Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 5, 2027-2045
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i5.7371

Augmented reality laboratory: Improving students' interest in social science learning

Abdul Bashith[1*], Saiful Amin[2], Lusty Firmantika[3], Muchammad Akbar Kurniawan[4], Idris[5]
[1,2,3,4]Universitas Islam Negeri Maulana Malik Ibrahim Malang, Malang, Indonesia; abbash98@pips.uin-malang.ac.id (A.B.).
[5]Universitas Negeri Malang, Malang, Indonesia.
[5]Chung Yuan Christian University, Taoyuan City, Taiwan.

Abstract: The Augmented Reality (AR)-based social studies laboratory is a vital tool for improving learning, especially in training and practical environments, to aid students. This study focuses on: (1) creating an AR-based social studies laboratory product; (2) evaluating the feasibility of the developed AR-based social studies laboratory product; and (3) assessing the influence of the AR-based social studies laboratory product on students' learning interest. The research adopts a Research and Development (R&D) methodology, using the Borg & Gall development model. A one-group pretest-posttest design is employed to gauge the effect of the AR-based social studies laboratory on learning interest. The product was tested with students and lecturers from the Social Studies Education program at three Islamic state universities in Indonesia. The results indicate that: (1) the AR-based social studies laboratory was developed through an 8-stage process using the Borg & Gall model; (2) the AR-based social studies laboratory is both feasible and effective for educational purposes; and (3) the AR-based social studies laboratory significantly boosts students' learning interest. Future researchers are encouraged to expand on this study by exploring additional materials or topics not covered here, such as developing virtual reality (VR) applications, to further improve the learning experience.

Keywords: *Augmented reality, Laboratory, Social science Learning, Students' interest.*

1. Introduction

The laboratory is a valuable educational tool, for example, in university social studies. The laboratory is an auxiliary tool for developing students' scientific competences by engaging students in practical, exploratory activities, as well as in the discovery and collection of information to increase their knowledge regarding social and environmental phenomena [1]. Moreover, laboratories provide a site for scientific research, experimentation, measurement, and training, all of which are required to achieve knowledge in numerous fields [2].

The social studies laboratory serves as a vital educational resource designed to connect abstract concepts with real-world events [3]. Social studies is a multi-disciplinary subject that brings together economics, history, geography, and sociology [4]. Its instructional approach lies in the social sciences, which examine society and how it cooperates with the environment [5]. Therefore, social studies is a field of study that needs adequate facilities and infrastructure, e.g., laboratories, to support effective learning [6].

The social studies laboratory should be a very potential environment for practicum and training that will enable learners to feel learning, broaden their views, and gain special abilities. Through these, they become adept and competent in the field of social studies. However, it is not easy to develop a social studies laboratory, because there are several obstacles. Research results Putri and Rizki [7] explained the obstacles in providing social studies laboratories, namely 1) social studies laboratories have not been made a priority scale; 2) creating social studies laboratories demands significant financial resources; 3)

History: Received: 3 March 2025; Revised: 28 April 2025; Accepted: 1 April 2025; Published: 20 May 2025
* Correspondence: abbash98@pips.uin-malang.ac.id

for institutions with limited space and land, it is a separate obstacle; and 4) requires special social studies laboratory staff who know about social studies laboratories. Based on study Septiandini [8] concluded that the obstacles faced in providing Social Sciences Education laboratories can be limited land, limited funds, perceptions of school personnel, and government regulations. In addition, in reality, the existence of Social Sciences Education laboratories has not received full attention and its use has not been optimal due to limited resources to handle it and lack of financial support from institutions [9, 10].

For resolution of the problem of establishing social studies laboratories with ease, developing virtual laboratories provides one possible measure. This sensible approach is planned to meet demands of 21st-century education skills for pupils, particularly the students of social studies who aspire to become future teachers and also belong to the digital-native population [11]. Students in the 21st century need to develop four key competencies: creativity, communication, collaboration, and critical thinking [12].

The integration of technology in virtual social studies laboratories enables students to more easily grasp learning materials, solve problems, communicate effectively, and collaborate with others [13]. Students, as a digital generation, have shown the ability to embrace the advancements in virtual laboratories. This is consistent with the findings of Setyawan and Wijayanti [14] which indicate that the majority of students hold a positive perception of virtual laboratories. Almost all students gave a positive perception on the aspects of innovation, motivation, benefits, effectiveness and presentation of practical procedures. Furthermore, Kurniawan, et al. [15] emphasized that an online questionnaire of 140 students identified a need for an application with high-end, real-world-like capabilities to aid in learning likes 360-degree Virtual Reality Panorama, Augmented Reality, a chatbox, and multimedia resources.

This study builds on that of Bashith and Amin [16] whose objective was to design a field laboratory from mobile learning. The findings indicated that mobile learning-based virtual field laboratory media is highly feasible for social studies learning with an 88.27% feasibility value (very effective category). Media developed has also been effective at enhancing students' learning achievements within the Study Program of Social Studies Education. Results agree with a study conducted by Al-Nakhle [17] Al-Nakhle; Erdoğan and Bozkurt [18] and Sasmito and Sekarsari [19] whose results support the fact that electronic field laboratories could successfully enhance scholarly performance. Virtual field laboratories not only enhance learning outcomes but also strengthen students' comprehension and proficiency in information technology [20].

