



Development of augmented reality feature modules on the introduction of historical monuments in Timor Leste

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ABSTRAK

Tujuan dari penelitian ini adalah untuk menghasilkan modul monumen bersejarah yang dilengkapi dengan fungsi augmented reality (AR) untuk siswa kelas IX yang valid/cocok untuk melengkapi pengajaran dan praktis untuk meningkatkan hasil belajar siswa. Penelitian ini menggunakan model pengembangan Lee dan Owens. Persentase hasil yang diperoleh dari validasi ahli media adalah 80%, dalam kategori valid dan layak. Pengetahuan material menyumbang 96,6% dari kelas yang valid dan layak. Siswa dan nilai ujian diterima dengan baik. Sementara itu, siswa yang ditugaskan secara acak mendapat nilai 93% (nilai bagus) dalam ujian mereka. Rata-rata pretest sebesar 90,75% dan rata-rata posttest sebesar 88,1%. Itu menunjukkan n-gain atau difference sebesar 65,52%. Oleh karena itu, dapat dikatakan bahwa terdapat perbedaan yang signifikan terhadap hasil belajar sebelum dan sesudah ujian. Berdasarkan kriteria, termasuk kriteria hasil belajar.

ABSTRACT

This study aims to produce a historical monument module equipped with augmented reality (AR) functions for the 9th-grade gymnasium, which is suitable for supplementing teaching and improving student learning outcomes. The study employed the development model suggested by Lee and Owens. The percentage results obtained through the validation of media experts were 80% of valid and feasible categories. The data yielded 96.6% valid and feasible in categories. The students' test results were well received. Meanwhile, randomly assigned students scored 93% (good grades) in their exams. The average of the pretest was 90.75% and the average of the posttest was 88.1%. This shows a gain or difference (n-gain) of 65.52%. Therefore, it could be claimed that there is a significant difference in learning results between pretest and posttest based on various criteria, including learning outcomes criteria.



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INTRODUCTION

The development of education in the age of the Industrial Revolution 4.0 is a process of shift, where the use of technology has reached the center of the change process in education. According to [Lase, \(2019\)](#), the industrial world needs an education that prepares a competitive, creative, and innovative generation. The world needs to quickly respond to the era of Industrial Revolution 4.0, including East Timor. In response to the issue, teachers must enrich their knowledge and ability to adapt to the challenges and new technologies.

Resources offer innovations designed to facilitate student success in learning. The social media presence can make students interested in learning. According to [Hasan et al., \(2018\)](#), learning media is a tool or situation used as a communication bridge in learning activities. The students must be exposed to necessary sources to be familiar with historical monument materials. This adaptation is expected to give students a broader and deeper understanding. Therefore, students can achieve meaningful learning experiences.

The world of education cannot separate learning and comprehension. Learning integrates new information with comprehension and memory, [Zahro et al., \(2018\)](#). Through learning, students increase their knowledge by integrating current information with their prior knowledge. [Saputra et al., \(2022\)](#) stated, 'Learning is an attempt to learn.' Good learning allows students to form and develop bits of knowledge for the students themselves. Learning in education is limited in space and time. The limitations of space and time make it difficult for students to develop their knowledge and search for new information around them.

[Fayiz et al., \(2020\)](#) claimed, AR is nothing but digital information placed on actual objects, where users can interact with the virtual content of the presence, which separates reality from the virtual world. AR means the ability to seamlessly and dynamically integrate graphics and other multimedia content into real-time camera views on a smartphone or computer. [Yilmaz & Göktaş, \(2018\)](#) proposed that AR represents a technology that combines the real world with virtual objects and provides interaction between real and virtual objects. In other words, a specific signal is captured, connected to a virtual object, and the results are translated into a program based on AR technology. Because it involves virtual objects, it is necessary to distinguish AR from the concept of virtual reality. Objects are displayed in real-time and the environment in AR, while virtual reality objects are displayed in a virtual environment. This feature differentiates AR from virtual reality VR. At the same time, building bridges between the virtual and real world is paramount for AR. In addition, three important characteristics distinguish AR from other technologies. These encompass (1) combining virtual and actual objects, (2) providing real-time interaction, and (3) existing three-dimensional objects. AR is an increasingly popular technology that can be used on desktops in addition to laptops, laptops, and smartphones. Applications developed with AR allow virtual three-dimensional (3D) objects, text, two-dimensional (2D) images, video, and animation to be utilized separately and also provide the same usage. Therefore, users can naturally interact with events, objects, and information ([Yilmaz & Göktaş, 2018](#)).

