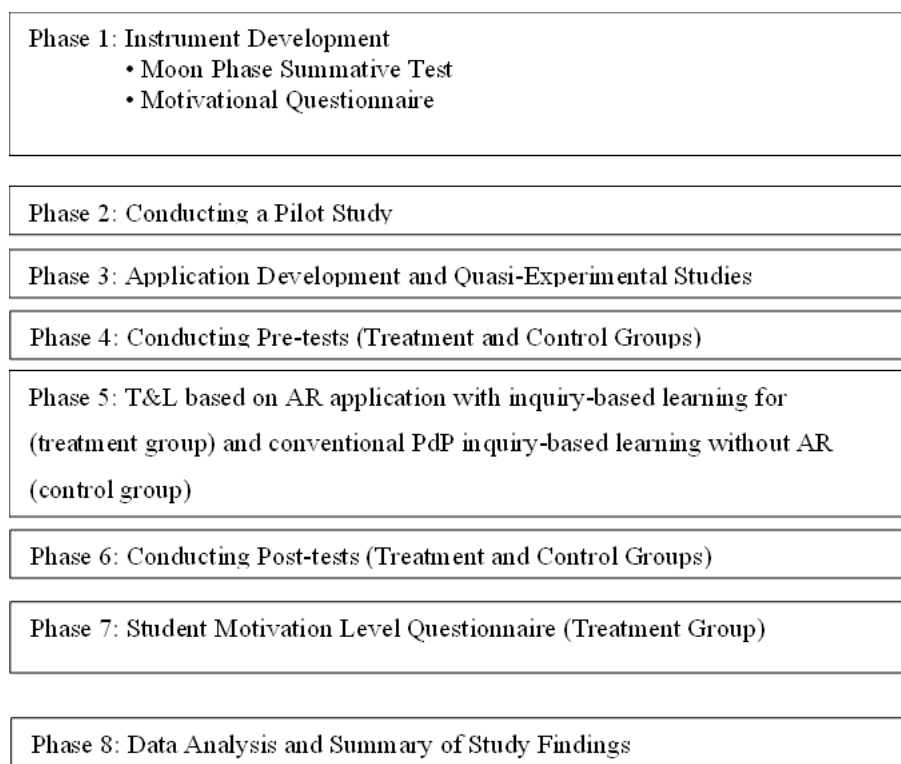


Figure 4. The steps of the research procedure

Phase 1: Instrument Development

In this study, the researcher has determined the research instrument that will be used. The construction of instruments is important to ensure that the research conducted can meet and achieve the research questions set in this study.

I. Achievement assessment test

There are two achievement assessment tests: the Pre-Test and the Post-Test, both structured with 30 objective and 2 subjective questions, aligned with the KSSR Science Revision curriculum. Questions were developed by modifying those from an exercise book and the KSSR Year 5 science textbook, following Bloom's Taxonomy, which categorizes educational objectives into six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. Although the same questions are used in both tests, their order differs (Krathwohl, 2002)

II. Questionnaire on the level of student motivation towards science learning.

The motivation questionnaire was adapted from previous research (Mustapha & Jamaludin, 2021) and administered to the treatment group after the science lesson. It consisted of two sections: demographic information and 12 motivation-related items focused on science learning. The questionnaire was written in Malay to address students' language limitations and used a four-point Likert scale, which is suitable for children aged 6–12, as their thinking tends to be dichotomous and may be confused by uncertain response options (Mellor & Moore, 2014).

Validity and Reliability of the Instruments

The instruments employed in this study, including the achievement test, and motivation questionnaire, were validated through expert review. Specifically, the achievement test was validated by two experts in science education which consist of a Senior Science Teacher and a Head of the Science Department. Both experts ensured that the test items aligned with the Curriculum Standard and the Moon Phases topic from the KSSR syllabus. Similarly, the motivation questionnaire was validated by a Guidance and Counseling Teacher who is qualified in psychometric evaluation. To ensure the reliability of the instruments, the test-retest method was used for the achievement test, which was administered to a sample of 15 fifth-grade students during the pilot study. The correlation coefficient (Pearson's r) between the pre-test and post-test was found to be 0.988, indicating excellent reliability with a very high consistency. Additionally, Cronbach's Alpha was used to assess the internal consistency of the motivation questionnaire. The Cronbach's Alpha values is 0.774 for the motivation questionnaire of which is considered acceptable to good according to standard reliability guidelines (Tavakol & Dennick, 2011).