The virtual laboratory created by Bashith and Amin [16] has a limitation in its content, as it is only viewable in 2D. The suggestion in the research is to develop a 3D virtual laboratory, so that it is as if students can learn the material in the real world. Hence, there is a need to create a Social Studies (IPS) laboratory based on Augmented Reality (AR).

Augmented reality integrates real-world settings with digital virtual components, such as text, 2D images, 3D models, audio, visual enhancements, and other sensory elements [21, 22]. AR has the capability to merge real-world objects with virtual-world elements, creating an immersive virtual laboratory experience [23]. The application of AR in virtual laboratories offers advantages for both interactive and authentic learning resources, as well as hands-on student learning experiences. In line with Monita, et al. [24] which explains that augmented reality is interactive, allowing students to see situations realistically and directly and imagine the results of the learning process that lecturers offer to students.

The incorporation of AR in creating social studies laboratories is driven by its significant benefits for enhancing the learning experience. Empirically, AR-based laboratories can 1) improve learning outcomes [25-27] 2) improve conceptual understanding [28] cognitive understanding [29-31] and scientific understanding [32]; 3) increase knowledge [33] and academic achievement [34]; 4) improve thinking process [33]; 5) improve laboratory skills [35, 36]; 6) reduce anxiety and increase intellectual accessibility [37]; 7) increase enthusiasm or interest in learning [33, 38, 39] and motivation to learn [30, 40, 41].

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 5: 2027-2045, 2025
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Several researchers have carried out studies centered on the creation and advancement of virtual laboratories namely, Adi, et al. [42]; Elisa, et al. [43]; Jaya [44]; Kholifa and Suswanti [45]; Koretsky, et al. [46]; Kusumaningsih, et al. [47]; Oidov, et al. [48]; Sirajudin, et al. [49]; Tüysüz [50]; Wahyuni and Atun [51]; Wijayanto, et al. [52] and Wulandari, et al. [53] . Generally, AR technology designed for educational purposes remains confined to specific subjects and has not yet been widely implemented in social studies education. This study focuses on creating an augmented reality (AR)-based social studies laboratory that can be comprehensively utilized within State Islamic Religious Universities. Moreover, the use of AR in social studies education remains relatively limited. As a result, this study introduces an innovative and alternative model for advancing educational technology. The main objective of this study is to create an AR-based social studies laboratory as an innovative learning resource designed to boost student engagement and foster a greater interest in learning. Research is crucial as AR offers numerous advantages, such as enabling students to interact virtually with learning materials and providing a more immersive educational experience [54, 55]. Additionally, this innovation can act as a strategic method for improving the quality of social studies education in Islamic religious universities.

2. Literature Review

2.1. Social Studies Laboratory

In Latin, laboratory means "place of work". This workplace is devoted to the purposes of learning and scientific research. Work activities in the laboratory such as conducting experiments and investigations related to the exact sciences or other fields of science Emha [56]. Sutara and Sahromi [57] stated that learning in the laboratory is carried out by students for experimental or research observations.

In essence, the laboratory means a place to work, broadly speaking, in addition to being carried out in the room but also in open areas such as certain nature. In the field of natural science, most of the practicum is done indoors. Forms of development in the application of natural science, practicum can be done outdoors. For example agricultural science, animal science, fisheries science and so on. Practicum in the field of social science and its applications, should be carried out outdoors which places the community as the main laboratory.

Indoor laboratories in universities are used as a means of learning, especially in the fields of natural science and technology. The learning is to train and improve students' skills in using laboratory equipment and making observations. Learning with an experience approach like this can encourage students to develop knowledge and skills. Knowles [58] says that the student learning approach has several characteristics, namely: 1) self-directed learner, namely students are able to organize and manage academic and non-academic activities. 2) Life experience and knowledge, namely students have experience in learning, so that they can increase their knowledge and skills. 3) Goal oriented, namely students have goals in their learning in a directed manner. 4) Relevance oriented, namely student learning orientation has relevance to the material being studied. 5) Problem solving oriented, is student learning is directed to be able to solve everyday problems.

Social studies laboratory is a place/location of practicum activities that are important and functional as a buffer of teaching and learning to meet competency standards. Social studies laboratory developed based on the competence of mastery of the field of social studies, such as subjects: geography, sociology, anthropology, history and economics [59]. This social studies laboratory has a function in the form of space to carry out trials or research and learning in implementing lecture materials in the classroom.

Social studies laboratory has a role as a place of supporting activities of class activities [60]. Further said that the function of social studies laboratories, namely 1) provide completeness between theory and practice; 2) provide scientific skills; 3) provide the courage to find the true truth scientifically in objects in the natural and social environment; and 4) instill confidence in the skills acquired during the learning process in the laboratory.

Edelweiss Applied Science and Technology
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2.2. Augmented Reality (AR)

Augmented reality is a combination of the virtual world and reality created by computers. Virtual objects can be text, animation, 3D models or videos that converge with the real environment, so that users can feel virtual objects are in the environment [61]. Augmented reality can directly or indirectly display real-world images that are added with information through computer visualization [62]. According to Azuma [63] there are three principles of augmented reality, namely 1) merging the virtual world with the real world; 2) running interactively in real time; and 3) there is integration between objects in three dimensions, namely virtual objects integrated in the real world.