[Vuță, \(2020\)](#) suggested that AR is the opposite of virtual reality, where existent objects are embedded in a virtual world. AR adds virtual objects to the real world. Thanks to vast technological development, AR can be done feasibly. AR makes it possible to visualize abstract concepts and to understand and model objects. It is widely used today in medicine, image processing, and gaming, but has largely fallen into disuse in the world of education. AR allows users to easily add virtual information to their environment ([Aprilinda et al., 2020](#)).

[Edwards-Stewart et al., \(2016\)](#) stated that AR input technology can be audio or visual. AR improves the understanding of the user and the world. Although AR is often considered a type of virtual reality, it is a technology with unique features and different uses. Virtual reality usually replaces the real world with a simulated world, immersing the user in a replicated or alternate reality. AR enhances the current environment by creating mixed reality rather than replacing it.

AR is the latest technology, reminiscent of Virtual Reality (VR) Paradigm ([Alcaniz et al., 2010](#)). Like virtual reality, AR has several official definitions and classifications. Some define AR as a distinct

case of virtual reality; others argue that AR is a more general term and see virtual reality as a unique case of AR. AR combines three-dimensional (3D) computer objects and superimposes text over factual images and videos in real-time. [Azuma \(1997\)](#) explained a compelling definition of AR as a variation of virtual reality. Virtual reality technology immerses users in a synthetic environment. When immersed, users cannot see the factual world around them. AR, in contrast, allows users to see the world through virtual objects placed on or connected to the real world. Therefore, AR only supplements reality, not completely replace it. With the help of AR applications, it is possible to show users an ordinary space where virtual and real objects live perfectly parallel. From a technological perspective, AR applications must meet three requirements ([Azuma, 1997](#)) as follows: integration of the real and virtual world, real-time interaction, and accurate 3D registration of virtual and actual objects.

[Luckin & Fraser, \(2011\)](#) stated that AR technology seems to provide excellent opportunities to engage learners and enhance knowledge-creation mechanisms. However, few works have undergone formal evaluation resulting in a deep and systematic understanding of how AR can improve learning. While [Wong et al., \(2014\)](#) argued that AR is a technology that augments reality with two- or three-dimensional computer-generated images—CGI, objects, and/or data—and allows users to interact with it ([Azuma 1997](#)). Furthermore, [Carmigniani et al., \(2011\)](#) defined AR as a direct or indirect representation of the real world by adding virtual computer-generated information. AR is interactive and is recorded in three-dimensional 3D format and combines real and virtual objects. Paul Milgram and Fumio Kishino define Milgram and the reality-virtuality continuum between real and virtual environments, consisting of AR and augmented virtuality. AR is closer to the real world, and AV is closer to a pure virtual environment.

[Bottani & Vignali, \(2019\)](#) explained AR as a term to describe a set of technologies that allow you to see your real environment in the form of elements or objects elevated. More specifically, AR describes a mediated reality where computer devices assist in enhancing visual perception of the physical environment. Compared to virtual reality, several technologies allow users to interact with computers in a simulated environment, both the real world and the imaginary one. AR does not attempt to replace the real world. Mixed reality includes AR technology and augmented virtualization.

