

Muara Takus Temple in the digital dimension: increasing historical understanding through augmented reality

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ABSTRACT

This research aims to investigate the impact of using augmented reality (AR) at Muara Takus Temple as a source of history learning for students' historical understanding. Experimental research methods were involved in this research. 88 secondary school students were used as samples. They were split into two groups, the experimental group and the control group, each of which had 44 randomly chosen participants. A history test and a questionnaire used for collecting data. Historical understanding data was analyzed using statistical analysis such as the t-test to compare differences between the experimental group and the control group. Data from the questionnaire was analyzed descriptively to identify user experience and satisfaction with the AR application. The computed t score of 6.21 is significantly higher than the 2.00 t table value. These findings indicate that the use of AR in history learning can increase student understanding and engagement. Apart from that, the use of AR also increases students' interest, motivation and interaction abilities and provides immersive experiences in history learning. This research confirms that AR has great potential to improve students' historical understanding while stimulating their interest, motivation, and interaction abilities in history subjects.

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1. INTRODUCTION

Knowing the past is essential to comprehending the evolution of humanity and the historical events that shaped the modern world [1]–[3]. As a scientific field, history is crucial to our understanding of how society, cultures, and civilizations have changed throughout time [4]–[7]. Historical sources are crucial for developing a solid historical understanding [6], [8], [9]. Documents, artifacts, notes, and other proof that offers a firsthand view of historical events can be included in these historical sources [7], [10]. The foundation for developing a thorough and accurate historical understanding in students is comprehending and evaluating historical materials [11], [12].

Understanding and assessing historical information is the cornerstone of helping students build a comprehensive and accurate historical understanding [13], [14]. This temple is not only a historical monument, but also an alluring work of architectural art with a rich cultural heritage. However, for many of the younger generation and local residents, understanding of the historical significance and cultural value of Muara Takus Temple is often limited to printed materials or conventional tourist guides [13]. This certainly has an impact on the incomplete understanding of the history of Muara Takus Temple. Several reasons why it is important to understand the history of Muara Takus Temple include: i) Muara Takus Temple is an integral part of the local

cultural heritage. Understanding and appreciating the cultural values embedded in these temples helps students feel more connected to their cultural roots and increases their sense of pride in local identity [7], [15]: ii) Local history contains knowledge about local wisdom that has existed for centuries. This can include ways of life, traditions, myths, and practices that are still relevant in modern society. Understanding this history helps protect and preserve local identity from loss due to globalization [16], [17]: iii) Muara Takus Temple is not an isolated entity, but is also connected to greater world history. Understanding local history can help students see how local events can influence global events and vice versa, help them connect the dots in broader history [4], [13]: and iv) Examining local history, including digging up information about Muara Takus Temple, involves important research skills. Students can learn how to search for historical sources, analyze information, and develop a deep understanding of the past [18], [19].

Based on the discussion above, Muara Takus Temple, as one of the meaningful historical heritages in Indonesia, is an important focal point in efforts to enrich our understanding of history in Indonesia. However, in an educational context, integrating historical sources in learning becomes a challenge and an opportunity [20], [21]. Students' comprehension and appreciation of history may be greatly influenced by how they engage with historical materials. As a result, it's critical to investigate different teaching strategies and materials that might aid students in more effectively recreating their historical comprehension.

Muara Takus Temple has a great historical significance and is pertinent to the history curriculum, but incorporating it into the teaching process might be difficult for a variety of reasons. Creating engaging and dynamic learning experiences for students is one of the challenges, as is the lack of funding for field trips to the Muara Takus Temple and instructors' ignorance of the temple's historical significance. According to the findings of interviews conducted with Riau's history subject teachers, there are a number of challenges in incorporating Muara Takus Temple as a historical source into the classroom. One of these challenges is that students who live far from the temple may find it challenging to visit. This results in gaps in the educational process, as some students might not be able to visit these historical locations personally. Furthermore, some students may find it difficult to afford travel expenses, admission fees, and housing, and there may not always be enough transportation to go to these historical locations.

A preliminary study measuring the historical comprehension of thirty high school pupils in Riau was carried out. Five indicators are used to assess students' historical knowledge: Understanding historical chronology, historical context analysis, historical source analysis skills, understanding of interrelationships between events, and understanding of change and continuity. Table 1 displays the analysis's findings.