Furthermore, Schmalstieg and Hollerer [64] explain that augmented reality is a variation of Virtual Environment (VE) or Virtual Reality (VR). Virtual reality technology seems to make users in a virtual environment. Virtual environment or virtual reality cannot see the real environment. In contrast, augmented reality places digital or computer information, such as images, audio, video, or haptic sensations, in the environment in real-time [65]. Augmented reality allows users to see the real world with virtual objects integrated or combined with the real world [66].

There are four platforms commonly used in augmented reality, namely computers, kiosks or window displays, smartphones, and AR lenses. Nistrina [67] explained that smartphones are the most widely used method to access augmented reality content. Smartphones can not only use their cameras and screens to identify designated markers, but can also use GPS and compass functions to add locations or points of interest based on relative location. In addition, Nistrina [67] puts tablet computers into the category of platforms that are often used in addition to smartphones because they have HD cameras and GPS capabilities.

One of the goals of Augmented Reality is to help users connect virtual information to the user's mind environment more easily, just like watching live video and to deepen the user's thinking and communicate with the real world [68]. In other uses, AR enhances thinking through the appearance of virtual objects that go beyond the real world. AR not only adds virtual objects to the real world, but also shows how digital data is used in the real world [69].

The use of educational media using augmented reality can stimulate students' thinking to think critically about problems and events that occur in everyday life, because the nature of educational media is to help students in the learning process regardless of the presence or absence of educators in the education system [70, 71]. So that the use of educational media with augmented reality can provide learning wherever and whenever students want to carry out the learning process. AR Learning Media can visualize abstract concepts for understanding and structure of an object model, making AR a more effective media in line with the objectives of learning media [72].

2.3. Learning Interest

Interest is an encouragement within a person so that they are interested in doing activities that are profitable, fun and ultimately bring satisfaction to themselves [73]. Another opinion related to interest is busy, interested, involved with an activity because they realize it is important [74]. Interest makes a person take action to achieve what is desired or goals [75]. The term interest is widely used in various fields, but in this study it is more directed at learning in college. Student learning interest is one of the supporters of achieving learning goals [76]. Interest arises because of the desire of students to know and understand something. Students who have interest will be encouraged to be more serious in learning, able to think critically, creatively and innovatively [77]. Students also feel happy and diligent in learning. This does not happen to students who are less interested in learning. Students tend to be resigned, apathetic, lazy and even forced to learn. Therefore, interest in learning affects learning objectives. Students who have a high interest in learning will try to get the best results. This statement is in line with Clayton Aldelfer's opinion that interest in learning tends to encourage students to carry out learning activities seriously in order to get the best results [78, 79].

Interested students will do their best activities, while without interest it will not be possible to act properly [80]. Students carry out learning activities without waiting for orders [81]. This is done

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because students feel happy in learning and the results are also more optimal [82]. If students feel less interested in learning, the results are also not optimal [83]. High learning interest affects learning outcomes and also affects the goal. Good learning interest will help students improve learning outcomes and achieve real learning goals [84]. Student learning interest can be seen from its indicators, namely indicators: feelings of pleasure, interest, attention and involvement [81, 85-89].

3. Methods

The present study adopts the Research and Development (R&D) methodology, using the development model proposed by Borg & Gall. Borg & Gall's development process has been streamlined into eight stages: 1) preliminary research; 2) product design; 3) product testing; 4) small-scale trials; 5) product amendment; 6) product finalization; 7) experimentation tests; and 8) product dissemination [90]. The development of this AR-based social studies laboratory product is facilitated by technologies such as Flutter and Unity 3D, which will be utilized to create AR-based learning media in the form of a virtual social studies laboratory. To assess the effect of the AR-based social studies laboratory on enhancing students' learning interest, a quasi-experimental design was implemented, specifically the one-group pretest-posttest approach.

The viability of the AR-based social studies laboratory was determined through feedback and evaluation provided by validators. Validation was carried out using subject matter experts in social studies and learning media experts. The product was tested with students and lecturers at three Islamic state universities in Indonesia: Universitas Islam Negeri (UIN) Imam Bonjol Padang, Universitas Islam Negeri (UIN) Maulana Malik Ibrahim Malang, and Universitas Islam Negeri (UIN) Mataram. The selection of trial sites was determined on three factors: 1) geographical distribution of the Social Sciences Education programs to the western, central, and eastern regions of Indonesia; 2) the fairly long establishment of the Social Studies Education programs; and 3) whether or not the Social Studies Education programs have been accredited. Data collection occurred in the period of the academic year 2023/2024 – 2024/2025.

The product development assessment instrument used a questionnaire with a Likert ranging of 1 (strongly disagree) - 5 (strongly agree) and documents. In an effort to collect data for formative evaluation purposes, the following instruments were used: (1) to revise the product from the validator using a questionnaire, (2) to assess the quality of the product using a questionnaire, (3) to evaluate the material scope by analyzing documents such as literature reviews, including books, laws, and scientific articles. The instrument to assess students' interest in learning used a questionnaire using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The form is a statement consisting of 20 items based on indicators: feelings of pleasure, interest, attention, and student involvement in learning using an AR-based social studies laboratory. The validity analysis of the learning interest instrument indicates that all statements are valid, with r-count values exceeding 0.3338. Additionally, the reliability results demonstrate values above 0.6, with a Cronbach's alpha of 0.772.