History is a compulsory subject in the primary school of Ensino Básico 3º Ciclo Privado Cristal Dili. It discusses past events or incidents as a reference and guide for future life. The goal is to shape a collective memory as people who understand the national journey to create a sense of unity. The subject aims to build students' understanding of the past. [LKPP, \(2015\)](#) and [Sihite et al., \(2013\)](#) recognised that learning materials require the application of AR technology. Developing AR requires the necessary 3D (three-dimensional) technologies and models. It entails consideration of several aspects to build an established framework. AR provides learners with fun learning. Advanced AR allows researchers to design and evaluate learning experiences ([Saputra et al., 2022](#)).

[Samsu et al., \(2020\)](#) said that the modules can be systematically and attractively interpreted as learning materials, including material content, and the methods and assessments can be used individually to achieve the expected results competency. Modules are one of the concepts of comprehensively and systematically packaged learning materials, where they include a series of designed learning experiences designed to help students achieve specific learning goals. While, [Rachmadyanti & Gunansyah, \(2020\)](#). carried out research entitled 'Development of Augmented Reality-Based Learning Media in the Digital Systems Course at the Informatics of UNESA.' The research intended to develop an AR book program for digital material systems on the Android platform. The research aims to promote independent learning without constraints of space and time. The research found that AR learning is very eligible and claims to be implemented in learning.

Later, the escalation of research on AR stimulated the organization of several conferences, among others: the International Conferences on the Concept of Augmented Reality, and Conferences on the World of Mixed Reality. Literature published in the 1990s identifies six main areas of possible

AR application: medical field, maintenance/editing, intelligence, robotics, entertainment, and military environment. Several updated visual categories encompass Outdoor, Mobile, and AR Collaboration (Bottani & Vignali, 2019). Furthermore, Bottani & Vignali, (2019) predicted promising growth of AR technology in the next two to three years. Georgel (2011) identified education and entertainment as the exciting categories for AR applications.

Industrial Augmented Reality (hereafter, IAR) describes AR applies. It supports industrial processes and identifies product design, production, assembly, maintenance/inspection, and training as key application areas for IAR. AR technology is one of the best and most intriguing innovations in the world of education. AR combines the real world with the virtual world and adds virtual objects to the real environment. In this context, AR applies to help students understand abstract concepts and visualize learning objects (Setyawan, 2019). Several studies have also shown the effectiveness of AR in learning, including history subjects (Vuță, 2020).

Kamiana et al., (2019) defined AR as a technology that combines the real world and virtual ones, which slants to actual objects rather than virtual ones. Virtual objects, in the form of animation, text, three-dimensional (3D) models, or videos, are co-created in a real environment when the user sees the virtual object in their environment. AR aims to facilitate users by presenting virtual information about both the surrounding environment and a real-time, half-kiel streaming video (Hapsari et al., 2018). Zlatanova, (2002) stated AR is an increasingly in-demand technology. By mixing the virtual world with the real world in different proportions, AR allows an immersion that virtual devices cannot provide. AR systems apply in numerous fields, such as environmental management operation and planning. However, such systems work limitedly indoors and cover a relatively small area. Advancements in computing, vision, and wireless technology made it possible to develop wireless field systems supporting complex analysis, decision, and control processes. Use of such systems in this process. It has two advantages: 1) local data transfer (location-based services) and 2) 2D, 3D geographic data transfer.

The development and the use of AR presentation of historical material monuments is still limited. Using AR in this context should provide students with a fun and engaging learning experience and help them gain a broader understanding of the history of the historical monuments of East Timor. Therefore, the study aims to develop a function module of AR for students of Ensino Básico 3º Ciclo Privado Cristal Dili IX for presentation material about historical monuments to improve learning quality and create more effective and intriguing learning methods.

Based on the points mentioned above, there is a need to develop AR as a teaching tool to present the historical monuments of East Timor through an interactive and easy-to-understand technology of AR that supports information about historical monuments. Create a better way to learn. Powerful, interactive, new, and exciting, this can be a solution to help students learn about historical monuments in a fun way.