Table 1. Riau high school students' historical comprehension

Aspect	Persentase (%)	Description
Understanding historical chronology	31.78	Low
Historical context analysis	25.04	Low
Historical source analysis skills	21.41	Low
Understanding of interrelationships between events	20.48	Low
Understanding of change and continuity	17.36	Low
Mean	23.21	Low

The percentage of students who understand different aspects of history, including historical chronology, historical context analysis, historical source analysis skills, understanding of how events relate to one another, and understanding of change and continuity, all show low levels, as can be seen from the Table 1. There are notable restrictions on the learning resources that are accessible to pupils, as seen by the average historical comprehension percentage of 23.21%. This might suggest that the learning resources now in use are insufficient or inefficient in giving pupils a thorough understanding of history. The low percentage of students who comprehend history is caused by limitations in learning materials, such as subpar textbooks, restricted access to a variety of historical sources, and a lack of use of contemporary technologies in history teaching. Consequently, in order to increase students' comprehension of history, teaching resources must be improved.

Given the aforementioned issues, investigating the Muara Takus temple requires a more pertinent strategy. Utilizing augmented reality (AR) technology as a historical resource is one method [22]–[25]. Students may now engage in more dynamic interactions with historical materials thanks to technology, which makes for an immersive and interesting learning environment [26], [27]. AR technology brings innovation in learning and exploring cultural heritage [28], [29]. Through the integration of cutting-edge technology and comprehensive historical research, this article will demonstrate how augmented reality can offer students immersive learning experiences, stimulate their curiosity, improve their historical understanding, and contribute to the preservation of this priceless legacy for future generations [30]–[32].

Research on the application of augmented reality in history education was conducted by Challenor and Ma [33], one of several previous relevant studies. These two studies, however, differ in that our research, which employs a direct experimental method, focuses on analyzing the effects of using AR at Muara Takus Temple as a learning resource to increase students' understanding of history, whereas Challenor and Ma's research [33], which uses a literature review method, aims to investigate the use of AR in general history education.

Similar studies by Koutromanos *et al.* [34] use AR technology as a tool to improve students' historical comprehension. Nonetheless, there are differences in the research topic and methodologies employed. An augmented reality game intended to educate about the history of a Greek island was designed, developed, and evaluated by Koutromanos *et al.* [34] using a research-based design method. In the meantime, our study examines the effects of utilizing AR at Muara Takus Temple as a historical education tool for students through experimental research methodologies.

Although Koti [35] research and ours have distinct goals and approaches, both of our studies center on the use of augmented reality in secondary school instruction. Using design-based research (DBR) methods, Koti research [35] attempts to create, develop, and examine novel AR instructional resources that increase student motivation and collaboration as well as enhance social skills. Meanwhile, utilizing experimental research techniques, our study examines the effects of utilizing AR at Muara Takus Temple as a source of historical learning for students' historical comprehension.

This study examines the impact of using AR technology at Muara Takus Temple as an innovative historical learning resource. Unlike previous studies that have investigated the general use of AR in history education [34], this research specifically explores how AR can enhance students' historical understanding of Muara Takus Temple, an important historical site in Indonesia. While prior research has provided initial insights into the effectiveness of AR [29], none have explicitly examined its impact on the rich cultural and historical values of Muara Takus Temple. Employing an experimental method, this study aims to fill this gap and provide empirical evidence on the real benefits of applying AR in this specific context.

Based on the background above, this research aims to analyze the use of the Muara Takus Temple Augmented Reality application as a history learning resource in improving students' historical understanding. In order to achieve this goal, this research will try to answer several important questions, including:

- Is there a statistically significant difference between the average score of the experimental group on historical understanding before and after implementing AR Muara Takus Temple as a source? history learning?
- Is there a significant influence from the use of AR at Muara Takus Temple as a historical learning resource on students' historical understanding?

By exploring the answers to these questions, it is hoped that this research will provide valuable insight into how AR Candi Muara Takus can be an effective and engaging learning resource in improving students' historical understanding.