Qualitative descriptive analysis was employed in evaluating social studies content experts, learning media experts, and small trials involving students and lecturers. The information, such as input, feedback, criticism, and suggestions for improvement from questionnaires, was used to modify the AR-based social studies laboratory product. Quantitative analysis utilized descriptive statistics in the form of percentages to review the data, with criterion scores measured in the form of a Likert scale. In addition, inferential statistical analysis was performed for the assessment of the impact of the AR-based social studies laboratory on students' interest in learning. This included statistical analyses such as normality tests, homogeneity tests, and paired sample t-tests, conducted using SPSS 23.0 for Windows at a significance level of 0.05.

The development of the 3D model of Bromo-Tengger-Semeru National Park was carried out using Unity 3D software (see Figures 1 and 2). Unity 3D was chosen for its ability to manage triangle (tris) and quad based modelling, with quad being used in this project due to its advantages in maintaining a cleaner model structure and providing more optimal mesh division. The production process in this stage

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 5: 2027-2045, 2025
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is very complex and takes a considerable amount of time. This was due to the high level of detail in each building structure as well as the large number of models that had to be incorporated into the application. Each model was developed taking into account various important characteristics, including lighting, materials, placement in the scene, and textures, to ensure an optimal level of accuracy and realism. Once the 3D models were created, the next stage was integration into the Flutter-based app. At this stage, the models that have been developed in Unity 3D are exported in a compatible format, and then incorporated into the Flutter project to support the development of interactive applications.

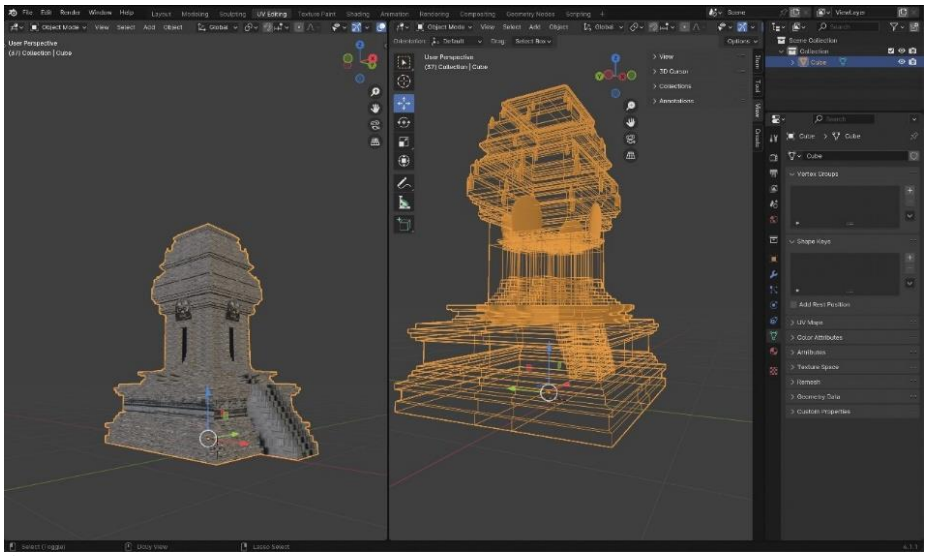

Figure 1.
Rendering process of Kidal Temple, Indonesia

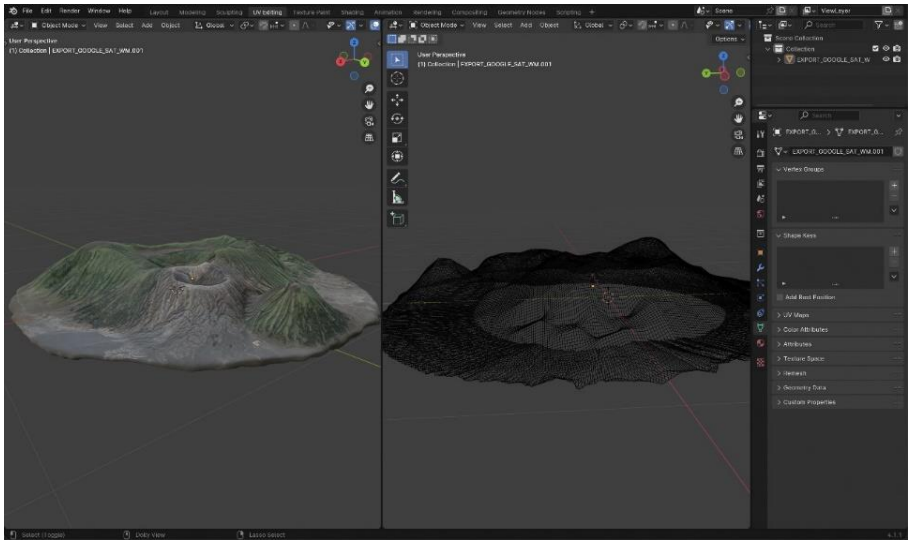

Figure 2.
Rendering process of Bromo Mountain, Indonesia

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 5: 2027-2045, 2025
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4. Result and Discussion

4.1. Social Science Laboratory Products Based on Augmented Reality

The overall design requirements for an augmented reality-based social science laboratory product include: (1) minimum smartphone specifications, the minimum operating system (OS) to run the application is Android 10. (2) Storage, this application has a size of 28 MB which can be installed directly to the smartphone's internal or external storage media. (3) Software, the development of this application uses Flutter and Unity 3D software (Link: https://play.google.com/store/apps/details?id=com.digilab.ar_sites_app&pcampaignid=web_share).