Phase 2: Conducting a Pilot Test

After completing the study instrument draft, a pilot study will be conducted, involving an achievement assessment test and a motivation questionnaire for science learning. The pilot study aims to confirm construct validity, content validity, and instrument reliability through expert evaluation. This study will involve 15 Year 5 students from one school who share a similar background with the respondents in the actual study specifically, mainstream Year 5 students with moderate achievement in Classroom-Based Assessment.

Phase 3: Application Development and Quasi-Experimental Studies

In the third phase, the researcher developed the Moon Phase AR application and designed 5E inquiry-based learning activities for the quasi-experimental study. The AR application was developed using the ADDIE Instructional Model, which includes Analysis, Design, Development, Implementation, and Evaluation phases to ensure a systematic approach. Additionally, the researcher determined a four-week study duration and outlined the study steps during this period (refer to Table 4).

Table 4. Implementation Schedule of Inquiry-Based Learning

Control Group	Week	Treatment Group
Pre Test		Pre Test
Title: Moon Phases		Title: Moon Phases
Conventional: 5E inquiry-based learning model without AR	1	Treatment: 5E Inquiry-Based Learning with AR
• Engagement		• Engagement
Title: Moon Phases		Title: Moon Phases
Conventional: 5E Inquiry-Based Learning without AR	2	Treatment: 5E Inquiry-Based Learning with AR
• Exploration		• Exploration
• Description		• Description
• Expansion	3	• Expansion
• Evaluation		• Evaluation
• Evaluation	4	• Evaluation
		• Post Test
		• Motivation Level Questionnaire

Phase 4: Conducting Pre-tests (Treatment and Control Groups)

In this phase, the actual study begins, where the researcher will conduct a pre-test, which is a formative test of achievement assessment for the Moon Phases topic to both the control group and the treatment group in two different schools. Students will be given a pre-test without directly informing them that they are involved in the study. The duration of formative test of this Moon Phase achievement assessment will last for one hour according to the time when tests at the primary school level are usually conducted.

Phase 5: T&L based on AR application with inquiry-based learning for (treatment group) and conventional T&L inquiry-based learning without AR (control group).

In this phase, both control and treatment groups received different learning processes, but were taught by the same researcher, an experienced teacher in Science. Students in the treatment group used the AR application with the 5E inquiry-based learning model approach, where they were guided to understand the use of the application and the concept of Moon Phases. On the other hand, the control group only followed 5E inquiry-based learning model without the aid of the application, using pictures, concept explanations, and inquiry activities only. The detailed schedule of teaching and learning sessions for both groups, including pre-tests, intervention activities, and post-tests, is presented in Figure 5, which outlines the four-week implementation process of the study. Even though the implementation process in four weeks, according to Koumpourous (2024) stated that many AR studies in education are short-term pilots with small samples, often due to the logistical constraints of classroom settings. These short-term studies can still provide valuable insights into immediate impacts on motivation and engagement.

Week	Date	Implementation Activities	Note
1	13 May 2024	Pre-Test (Control And Treatment Groups)	• 30 control group students • 30 treatment group students
	14 May 2024	Moon Phase Conventional PdP (Control Group)	• 30 control group students
	15 May 2024	T&L With My Lunar AR (Treatment Group)	• 30 treatment group students
2	20 May 2024	Moon Phase Conventional T&L (Control Group)	• 30 control group students
	23 May 2024	T&L With My Lunar AR (Treatment Group)	• 30 treatment group students
3	4 June 2024	Moon Phase Conventional T&L (Control Group)	• 30 control group students
	5 June 2024	T&L With My Lunar AR (Treatment Group)	• 30 treatment group students
4	10 June 2024	Moon Phase Conventional T&L (Control Group)	• 30 control group students
	11 June 2024	T&L With My Lunar AR (Treatment Group)	• 30 treatment group students
	12 June 2024	Post-Test (Control Group)	• 30 control group students
	13 June 2024	Post-Test (Treatment Group) Motivation Questionnaire	• 30 treatment group students

Figure 5. The implementation of the My Lunar AR application in learning

Phase 6: Conducting Post-tests (Treatment and Control Groups)

In this phase, after the learning session for the control group (conventional) and the treatment group (with the help of the AR application), the teacher will give a post-test to both the control and treatment groups to test their mastery of the Moon Phases topic. The post-test, which is a formative test to evaluate the achievement of this Moon Phases topic, will also be carried out within one hour and have the same test items as the pre-test.

Phase 7: Conducting a Questionnaire on Student Motivation Levels After Using the AR Application

In this phase, the motivation level questionnaire after the 5E inquiry-based learning model with the help of the Augmented Reality application is carried out will be given to students in the treatment group to see the student's responses to the use of the AR application and also the level of motivation student.