The development and application of AR in appointing historical monuments is still limited. AR implementation should provide students with a fun and engaging learning experience. It helps them gain a broader understanding of the history of the monuments of East Timor. Therefore, this research aims to develop an AR function that presents material related to historical monuments to the students of Ensino Básico 3º Ciclo Privado Cristal Dili IX to improve the quality of learning and create more effective and engaging learning experiences.

METHOD

This R&D model uses the model of Lee and Owens because it has relevant steps to multimedia development. The model has five phases, i.e., analysis, planning, development, implementation, and evaluation phase (Hapsari et al., 2018). Figure 1 shows the steps involved in this research.

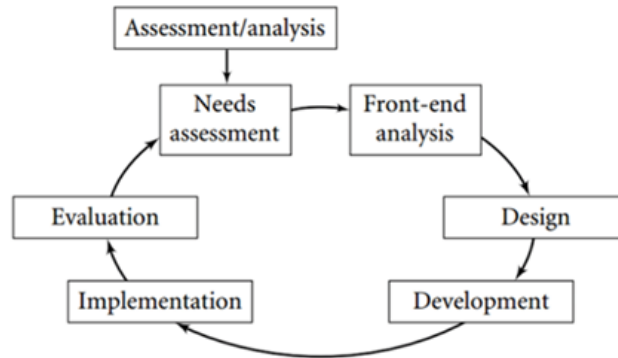


Figure 1. Lee & Owens development model (Lee & Owens, 2014)

These steps are not absolute to completely follow. The developer can adapt the steps based on the conditions prevailing in the field. It is the most suitable stages for the study can be naturally chosen and determined based on the circumstances encountered in the development process. Therefore, the study takes three steps in the model due to time, cost, and power constraints. In this way, developers take only three steps: analysis, design, and development. It is described in the [Figure 2](#).



Figure 2. The performed stages

Analysis

This stage is the first step in development. There are two steps in the phase: needs assessment and front-end analysis.

Needs analysis

Needs analysis is conducted before production activities are carried out. Needs are the gap between the desired learner and his current skills, abilities, and attitudes ([Sumardani et al., 2020](#)). At this stage, the developer conducts a preliminary survey to determine the field conditions. The first study was conducted through interviews with high school students of the Ensino Básico 3º Ciclo Privado Cristal Dili. Field conditions indicate that only learners use slides to explain existing material. In addition, students also take the material via the Internet, which is why it does not correspond to the competence to achieve. Therefore, it is difficult for students to understand the material presented. Based on the results of the above findings, it can be concluded the students of Ensino Básico 3º Ciclo Privado Cristal Dili IX institute need attachments to explore historical monuments using AR.

Initial and final analysis

Preliminary analysis is a technique used to analyze collected data and information, after which it determines which data and information will be used in development. This previous analysis phase has several functions, including analysis of audience, technology, situations, tasks, issues, milestones, goals, media, data, and costs. However, developers only do individual analyses other than cost analysis because they are not directly related to learning. The following are the results of analyses based on field observation activities.

Based on audience analysis, the developer targets Grade IX junior high school Ensino Básico 3º Ciclo Privado Cristal Dili with 23 students. According to the findings, the average child of class IX can use a smartphone. Analysis of this situation in the teaching and learning of Ensino Básico 3º Ciclo Privado Cristal Dili went well. The learning environment in this school is comfortable and supportive. The relationship between teachers and students is good. Teachers and students have sufficient

technical knowledge. No major obstacle was found, so the implementation of AR was successful.

Analyzing the assignments, the students get the apps and modules shared by the developers, and then the students install the app on their smartphones. After that, students can use the installed app by scanning the QR code on the module. With this program, students expect to understand the material of historical monuments better. Based on the problem analysis and identification during the observation of junior high school Ensino Básico 3º Ciclo Privado Cristal Dili, the developer did not find problems in the development of AR function modules, but still needed the help of teachers to keep the students under control. Based on the above analyses, it was concluded that the proper media image complements the AR modular function. The content or content of the media is central to this development. The content of this media is in the form of objects, monuments, and information.