The product specifications for the augmented reality-based social science laboratory are described as follows. Application opening screen image. Register/Sign Up then Login to enter the Main Menu of the application (Fig. 3). Users can go to the Menu consisting of About, Site, Assignments & Quizzes, and Developers (Fig. 4). Each sub-menu can be pressed. Users can click on the Site and select the location of the social science learning material (Fig. 5). This material is equipped with a summary of the material and AR regarding social studies learning. Especially students, can press Assignments and Quizzes to work on assignment worksheets (Figure 6). Users can visit the Developer menu and click on one of the photos to see the biography of each developer.

Figure 3.
Login Main Menu

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Vol. 9, No. 5: 2027-2045, 2025
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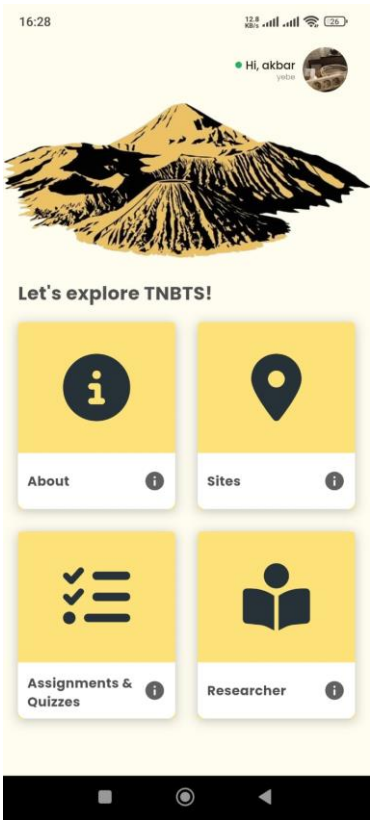

Figure 4.
Sub Menu.

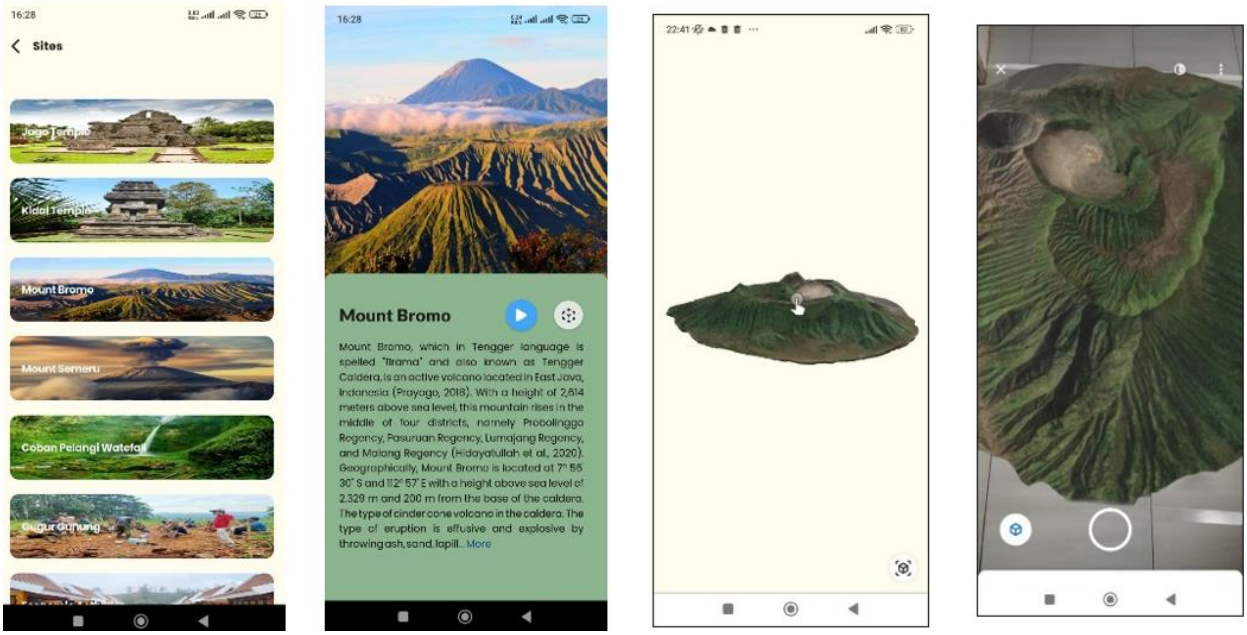

Figure 5.
Sites.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 5: 2027-2045, 2025
DOI: 10.55214/25768484.v9i5.7371