2. METHOD

This research is a type of experimental research. AR technology is applied as a learning resource for students to improve their historical understanding. In order to achieve the objectives set in research regarding the use of AR at Muara Takus Temple as a source of history learning to improve students' historical understanding, this research adopts a quasi-experimental approach. Score comparisons were made between the experimental group who received instruction using AR and the control group who received conventional instruction.

The total sample used consisted of 88 high school (senior high school) students who were divided into two groups, namely the experimental group and the control group, each consisting of 44 people. This sample was randomly selected from various secondary schools in Riau. One limitation of this study is the relatively small sample size of 88 students. Although this sample size is sufficient to detect statistically significant differences using t-tests, it may not be large enough to generalize the findings to a broader population. According to Cohen [36], a sample size of at least 30 per group is recommended for detecting a medium effect size with 80% power in a two-tailed test. Our sample size meets this criterion, but larger samples would provide more robust and generalizable results. Additionally, larger sample sizes would allow for more detailed subgroup analyses and increase the reliability of the findings. Future research should consider using larger samples to validate and extend the findings of this study.

The research instrument used for data collection was a history test before and after using the AR application at Muara Takus Temple to measure students' historical understanding and a questionnaire to measure students' experience in using the AR application. Historical understanding data will be analyzed using t-test statistical analysis to compare differences between the experimental group and the control group. Data from the questionnaire was analyzed descriptively to identify user experience and satisfaction with AR

applications. Data analysis was carried out with the help of statistical software such as SPSS to test research hypotheses and present findings scientifically.

The hypotheses of this research are:

- There is a statistically significant difference between the experimental group's average score on historical understanding before and after implementing AR at Muara Takus Temple as a source of historical learning.
- There is a significant influence of the use of AR at Muara Takus Temple as a historical learning resource on students' historical understanding.

2.1. Equality value

To evaluate the effectiveness of using AR at Muara Takus Temple as a history learning resource to improve students' historical understanding, this research applies a comprehensive approach. One crucial step is to assess whether there is baseline equivalence between the experimental group, which received instruction via AR, and the control group, which followed traditional teaching methods. The Table 2 below presents the equality scores between these two groups with respect to relevant variables such as mean (Mean) and standard deviation (standard deviation). This data is the basis for determining whether the comparison between the experimental and control groups in historical understanding before the AR intervention is equivalent or not.

The Table 2 shows that before the AR intervention, both groups had good equality in terms of historical understanding. There was no significant difference between their historical comprehension means, and the relatively similar standard deviation values indicated a similar distribution of data between the two groups. The results of statistical tests with t-value and sign values also indicate that this difference is not statistically significant. Therefore, the initial equality between the control group and the experimental group was met before the implementation of AR, which provides a strong basis for further analysis related to the impact of AR intervention on students' historical understanding.

Table 2. Equality score table between control group and experimental group

Variable	Control group	Experimental group
N	44	44
Mean (rate-rate)	22.5	21.8
Standard deviation	8.2	7.6
Nilai t (t-value)	1.34	0.98
Significance (sign)	0.191	0.332

Table 3 presents indicators crucial for assessing historical understanding. The first aspect highlighted is understanding historical chronology, which assesses students' proficiency in sequencing and organizing historical events chronologically, starting from the earliest occurrences to the most recent ones. This indicator is fundamental as it demonstrates the student's grasp of the timeline of historical developments. The next aspect, historical context analysis, delves into students' capability to analyze the broader social, cultural, political, and economic contexts surrounding specific historical events. This involves understanding how these contextual factors influenced and shaped the events in question, reflecting a deeper comprehension of historical processes. Another critical aspect is historical source analysis skills, which measures students' ability to critically evaluate various historical sources such as documents, artifacts, or reports. This includes assessing the reliability, bias, and relevance of these sources in understanding historical events, thereby honing the student's analytical prowess. Understanding of Interrelationships between events is also paramount, requiring students to identify and elucidate the connections and interdependencies between different historical events or developments. This involves recognizing how one event can trigger or influence another, showcasing a nuanced understanding of historical causation. Finally, understanding of change and continuity encompasses students' proficiency in recognizing and explaining changes and continuities within historical contexts. This involves discerning social, political, economic, or cultural changes over time, as well as identifying elements that persist across historical periods. Mastery of these indicators collectively indicates a robust understanding of history, encompassing not just factual knowledge but also critical thinking and analytical skills essential for historical literacy.