Design

The design phase is the design phase of the product or environment, according to which the development is carried out. (Sumardani et al., 2020) described the planning phase carried out several activities, including a schedule of activities and project team, Media specification, Content structure (Lesson Structure), and Configuration Control. The material presented in the function module of AR is related to social sciences, and the material on the presentation of historical monuments with functions of AR for the IX class high school. In addition, product design includes module production, planning, application, and content structure creation.

Development

At this stage, different skills are necessary to develop a digital product and, of course, in this development, AR capacity in the form of a historical monument module. In this stage, the design analysis and the identified activities were carried out, including product prototype, user interface design, buttons, images, continuous product evaluation, and verification. This step is done to evaluate whether the produced multimedia is suitable for use or not to obtain the materials for the production version. Interactive multimedia testing by media and material experts to find bugs in the developed product. The developer continuously checks the product if she finds defects.

The next step is to test the validity of the learning environments. Media and property experts carry out media verification. Selected media experts are teachers from the Department of Educational Technology with diplomas in graduate school. The experts master the knowledge, skills, and experiences focused on developing educational media. The material expert is a lecturer at the Institute Superior Cristal Dili, who has a diploma in educational technology and teaches historical subjects related to historical monuments.

RESULTS

The initial development result is a historical monument module with AR features placed on the image of the monument with additional annotations or signs and displaying historical information about the monuments. In addition to the modules, other development products are AR technology applications with product usage instructions and labeling on the integrated modules. Reminders are made when the AR application detects characters on the module. Once the AR app recognizes the brand, the product is ready to use. The displayed information corresponds to the signs of the module (see [Figure 3](#) and [4](#)). Pressing the information button displays the history information shown in [Figure 5](#).



Figure 3. Marker modules



Figure 4. The smartphone is directed to the marker



Figure 5. Monument information display

The process of data analysis is carried out after collecting all the necessary data. This data analysis is needed to produce high-quality AR based educational media that meet the criteria of validity, effectiveness, appeal, and practicality. There are instructions in the classification table to convert the average score obtained in the evaluation of AR learning media for the history subjects of IX high school students into quality grades Lolowang et al. (2017) used as in the Table 1.

Table 1. Instructions for converting average scores for each aspect as qualitative data

| Scoring range | Criteria |
|--------------------------|------------|
| $\bar{x} > 4.2$ | Excellent |
| $3.4 < \bar{x} \leq 4.2$ | Good |
| $2.6 < \bar{x} \leq 3.4$ | Sufficient |
| $1.8 < \bar{x} \leq 2.6$ | Not good |
| $\bar{x} \leq 1.8$ | Very bad |

The data analysis phase describes information obtained from experiments and data analyses obtained from media experts, material experts, and respondents. Media expert test data was obtained from one educational media expert, namely a lecturer in the Department of Educational Technology, at Malang State University. Experimental data on the distribution of material experts was obtained from a single material expert S2 educational technology lecturer at Instituto Superior Cristal Dili. The student respondents were 23 IX class students. Data analysis by media experts, i.e., lecturers on educational technology, gave 80% of the result. Based on the established criteria, it can be explained that the development of historical modules with AR historical material IX school Ensino Básico 3º Ciclo Privado Cristal Dili belongs to the valid criteria and is worth studying.

Results of data analysis performed by material experts S2 Educational Technology Lecturers of the Cristal Dili Higher Institute were 96.6%. Based on the established criteria, it can be explained that the development of historical modules containing historical material of AR for the IX high school belongs to the valid criteria and is suitable for learning. Escola Ensino Básico 3º Ciclo Privado Cristal Dili IX grade audience/student data analysis in field tests gave an 88.1% result (see Figure 6). Based on the established criteria, it can be explained that the development of historical modules containing the material of the AR historical monument for the class IX Junior High School belongs to the valid criteria and is suitable for use in teaching.