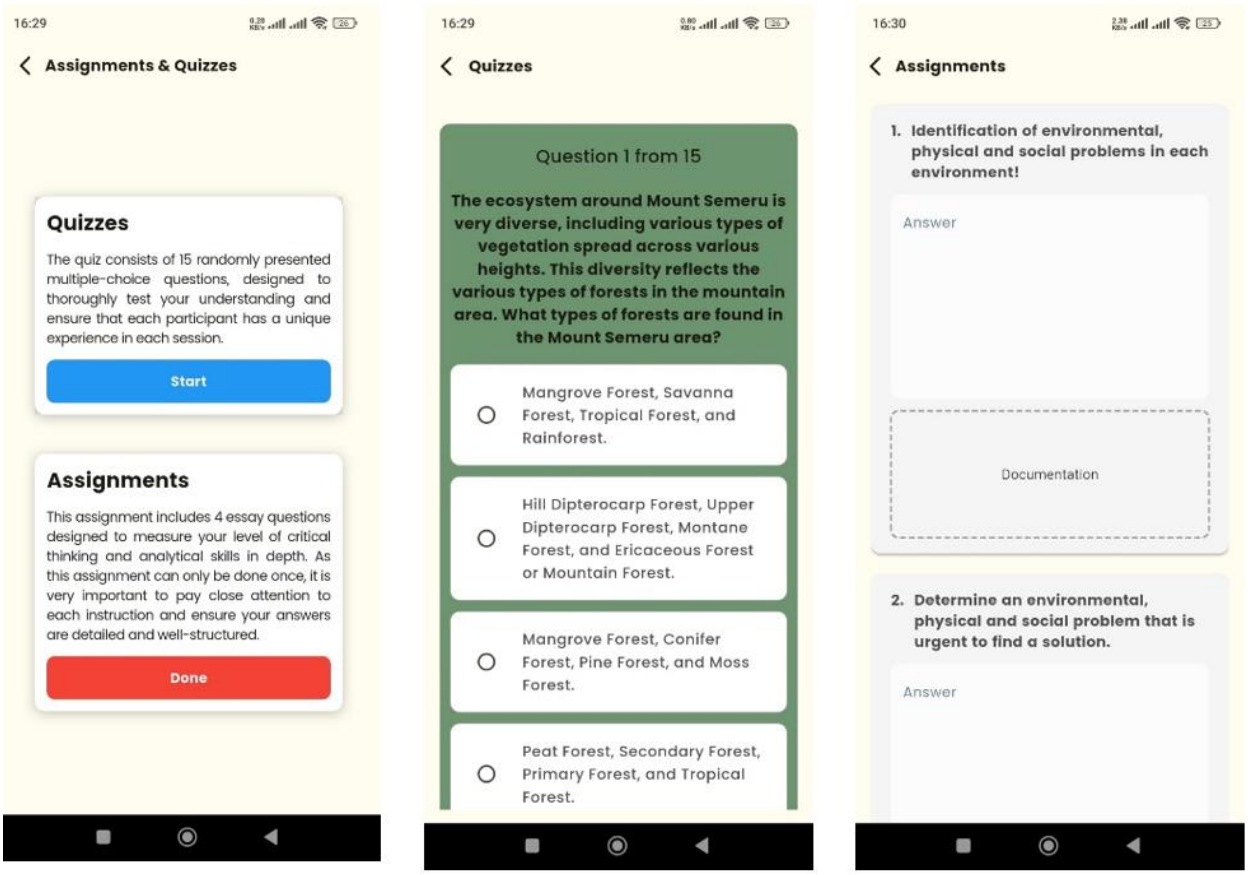

Figure 6.
Assignments and Quizzes.

4.2. Product Eligibility

The collected data consists of information obtained through the following phases: (1) validation data provided by material experts; (2) validation data from media experts; and (3) results data gathered during the field trial. In the stage of validation, each expert received an assessment instrument and the social studies laboratory media product based on augmented reality to be assessed. They were asked to score based on what they know, and the maximum obtainable score is five (5) and the minimum one (1).

In order to measure the feedback and sentiment of each validator, a response questionnaire with varying question numbers was utilized. For this social studies lab media utilizing augmented reality, the questionnaire contained 16 questions for social studies content experts, 16 for media experts, 15 for students, and 15 for lecturers

4.2.1. Subject Matter Expert Validation

The data gathered from the material expert included quantitative data, represented by scores from the questionnaire assessment on a scale of one (1) to five (5). Additionally, qualitative data, comprising comments and suggestions for the augmented reality-based social studies laboratory media, was collected using the same questionnaire. The following are the stages carried out in the field. The augmented reality-based social studies laboratory media developed along with the questionnaire were given to material experts on Friday, July 5, 2024. After being given, the material experts were given time to assess and respond to the contents of the augmented reality-based social studies laboratory

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ISSN: 2576-8484
Vol. 9, No. 5: 2027-2045, 2025
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media based on the questionnaire questions. The next stage was to improve the augmented reality-based social studies laboratory media based on comments from material experts.

The percentage response rate, as per the quantitative analysis of the questionnaire by material experts, was 88.75%. The percentage rate demonstrates that the augmented reality-based social studies laboratory media product meets the required standards and falls into the highly effective category. Although it is not mandatory to make changes, the researcher rewrote the product including the suggestions and comments of subject matter experts in order to reach its perfection and refinement.