The questionnaire presented in Table 4 assesses various aspects of student experience and satisfaction in using (AR) for learning about the history of Muara Takus Temple. In terms of student learning interests, respondents expressed increased interest in exploring the temple's history and a desire to delve deeper into previously unknown aspects, attributing this curiosity to their experience with AR. Additionally, AR was found to enhance motivation to learn history, with students feeling more driven to study diligently

and attend history lessons. Interaction capabilities with AR were perceived positively, as students felt it offered direct interaction with historical objects, improving analytical and understanding skills. The visualization quality of AR was praised for aiding in understanding historical details, with respondents finding the visual presentations clear, informative, and impressive. Furthermore, AR provided an immersive experience, with students feeling as though they were actively participating in historical events, contributing to a more in-depth and enjoyable learning experience overall.

Table 3. Indicators of historical understanding

Aspect	Description
Understanding historical chronology	Students' ability to sequence and organize historical events in the correct time sequence, starting from those that occurred earliest to those that occurred most recently.
Historical context analysis	Students' ability to analyze and understand the social, cultural, political, and economic context surrounding a particular historical event, as well as how that context influenced and shaped the event.
Historical source analysis skills	The student's ability to analyze and evaluate historical sources, such as documents, artifacts, or historical reports, to determine the source's reliability, bias, and relevance in understanding historical events.
Understanding of interrelationships between events	Students' ability to identify and explain relationships or interrelationships between different historical events or developments, including how one event may influence or trigger another.
Understanding of change and continuity	Students' ability to recognize and explain changes that occur in history, whether social, political, economic or cultural changes, as well as understand the elements that remain consistent over time in a historical context.

Table 4. Questionnaire measuring student experience and satisfaction in using augmented reality

Aspect	Questionnaire statement
Student learning interests	<ul style="list-style-type: none"> – I felt interested in exploring more about the history of Muara Takus Temple after using AR – The experience of using AR made me want to know more about the history of Muara Takus Temple. – AR piqued my interest in understanding aspects of history that I previously knew nothing about.
Motivation to learn	<ul style="list-style-type: none"> – Using AR in learning history makes me more motivated to study diligently. – I feel more motivated to attend history lessons thanks to the use of AR. – AR provided a learning impetus for me to understand more deeply about Muara Takus Temple
Interaction capabilities	<ul style="list-style-type: none"> – I feel AR gives me the opportunity to interact directly with historical objects. – The ability to interact with AR makes learning history more interesting. – AR helped me develop better analytical and understanding skills.
Visualization quality	<ul style="list-style-type: none"> – The quality of visualization in AR really helps me understand the details of historical objects. – I feel the visualization presented through AR is very clear and informative. – AR provides an impressive visual presentation of the history of Muara Takus Temple.
Immersive experience	<ul style="list-style-type: none"> – I feel like I'm really in the middle of historical events when using AR. – The experience of using AR took me into the immersive historical world of Muara Takus Temple. – AR provides a more in-depth and enjoyable history learning experience.

3. RESULTS AND DISCUSSION

In this research, we collected demographic data from a total of 88 class XI students involved in experimental research regarding the use of AR at Muara Takus Temple as a history learning resource in increasing students' historical understanding. The students were split into two groups: the control group, which did not employ AR in their education, and the experimental group, which did. The following table provides details on the age, gender, and if the pupils have ever used augmented reality previously.

Table 5 shows the demographic information of students who are split into two groups the control group and the experimental group—in the context of a study on AR as a historical learning tool at Muara Takus Temple to improve students' historical comprehension. There were 44 students in the control group, and their average age was almost 16.5 years. There are twenty male pupils and twenty female students within this total. Furthermore, of the students in this group, 42 had never experienced augmented reality before, and 2 had. Meanwhile, 44 students with an average age of 16.4 years were also part of the experimental group. In this group, there were 22 male students and 22 female students. Of the total students in the experimental group, there were 3 students who had used AR and 41 students who had never used AR. The total of the two groups was 88 students, with details of 42 men and 46 women. Of the total, 2 students had used AR before, while 47 students had never used AR. This demographic data will help in analyzing student characteristics in the research context as well as understanding differences in learning outcomes between the control group and the experimental group.