Validation results from media experts show that the total score of the 15 statements of the existing validation tool form is 80. The evaluated aspects are media quality aspects, technical quality aspects, and display aspects. The product version is the outcomes from data analysis by media and material experts and the results of audience testing of electronic games, which have been validated so that the product is complete and more effective for learning.

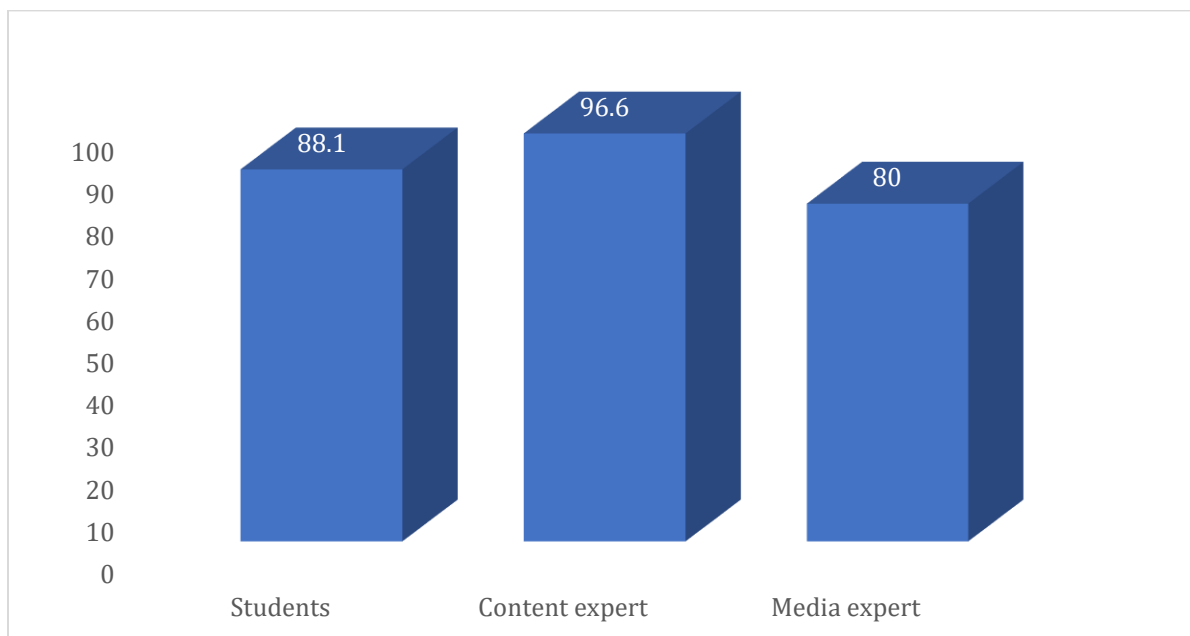


Figure 6. Validity test analysis results

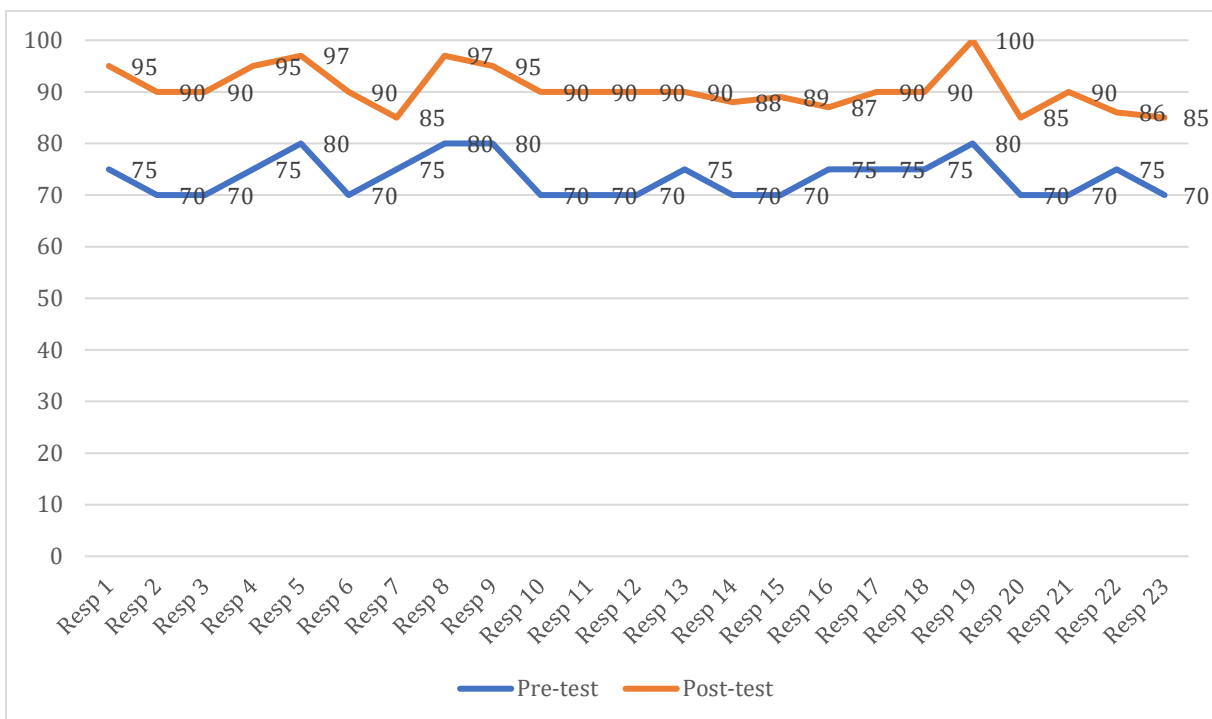


Figure 7. Pre-test and post-test results data

Media experts responded that without the background of AR objects, the historical monuments displayed can limitedly be seen from one side. They add Video cannot be played on mobile devices. The experts suggest explaining the text and giving clear instructions in the language of communication, so students can easily understand it in the learning process. The request to use the Indonesian language in filling out the questionnaires needs direct assistance based on responses from material experts because both teachers and students still have problems with the use of the Indonesian language both in oral and written form.

The media developed to present historical monuments equipped with AR functions received validation results from 80% of media experts, 96.6% of material experts, and 100% of public tests. In conclusion, AR has evolved a function history module that is feasible and effective, increases students' understanding, and makes students more active (Kartika et al., 2022). The effectiveness of the proposed multimedia product is confirmed by the tests carried out on Flickr (Saifudin et al., 2020).

After the experiment, students' pretest and posttest scores improved (see Figure 7). The criteria show historical monument utilizing AR is considered effective and can increase students' understanding of historical material in the learning process. Twenty-three students showed improvement in their pre-and post-exam results in history subjects. The conclusion is that students' understanding of the learning process increases. Meanwhile, most students prefer to access the app via smartphone for convenience reasons. This application raises students' engagement in the learning process. Overall, the study found the success of AR-based learning interventions depends on several factors, such as learner characteristics, technological stability, and content compatibility. Below are implications for future practice and research (Hakim et al., 2021).