Phase 8: Data Analysis and Summary of Study Findings

The last phase is the data analysis phase. This phase involves the process of analyzing pre-test and post-test data, motivation level questionnaires and also perception questionnaires and summarizing the results of the research that has been carried out. All the data found will be collected, processed and analyzed in order to answer the research questions.

6.2 Research Population

The population of this study consists of Year 5 students following the KSSR curriculum under the "Earth and Space" theme, specifically the topic of Moon Phases (Casteel & Bridier, 2021; Harwood, 2009). The sample was selected using a quantitative quasi-experimental approach with purposive sampling, which is appropriate when random sampling is not feasible (Campbell et al., 2020). Sample size was determined based on established guidelines, as a minimum of 30 students per group is considered sufficient for quasi-experimental studies to ensure statistical validity and reliability (Krejcie & Morgan, 1970; Andrade, 2020). Accordingly, this study involved 60 students, with 30 in the control group and 30 in the treatment group, which aligns with recommended practices and supports meaningful statistical analysis.

The participants were Year 5 students from the Kulai district, selected due to previously reported moderate levels of technology use (Hassan & Kamisan, 2010). Practical considerations such as time and financial constraints were also taken into account to ensure feasibility and data quality (Bonevski et al., 2014). Inclusion criteria required students to

follow the Year 5 KSSR curriculum, have access to a computer lab, and demonstrate moderate Classroom-Based Assessment achievement. Two intact classes were selected, Class A as the control group and Class B as the treatment group, in line with quasi-experimental research guidelines (Krejcie & Morgan, 1970).

Table 6. Population and Sample Tables

School	Total Population	Sample Study (Year 5 Intermediate Level students)
School 1	315	30
School 2	350	30

7. Findings

7.1 Comparative Analysis of Student Achievement Levels for Moon Phases Topic: Control Group and Treatment Group Students (Pre-Test and Post-Test).

Inferential statistical analysis was conducted on the pre and post test scores of the control and treatment groups, both of which demonstrated homogeneous characteristics. A Paired Samples t test was applied to compare students' achievement before and after learning the Moon Phases topic. The control group learned through conventional 5E inquiry-based instruction, while the treatment group received the My Lunar AR intervention integrated with the 5E model. The hypotheses for this analysis were established based on these comparisons.

H₀₃: There is no difference between the level of student achievement for students between the control and treatment groups before learning the Moon Phases topic

H₁₃: There is a difference between the level of student achievement for students between the control and treatment groups before learning the Moon Phases topic

H₀₄: There is no difference between the achievement of the Moon Phases topic for students between the control and treatment groups after learning the Moon Phases topic

H₁₄: There is a difference between the achievement of the Moon Phases topic for students between the control and treatment groups after learning the Moon Phases topic

Table 7. Comparative Analysis of Student Achievement Levels in the Control Group and the Treatment Group for the Pre-Test and Post-Test

Pre-Test	N	Mean	Standard Deviation	t-value	df	Sig.
Student achievement level (Control) *before learning Moon Phases	30	19.17	5.344	-1.308	29	.201
Student achievement level (Treatment) *before learning Moon Phases	30	21.00	8.166			
Post-Test	N	Mean	Standard Deviation	t-value	df	Sig.
Student achievement level (Control) *after conventional Moon Phases learning	30	40.00	9.699	-9.266	29	.001
Student achievement level (Treatment) *after learning the Moon Phases with the My Lunar Ar application with 5E Inquiry-based learning	30	59.13	13.673			

The pre-test analysis shows that the null hypothesis (H_{03}) cannot be rejected ($t = -1.308$, $p > 0.05$), indicating no significant difference in achievement between the control and treatment groups before learning the Moon Phases topic. Although the treatment group scored slightly higher ($M = 21.00$, $SD = 8.166$) than the control group ($M = 19.17$, $SD = 5.344$), the small mean difference of 1.83 was insufficient to indicate a real difference.

In contrast, the post-test results show that the null hypothesis (H_{04}) is rejected ($p < 0.05$), demonstrating a significant difference in achievement after instruction using the 5E inquiry-based learning model with the My Lunar AR application. The treatment group outperformed the control group, with a substantially higher mean score ($M = 59.13$, $SD = 13.673$) compared to the control group ($M = 40.00$, $SD = 9.699$), a mean difference of 11.743.

7.2 Descriptive Analysis of Motivation Levels After Learning the Science of Moon Phases using the My Lunar AR Application with 5E Inquiry-based Learning Model

To answer the second research question, the level of student motivation after using the My Lunar AR application was measured only for the treatment group since only the treatment group used this application. Table 8 shows the research data obtained for the level of motivation after using the AR application with inquiry-based learning.