Table 5. Students' information

Group	The number of students	Average age	Gender (male/female)		Have you ever used AR (yes/no)	
			Man	Woman	Yes	No
Control	44	16.5	20	24	2	42
Experiment	44	16.4	22	22	3	41
Total	88		42	46	5	86

3.1. Hypothesis test

- Hypothesis 1: There is a significant difference in the average scores of the control and experimental groups.

The first hypothesis states "There is a statistically significant difference between the average score of the experimental group on the historical understanding scale before and after implementing AR at Muara Takus Temple as a source of historical learning." To test this hypothesis, the researcher carried out a T test calculation to compare the average score of the experimental group before and after implementing Augmented Reality at Muara Takus Temple on students' historical understanding. The T test results are presented in the following Table 6.

Table 6. T test results of hypothesis 1

Group	N	Mean	St. Deviation	df	Tabulated t-value	Calculated t-value	Sig	Effect Size (η^2)
Pre	44	62.3	8.5	43	2.05	5.39	0.001	0.50
Post	44	85.2	10.1					

The statistical study of students' historical knowledge in relation to their use of AR as a learning tool is displayed in the Table 5. The average score of students' historical understanding before using AR at Muara Takus Temple was 62.3, with a standard deviation of 8.5. While the average score has increased significantly to 85.2, with a standard deviation of 10.1 after using AR Candi Muara Takus as a historical learning resource.

The table above shows that there is a statistically significant difference between the scores of the experimental group before and after the application of AR, with a calculated t-value of 5.39. The significance (Sig.) is 0.001, indicating that this difference did not occur by chance, and the effect is also quite large with an effect size of 0.50. These results support the first hypothesis which states that the use of Muara Takus Temple AR as a historical learning resource has a significant positive impact on students' historical understanding.

- Hypothesis 2: There is a significant influence from the use of AR at Muara Takus Temple as a source of history learning on students' historical understanding

The second hypothesis in this research aims to investigate the significant influence of using AR at Muara Takus Temple as a source of history learning on students' historical understanding. Statistical analysis was carried out to compare the results of historical understanding between the experimental group that received instruction via AR and the control group that followed conventional learning methods. The Table 7 presents the findings from this analysis.

Table 7. T test results of hypothesis 2

N (experiment)	Mean (experiment)	St. deviation (experiment)	N (control)	Mean (control)	St. deviation (control)	df	Tabulated t- value	Calculated t- value
Post	44	89.8	7.2	44	71.3	6.5	86	2.00

Based on the Table 7, the average historical understanding of the experimental group is 89.8 and the standard deviation is 7.2. Meanwhile, the control group also had the same sample size, namely 44 students, with an average historical understanding of 71.3 and a standard deviation of 6.5. This shows that there is a difference in the average score between the control group and the experimental group after using AR Muara Takus Temple as a source of history learning. The statistical test results show that the T value calculated for comparison between the two groups is 6.21, while the T value tabulated with degrees of freedom (df) of 86 is 2.00. The calculated T value is greater than the T table so it is concluded that there is a significant influence using augmented reality at Muara Takus Temple as a source of history learning for students' historical understanding. This is also confirmed by The significance value (Sig), namely 0.000 (smaller than 0.05), indicates that the difference between the two groups is statistically significant. Therefore, it can be concluded that the use of Muara Takus Temple AR as a history learning resource has a significant impact in increasing

students' historical understanding. The effect size (effect size) of 0.40 indicates that the AR intervention has quite a large influence in increasing students' historical understanding in the experimental group.

These results show that AR can be an effective tool for deepening students' understanding of historical material and has the potential to be applied in a broader history learning context. Next, testing is carried out on aspects that influence students' historical understanding. The results of the analysis are presented as follows:

3.2. Historical understanding

Table 8 shows the difference in the average score of students' historical understanding in the experimental group before and after the influence. The Table 8 shows that the average posttest score is higher than the pretest score, so there is a statistical difference between before and after using AR Candi Muara Takus as a history learning resource to improve historical understanding. This is also indicated by the significance value (Sig) which is smaller than 0.05. In the aspect of understanding historical chronology, the average score before training was 68.23 and increased to 95.67 after training. A similar thing happened in the historical context analysis, where the average score before training was 65.78 and increased to 92.76 after training. Historical source analysis skills also experienced a significant increase from 64.56 to 91.54 after training. In addition, understanding of the relationship between events and understanding of change and continuity in a historical context also experienced a significant increase. Understanding of interrelationships between events increased from 70.91 to 94.78, while understanding of change and continuity increased from 68.12 to 93.24 after training. These results show that the training or teaching provided has a significant positive effect on students' understanding of history, with a fairly large effect size, indicating that the change in understanding is not just the result of chance, but rather the result of effective intervention in history learning.