In addition to quantitative data, there is also qualitative data, namely in the form of comments. Each questionnaire compiled by the researcher has a comment column provided specifically for material experts to provide responses to the existing augmented reality-based social studies laboratory media. Comments from material experts, namely 1) the examples given should be up to date and 2) student performance sheets can use problem solving to foster work ethic. Based on several comments, the researcher made improvements according to suggestions and responses from material experts. In addition to referring to written suggestions, they also coordinated with material experts to revise the material.

4.2.2. Media Expert Validation

The data obtained from media experts were in the form of quantitative data, namely questionnaire assessment scores in the form of answer choices between one (1) to five (5). In addition, qualitative data, including feedback and recommendations on the augmented reality-based social studies laboratory media, was gathered via questionnaires.

The following are the stages carried out in the field. The augmented reality-based social studies laboratory media developed along with the questionnaire were given to media experts on Monday, July 8, 2024. After being given, the media experts were given time to assess and respond to the augmented reality-based social studies laboratory media design based on the questionnaire questions. The next stage was to improve the augmented reality-based social studies laboratory media based on comments from media experts.

According to the analysis by media experts, the response percentage value was 90.00%. It indicates that social studies laboratory media product based on augmented reality has met the specific standards and belongs to the very effective category. Although revision was not a prerequisite, the research improved the product according to the recommendations and input of media professionals to enable it to be completed and perfected.

In addition to quantitative data, there is also qualitative data, namely in the form of comments. Each questionnaire compiled by the researcher has a comment column provided specifically for media experts to provide responses to the existing augmented reality-based social studies laboratory media. Comments from media experts, namely 1) naming the menu using Indonesian to be consistent with the content; 2) it is necessary to provide a description of the "Back" button; 3) writing the names of the site locations needs to be given glow text; 4) it is essential to include audio in the descriptions of each site; and 5) integration of social studies material can be included in a thematic study.

Based on several comments, the researcher made improvements according to suggestions and responses from media experts. In addition to referring to written suggestions, they also coordinated with media experts to revise the design of learning media.

4.2.3. Product Trial

The trial of the augmented reality-based social studies laboratory development product was conducted on students and lecturers Social Studies Education Study Program from 1) UIN Maulana Malik Ibrahim Malang; 2) UIN Imam Bonjol Padang; and 3) UIN Mataram. The augmented reality-based social studies laboratory product developed along with the questionnaire was given to students and lecturers. Before students and lecturers completed the questionnaire response sheet, the researcher initially clarified the purpose of distributing the questionnaire and introduced the augmented reality-

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based social studies laboratory media developed as part of the study. Furthermore, students and lecturers were given time to assess and respond to the augmented reality-based social studies laboratory media product based on the questionnaire questions. The next stage was to improve the augmented reality-based social studies laboratory media based on student and lecturer comments.
Below is a summary of the product trial data presentation results for students. See table 1.

Table 1.
Student Response Questionnaire Recapitulation Data.

College	Percentage (%)
UIN Maulana Malik Ibrahim Malang	84.46
UIN Imam Bonjol Padang	86.26
UIN Mataram	83.38
Average	84.70

The data summary in Table 1 reflects the evaluation outcomes from the student response questionnaire. Referring to the quantitative assessment of the student questionnaire, the average percentage response value was 84.70%. Based on the percentage value, AR-based social studies laboratory media product meets the required standards and qualifies as effective. Although it does not need to be revised, for the sake of the perfection of the product from the development, the researcher made improvements according to student comments.

In addition to quantitative data, there is also qualitative data, namely in the form of comments. Each questionnaire compiled by the researcher has a comment column provided specifically for students to provide responses to the existing augmented reality-based social studies laboratory media. Comments from students in general, namely 1) it needs to be improved in the augmented reality (AR) section so that it can be accessed and appears optimally on all types of mobile phones, so that more users can experience the interactive experience offered and 2) it is important to ensure that this application is compatible with various operating systems and device specifications, so that the user experience is not disturbed. Based on several comments, the researcher made improvements according to input from students. Below is a summary of the limited trial data presentation results for lecturers. See table 2.

Table 2.
Recapitulation Data of Social Studies Education Lecturer Response Questionnaire.

College	Percentage (%)
UIN Maulana Malik Ibrahim Malang	97.33
UIN Imam Bonjol Padang	97.33
UIN Mataram	98.67
Average	97.78

Referring to on Table 2, the quantitative assessment of the questionnaire from the lecturer, the average percentage response value was 97.78%. Based on the percentage value, it is concluded that the social studies laboratory media product based on augmented reality has met the appropriate standards and is in the very effective qualification. Although it does not need to be revised, for the sake of the perfection of the product from the development, the researcher made improvements according to the lecturer's comments.

In addition to quantitative data, there is also qualitative data, namely in the form of comments. Each questionnaire compiled by the researcher has a comment column provided specifically for lecturers to provide responses to the existing augmented reality-based social studies laboratory media. Comments from lecturers in general, namely 1) audio is presented on the site description to make it more interesting and 2) a kind of student worksheet is given to measure problem-solving abilities. Based on several comments, the researcher made improvements according to input from lecturers.

The following provides an overview of the limited trial data findings for lecturers, as summarized in Table 3.

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Table 3.
Recapitulation of Assessment Results of All Respondents in the Augmented Reality-based Social Science Laboratory.