Table 8. Descriptive Analysis of Motivation Levels

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
N	Valid	30	30	30	30	30	30	30	30	30	30	30	30
	Missing	0	0	0	0	0	0	0	0	0	0	0	0
Min		3.63	3.70	3.87	1.27	3.80	3.73	3.70	3.67	3.87	3.67	3.57	3.77
Std. Dev.		.490	.466	.346	.450	.407	.450	.466	.479	.346	.479	.504	.430

A descriptive analysis was made to measure and use mean score interpretation to determine the level of student motivation for the treatment group after the use of the AR application with inquiry-based learning for the Moon Phases topic, as shown in Table 9.

Table 9. Interpretation of Min Score

Min Score Range	Interpretation
1.0-2.0	Low
2.1-3.0	Moderate
3.1-4.0	High

Referring to Table 10, for the findings of the study of student motivation levels after using the My Lunar AR application with 5E inquiry-based learning model, all items obtained a high mean score range and one item in a low range.

Table 10. Questionnaire Item Analysis of Students' Motivation Levels after using the My Lunar AR application

No.	Item	Min	Min Interpretation	Std. Dev.
1.	I love learning science using the Moon Phase AR application	3.63	high	.240
2.	I feel at a loss if I don't follow a science lesson with the help of the Moon Phase AR application	3.70	high	.217
3.	The use of the Moon Phase AR application helped to attract my attention throughout the study	3.87	high	.120
4.	Using the Moon Phase AR application is boring	1.27	low	.202
5.	I am confident that the contents of the Moon Phase AR application will be useful for me	3.80	high	.166
6.	I was able to relate the content of the Moon Phase AR application to what I had learned.	3.73	high	.202
7.	I am trying to understand the science concepts learned through the Moon Phase AR application	3.70	high	.217
8.	I like to ask the teacher if I don't understand the concept when using the Moon Phase AR application	3.67	high	.230
9.	I am confident that I can answer the Moon Phase question after studying it	3.87	high	.120
10.	I like to discuss with my friends the science concepts I learned	3.67	high	.230
11.	I like to read and use science-related material resources	3.57	high	.254
12.	I had a lot of fun while learning to use the Moon Phase AR application	3.77	high	.185

The data show that the level of student motivation in the treatment group after using the AR application with 5E inquiry-based learning model is high, with an overall mean score range of 3.52. The mean score of each question is also high, such as item 1 (3.63), item 2 (3.70), item 3 (3.87), and item 4 (1.27), which are low because they are negative statements, showing that students do not agree with the statement.

7.3 Analysis of the Relationship Between Student Achievement Levels and Motivation Levels After Using Augmented Reality Applications.

Inferential statistical analysis using Spearman's correlation was conducted to find the direction of the relationship between the level of student achievement and the level of student motivation after students underwent a learning session using the AR application with the 5E inquiry-based learning model. The research data to determine this relationship is the difference in pre-test and post-test scores and the mean score of the student motivation level questionnaire conducted on students from the treatment group. Table 11 shows Spearman's correlation analysis, which shows the relationship between the level of student achievement and the level of motivation after using the AR application.

Table 11. Spearman Correlation Analysis of Student Achievement Level with Motivation Level

		Achievement Level	Motivational Level
Achievement Level	Spearman correlation	1.00	- 0.81
	Sig. (2-tailed)	.	.672
	N	30	30
Motivational Level	Spearman correlation	-0.81	1.00
	Sig. (2-tailed)	.672	.
	N	30	30

Spearman's Rho correlation analysis showed a value of -0.81 between student achievement level (pre and post-test score difference) and the average value of the motivation level questionnaire, which shows a weak and negative relationship. The significant value (2-tailed) is 0.672, exceeding alpha $p > 0.05$, which indicates that there is no statistically significant evidence for the relationship between the level of student achievement and the level of motivation. Therefore, there is no evidence that the level of student achievement affects the level of motivation or vice versa.

8. Discussion

This study examined the impact of the My Lunar AR application integrated with the 5E inquiry-based learning model on primary students' achievement in the Moon Phases topic. Findings showed that the treatment group using AR significantly outperformed the control group receiving traditional instruction, consistent with past studies showing AR can enhance conceptual mastery (Alzahrani, 2020; Chiang, Yang, & Hwang, 2014; Syawaludin et al., 2019). However, some research cautions that AR does not always guarantee superior outcomes, highlighting the need for thoughtful integration (Chen et al., 2019). This explain novelty of this study on integration of Augmented Reality (AR) customised application with the 5E inquiry-based learning model in primary education in Malaysia, specifically for teaching abstract concepts like Moon Phases. While previous research has examined AR and inquiry-based models separately, this study uniquely combines both to enhance student motivation and achievement. It provides valuable insights into how AR can improve the efficacy of the 5E model, leading to a more engaging and immersive learning experience (Poongavanam et al; 2025).