Table 8. Students' historical understanding in the experimental group before and after the influence

Aspect	To	N	Mean pre	St. dv	t-value	Sig	Effect size (η^2)
Understanding historical chronology	Pre	44	68.23	6.35	8.47	<0.001	0.63
	Post	44	95.67	5.92			
Historical context analysis	Pre	44	65.78	5.71	11.26	<0.001	0.73
	Post	44	92.76	6.11			
Historical source analysis skills	Pre	44	64.56	6.04	10.57	<0.001	0.69
	Post	44	91.54	5.87			
Understanding of interrelationships between events	Pre	44	70.91	7.12	9.23	<0.001	0.67
	Post	44	94.78	6.45			
Understanding of change and continuity	Pre	44	68.12	6.21	7.98	<0.001	0.61
	Post	44	93.24	5.78			

The Table 9 presents the results of descriptive analysis regarding students' experiences and satisfaction in using AR at Muara Takus Temple which was tested on 44 students in the experimental class. From the table above, the results of the descriptive analysis show that students show a high level of interest in learning about the use of AR in learning the history of Muara Takus Temple. The average response scores for statements related to interest in learning are all in the high range (between 4.4 to 4.6), which indicates that the use of AR has succeeded in arousing students' interest in understanding the history of Muara Takus Temple in more depth. The use of AR also influences students' learning motivation. The results of the analysis show that students feel more motivated to study history diligently and attend history lessons thanks to the use of AR. The average response score reflects a high level of motivation (between 4.2 to 4.5), indicating that AR provides learning encouragement for students to understand more deeply about Muara Takus Temple. Students feel that AR provides a good opportunity to interact directly with historical objects, and this makes learning history more interesting. The average response score for interaction skills was also high (between 4.3 to 4.5), indicating that AR can help students develop better analytical and comprehension skills.

The quality of visualization in AR is considered to really help students understand the details of historical objects. The results of the analysis show that students feel that the visualization presented through AR is very clear and informative. The average response score on this aspect is also high (between 4.5 to 4.7), indicating that AR provides an impressive visual presentation of the history of Muara Takus Temple. Students feel that using AR provides an in-depth and enjoyable history learning experience. The analysis results show that students feel like they are truly in the middle of historical events when using AR, and this experience brings them into the immersive historical world of Muara Takus Temple. The average response score on this aspect is also high (between 4.6 to 4.7), indicating that AR provides a very positive and memorable history learning experience. Overall, the results of the descriptive analysis show that the use of AR at Muara Takus Temple in history learning is very positive in stimulating students' interest, motivation, interaction skills, visual understanding and learning experiences. All aspects of measurement show a high

level of satisfaction among students, which indicates that AR has great potential to improve students' historical understanding in the context of learning the history of Muara Takus Temple. The results of this study indicate that the use of AR technology is significantly correlated with enhanced historical understanding among students. The AR-based learning method we proposed successfully increased interaction and learning motivation, where students demonstrated a proportional improvement in their ability to analyze historical sources and understand chronological contexts.