DISCUSSION

Devices such as smartphones are chosen to access educational media for several reasons including device penetration, the number of smartphones, and accessibility (Hapsari et al., 2018). The AR technology used to develop this resource is marker-based AR technology, or marker, that is, to see virtual objects in the form of 3D monument models. This application must have the objects of

the marker image scanned by the smartphone camera. Characters are invited. With existing marker-based AR technology, a given object can be loaded onto the screen by only one character, and another character must be added to display it again on the same object screen. This situation creates a problem where the relevant characters must be extracted and printed on the screen (Adami & Budihartanti, 2016). Using AR technology to develop educational media offers a different experience for teachers and students. AR can be used to bridge the gap between hands-on learning and theoretical practice by combining real and virtual components to create a unique learning experience. A systematic review of research and applications has identified the use of AR in education is effective for several purposes, such as improving learning, facilitating learning, engaging students, and promoting positive attitudes Lolowang et al., (2017). Virtual learning experiences are not simply about acquiring knowledge so learning environments must be designed in a constructed way to get the full benefit of learning.

This study aimed to develop an AR history module for historical monuments in East Timor. The study found that the actual results and strengths achieved 96.6% agreement with the empirical results provided by the material experts. In measuring the practicality aspect, individual tests, group tests, and field tests were conducted. The analysis results of which showed percentages of 93%, 90.75% - 88.1%. Generally, modular products of historical monuments with AR functions are considered convenient to use in educational activities.

The results also show that implementing a history module with AR functions increases students' understanding of the material of the historical monument. This can be seen in Student N-Gain value analysis results in learning results as high as 0.65 and the efficiency percentage is 65.52, which is classified as 'quite effective.' Moreover, from the t-test results obtained, $\text{sig } 0.00 < 0.05$ means that the use of AR features in history modules affects students' learning outcomes. The result is harmonious with the findings gained by Mustaqim et al., (2016). He implemented AR to promote critical thinking about problem-solving. In addition, Aprilinda et al., (2020) in her study found advanced AR improves students' material understanding. AR application in learning media offers a different experience for both teachers and students. Bloom & Reenen, (2013) described AR functions to bridge the gap between real-world learning and virtual learning. The process combines real and virtual elements to create a unique learning experience. A systematic review of research and applications found that AR application in learning serves many purposes, including improving learning outcomes, motivating learning, student engagement, and positive attitudes Setyawan, (2019). According to Bloom & Reenen, (2013), the limitation of using VR or AR technology in educational settings is not the application but how students behave towards the app. Virtual learning experiences do not necessarily stop at the process of acquiring knowledge. Therefore, the constructivist approach is suitable to design the learning environment to pursue meaningful learning.

Learning modules of historical monuments with AR functions can be used anywhere and anytime. The students' perceptual data show that learning with the historical monument modules equipped with AR functions is very fun, easy, appealing, and suitable to use as a technology that facilitates independent learning for students. Learning through historical monuments modules with AR functions can also help increase student motivation and understanding of East Timor's historical monuments. Thus, it can be concluded that the development of historical monument modules with AR functions is effectively and efficiently used in learning history subjects.

CONCLUSION

The development of modular products for historical monuments with AR functions does not exclude the possibility of further research exploring the topic. However, the analysis of learning problems should consider the needs of the field and learning objectives. The historical monument module product with AR features developed in this study could not meet the general advice of serious experts, such as adding manuals and learning activities to problem-solving. Obstacles found are as follows: unfamiliarity with the use of AR, the technical characteristics of smartphones, such as limited RAM capacity, smartphone absence, and poor network connections. Accommodating the condition,

printed modules and assignments are needed. The limitation in strong and stable network connection hinders the researcher from following the suggestion of developing a sophisticated product because the students will find it hard to use the app with AR due to the poor connection. Field tests also showed that students disapproved of the materials. Upon examining the first module test, it became clear that they were indifferent to reading because the given material had too many words, so it was tiring for the students. Further research offering solutions to the obstacles mentioned above, especially in the field of historical modules, is anticipated.

Author contributions

The authors made significant contributions to the study's conception and design. The authors were in charge of data analysis, interpretation, and discussion of results. The final manuscript was read and approved by the authors.

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Conflict of interest

The authors declare that there is no potential conflict of interest.

Data availability statement

All data are available from the authors.

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