A key contributor to improved performance in the treatment group was the use of 3D visualisation, which offered realistic representations of Moon Phases. This aligns with studies showing that 3D AR elements strengthen learning by merging digital information with visualisation (Ali et al., 2021; Klopfer & Squire, 2008). While control-group students grasped basic ideas such as rotation and light reflection, they struggled with more complex reasoning tasks. The effectiveness of AR was further reinforced by studies such as Quintero et al. (2019), who argue that 3D AR facilitates meaningful learning through seamless digital-real integration. AR allowed students to virtually interact with scientific phenomena, improving visualisation and conceptual understanding (Ali et al., 2021; Klopfer & Squire, 2008). In contrast, the control group demonstrated only modest improvements and difficulty with higher-order thinking.

The findings show that reliance on memorisation limits students' ability to engage in higher-order cognitive tasks, supporting the view that memorisation alone is insufficient for developing critical thinking (Lili Supardi, 2021). In contrast, inquiry-based approaches, particularly the 5E inquiry-based learning model, promote active engagement through questioning, exploration, and reflection, leading to stronger conceptual understanding (Rubani et al., 2018; Schroeder et al., 2007). Consistent with prior studies, integrating inquiry-based learning with ICT enhances scientific and cognitive understanding by supporting active exploration and meaningful learning experiences (Gerhátová et al., 2021; Wu & Yang, 2022; L. Wu et al., 2023). The use of AR further increased student motivation, with high motivation scores in the treatment group, reinforcing evidence that visualisation technologies positively influence learner engagement and interest in science learning (Uukkivi & Labanova, 2018; Petrovych et al., 2023).

AR-supported learning also strengthened classroom interaction by encouraging discussion, questioning, and visualisation of scientific concepts, reinforcing an inquiry-driven learning environment (Xue & Wang, 2021; Hanid et al., 2020). However, despite increases in both motivation and achievement, no significant correlation was found between the two, indicating that higher motivation does not necessarily translate into improved academic performance.

This finding aligns with earlier studies reporting no direct relationship between motivation and achievement (Aroma et al., 2021; Jee et al., 2017) and supports evidence that academic outcomes are shaped more strongly by cognitive processing, task design, instructional quality, and prior knowledge (Zhao et al., 2023). Overall, the findings confirm that integrating AR with inquiry-based pedagogy enhances conceptual understanding and engagement, while highlighting the need for further research on long-term learning effects and higher-order cognitive outcomes.

Recommendations and Suggestions

Future research should examine the use of AR across different subjects and student groups, with a focus on its long-term effects on higher-order thinking, collaboration, motivation, and achievement. Mixed-methods and longitudinal approaches, including interviews and classroom observations, would provide deeper insights into students' learning experiences and help clarify how instructional design and contextual factors influence learning outcomes. Overall, this study highlights the potential of AR-integrated inquiry-based learning, such as My Lunar AR, to enhance conceptual understanding and transform primary science classrooms into engaging, technology-rich learning environments.

Limitations

This study has a few limitations that should be considered. First, the sample size of 60 students, while adequate for this study, limits the ability to apply the results to a larger population. The students were from one specific area, so the findings may not apply to other regions or groups. Future studies should aim to increase the sample size and include more diverse participants. Second, the four-week trial may not fully capture the long-term effects of using AR on student motivation and achievement. A longer study or follow-up assessments would be helpful to see if the effects last over time. Additionally, the use of questionnaires to measure motivation and achievement relies on self-reported data, which can be biased. Future studies could use multiple methods, such as observations or interviews, to get a complete and more accurate picture.

9. Conclusion

This study addresses a gap in the literature concerning primary students' difficulties in understanding abstract scientific concepts such as Moon Phases by integrating the My Lunar AR application with the 5E inquiry-based learning model. The findings show that this integrated approach significantly improves student achievement and motivation compared to conventional teaching methods, as AR provides an interactive and visually engaging learning environment that supports conceptual understanding and active participation. However, although both motivation and achievement increased, no significant direct relationship was found between them, suggesting that other factors such as cognitive processing, instructional design, and prior knowledge may play a more influential role in academic outcomes. Overall, the study contributes evidence that AR technology, when carefully aligned with inquiry-based pedagogy, can effectively support critical thinking, visualisation, and problem-solving skills in primary science learning.

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No additional data are available.

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