Table 9. Experience using augmented reality muara takus temple

Aspect	Questionnaire statement	Average response score
Student learning interests	I felt interested in exploring more about the history of Muara Takus Temple after using AR	4.5
	The experience of using AR made me want to know more about the history of Muara Takus Temple.	4.4
	AR piqued my interest in understanding aspects of history that I previously knew nothing about.	4.6
Motivation to learn	Using AR in learning history makes me more motivated to study diligently.	4.3
	I feel more motivated to attend history lessons thanks to the use of AR.	4.2
	AR provided a learning impetus for me to understand more deeply about Muara Takus Temple	4.5
Interaction capabilities	I feel AR gives me the opportunity to interact directly with historical objects.	4.4
	The ability to interact with AR makes learning history more interesting.	4.5
	AR helped me develop better analytical and understanding skills.	4.3
Visualization quality	The quality of visualization in AR really helps me understand the details of historical objects.	4.6
	I feel the visualization presented through AR is very clear and informative.	4.7
	AR provides an impressive visual presentation of the history of Muara Takus Temple.	4.5
Immersive experience	I feel like I'm really in the middle of historical events when using AR.	4.6
	The experience of using AR took me into the immersive historical world of Muara Takus Temple.	4.7
	AR provides a more in-depth and enjoyable history learning experience.	4.6

3.3. Discussion

The results of statistical analysis show that there is a very significant difference between the experimental group (which used AR) and the control group in terms of students' historical understanding. The high t-calculated value, namely 6.21, is much greater than the t-tabulated value of 2.00 with degrees of freedom (df) of 86. This confirms that the difference is not just a coincidence, but is very statistically significant. The significance value shows a very low value (0.000) also confirming the significance of the difference. Apart from that, the effect size in the form of η^2 of 0.40 shows that the use of Augmented Reality has a fairly large effect size on students' historical understanding. This means that the use of AR technology in history learning has a real positive impact in increasing students' historical understanding.

These findings support several relevant previous research results that the use of AR technology in a learning context can increase students' understanding and involvement in the learning process [27], [33], [37]. These results are consistent with literature showing that the use of AR can provide a more interactive, immersive, and interesting learning experience [29], [38]. Therefore, the use of AR as a history learning resource at Muara Takus Temple has the potential to significantly improve students' historical understanding.

Based on research findings, it can be seen that every aspect of historical understanding has increased after using Augmented Reality as a source of history learning. AR as a learning resource in History subjects has been proven to have a significant influence in increasing students' historical understanding. AR provides an interactive and engaging learning experience for students [28], [39]. With AR technology, students can interact with historical objects that are replicated in 3D or live images, making learning more interesting than conventional learning that only focuses on textbooks [30]–[32]. Augmented Reality allows students to view and explore historical sites or historical artifacts in a real context. This helps students to better understand how historical events unfolded, how artifacts were used, and how the environment influenced historical events [40]–[42]. Augmented Reality can provide contextual information that is useful in historical

understanding [23], [25], [33]. Students may have a better understanding of the historical context by, for instance, pointing their AR device at a historical map to see extra information such as dates, locations, and pertinent historical facts surface. Students can freely research history thanks to augmented reality technologies [43]–[45]. This gives students the opportunity to actively study while developing their grasp of history through practical application. Using AR can motivate pupils to study history more. The allure of augmented reality technologies and interactive educational opportunities might pique students' curiosity about historical events. Certain pupils may find it challenging to comprehend historical ideas just from reading. By offering more interesting learning opportunities and tangible visuals, AR aids in overcoming these challenges.

Students' attention, motivation, and interpersonal skills are all impacted by using augmented reality as a resource for learning about history [20], [46]. AR offers students creative and captivating educational opportunities. With the use of AR technology, students may engage with historical materials in more lifelike visual formats, such as 3D copies or live photographs. Increased student participation in interactive history instruction can boost their enthusiasm for the subject matter [47], [48]. Through novel and engaging experiences, students' enthusiasm for studying and comprehending history grows. Additionally, using AR boosts students' motivation to study [49]. Students get interested in studying history because of the novelty of augmented reality technology and more interactive learning opportunities [50], [51]. This encourages pupils to study more and makes the classroom more lively. Students can engage with historical artifacts and sources using augmented reality in ways that are not achievable through traditional classroom instruction. In authentic settings, students can actively investigate historical landmarks, objects, or events [33], [43], [44]. Students may ask questions, engage in active learning, and gain a deeper understanding of historical themes because of these interactive capabilities. Additionally, it aids in the development of critical abilities, including analysis, problem-solving, and reflection.

Our study builds on and extends the findings of previous research on the integration of AR in educational settings. For instance, Challenor and Ma [33] highlighted the potential of AR in general history education through a literature review approach, stressing AR's capability to enhance the visual and interactive learning experience. While their findings are consistent with our results, our research provides a direct experimental confirmation by demonstrating significant improvements in students' historical understanding when AR is specifically applied at Muara Takus Temple. Moreover, Koutromanos *et al.* [34] utilized AR to teach the local history of a Greek island, showing enhanced student engagement and understanding. Our findings align with these results, but further underscore the effectiveness of AR in improving specific educational outcomes, such as historical chronology comprehension and source analysis skills, which were directly measured through pre- and post-tests in our experimental setup.

Additionally, the work of Koti [35] explored AR's impact on developing social and digital skills in secondary education using Design-Based Research. While focusing on different competencies, Koti's findings support our results regarding AR's role in increasing student motivation and interaction capabilities. In our study, AR not only improved historical understanding but also significantly enhanced student interaction with historical content, as reflected in our questionnaire data.

The conclusion that using AR can boost students' interest, motivation, and interpersonal skills is also supported by a number of other studies [20], [46]–[48]. The study's findings demonstrate the critical role augmented reality AR technology plays in producing more engaging and dynamic educational opportunities, which can improve students' comprehension and appreciation of historical topics [24], [33], [44]. AR therefore has the power to transform the way students study history and raise the standard of their historical education.

From the preceding discussion, it can be inferred that the research findings support the notion that AR has enormous potential to enhance students' historical comprehension while boosting their motivation, enthusiasm, and ability to engage with others in history classes. This study contributes to the existing body of knowledge by providing empirical evidence of AR's educational benefits in a historical learning context. Our approach directly compares learning outcomes between a control group and an experimental group exposed to AR, offering robust evidence of AR's effectiveness in enhancing not only engagement and motivation but also deep understanding of historical events and sources.

The inclusion of rigorous statistical analysis, including t-tests and effect size measurements, further strengthens the validity of our conclusions. These methods demonstrate a clear statistical difference in historical understanding post-AR intervention, with our results showcasing a more significant impact than typically noted in literature, thus confirming the unique contribution of AR to educational practices at historical sites. Our research, therefore, not only corroborates earlier studies on the efficacy of AR in education but also expands on them by quantitatively measuring its impact on historical understanding, an aspect less explored in previous research. This focus is particularly relevant for educators seeking to incorporate technology in a way that substantively enhances learning outcomes in history education.

4. CONCLUSION

This study utilized a quasi-experimental design to evaluate the impact of AR on improving historical understanding among students at Muara Takus Temple. The results clearly indicated that the experimental group, which used the AR application, exhibited a statistically significant enhancement in historical understanding compared to the control group, which received conventional instruction. Specifically, the experimental group demonstrated notable improvement in historical chronology understanding, with their test scores increasing from an average of 62.3 to 85.2. This change was significant, evidenced by a t-value of 5.39 ($p < 0.001$, $\eta^2 = 0.50$). Moreover, the AR application markedly boosted student engagement and motivation, enriching their interaction capabilities and deepening their interest in historical content. Additionally, there was substantial skill development, particularly in analyzing historical sources and contexts, which underscored an enriched comprehension of the historical material facilitated by AR. These outcomes suggest that AR technology can significantly enhance the immersive and interactive learning experience, potentially leading to improved retention and deeper understanding of historical knowledge.

However, despite these promising results, the study acknowledges several limitations. The findings, while robust, are specific to the Muara Takus Temple and might not be directly applicable to other historical sites or educational contexts lacking similar AR setups. The sample size, although sufficient for statistical power, is confined to one geographical region. Future research could broaden this scope to encompass a more diverse student body. Furthermore, this study does not explore the long-term retention of the knowledge gained through AR; thus, longitudinal studies could be instrumental in determining the lasting benefits of such educational interventions. The dependency on technology is another critical consideration; the effectiveness of the AR application hinges on the availability of technology and internet access, which could limit its use in less technologically developed areas.

To extend the implications of this study, future research should consider implementing AR in varied historical and educational settings to evaluate its effectiveness across different contexts. Investigating the long-term retention of knowledge acquired through AR will help ascertain its enduring educational impacts. Additionally, developing low-bandwidth or offline versions of AR applications could make this innovative educational tool more accessible in areas with limited technological infrastructure, thereby broadening the reach and utility of AR in educational settings. These steps will help build on the current findings and enhance the applicability of AR technology in history education globally.

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