No.	Correspondent	Percentage (%)	Category	Conclusion
1.	Subject Matter Expert	88.75	Very effective	Worthy
2.	Media Expert	90.00	Very effective	Worthy
3.	Student	84.70	Effective	Worthy
4.	Lecturer	97.78	Very effective	Worthy
Average		90.31	Very effective	Worthy

The findings conclusively show that the augmented reality (AR)-based social studies laboratory media meets the required standards. This is supported by an average validation score of 90.31% from experts and positive outcomes from limited trials. These findings demonstrate that AR-based media is both highly effective and well-suited for serving as a learning tool in the Social Studies Education program's lectures.

4.3. The Influence of Augmented Reality-based Social Studies Laboratory on Interest

The application of AR-based social studies laboratory media in learning, whether during discussions or lectures, varies according to the specific context. Information regarding students' learning interest was gathered through a questionnaire. The questionnaire assessing learning interest was distributed both prior to and following the product trial. Comparison of learning interest data before and after the learning process in this study is depicted in Figure 7.

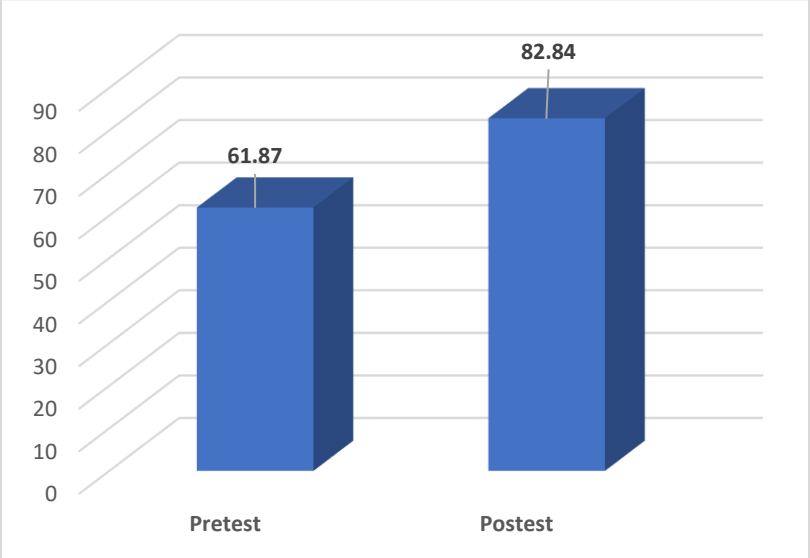

Figure 7.
Student Learning Interest Data.

The data in Figure 7 reveals that the average student learning interest before using AR-based social studies lab media was 61.87. After implementation, the average interest increased to 82.84, showing a significant rise of 20.97. The gain score data confirms a clear improvement in learning interest, demonstrating that the AR-based social studies laboratory media has effectively enhanced students' engagement and interest in learning.

Following this, the effectiveness of the learning interest data was evaluated using a paired sample t-test, conducted after performing normality and homogeneity tests. The outcomes of the normality test are displayed in Table 4 below, and the results of the homogeneity test are provided in Table 5 below.

Table 4.
Normality Test Results.

Value	Kolmogorov-Smirnova		
	Statistic	df	Sig0.
Pretest	0.092	82	0.083
Posttest	0.094	82	0.073

Table 5.
Homogeneity Test Results.

Levene Statistic	df1	df2	Sig.
28.091	1	162	.000

Table 4 indicates that the pretest significance value (0.083 > 0.050) and posttest significance value (0.073 > 0.050) demonstrate that the learning interest data follows a normal distribution. However, Table 5 also shows a significance value of 0.000 < 0.050, indicating that the data does not have homogeneous variance. A follow-up comparison test was performed to assess learning interest before and after the intervention, with the outcomes detailed in Table 6.

Table 6.
Paired Sample T-Test Results.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Posttest - Pretest	20.976	14.501	1.601	17.789	24.162	13.099	81	0.000

The t-test results in Table 6 show a significance value of 0.000 < 0.050, leading to the rejection of H0. This confirms a statistically significant difference in students' learning interest before and after using the AR-based social studies laboratory media. The developed media has effectively increased students' interest in social studies, particularly in topics related to social, cultural, and economic activities. The use of AR in education has demonstrated a positive impact by creating a more interactive, engaging, and immersive learning environment.

The use of AR in education has shown a beneficial impact on increasing students' interest in learning, primarily by providing a more captivating, interactive, and immersive educational environment [91, 92]. This technology enables students to engage directly with learning materials through more realistic and immersive three-dimensional visualizations, which cannot be achieved using traditional methods like textbooks or lectures [93]. By offering an interactive and dynamic learning experience, AR improves comprehension and retention, helping to simplify complex concepts and make them more engaging and accessible for students. Through interactive elements, AR can arouse students' curiosity and stimulate exploration of complex and abstract concepts, such as in medicine, engineering, and science [94-96]. Additionally, gamification features in AR, including interactive simulations and technology-based challenges, can increase students' engagement in the learning process [97].

While there is a lot of evidence showing the effectiveness of AR in increasing interest in learning, several factors affect the degree to which this technology can be optimally utilized in education [98]. A key factor is technological readiness, which encompasses the availability of compatible devices like smartphones, tablets, or AR headsets that support learning applications [99]. In addition,Fidan and Tuncel [100] explained that the ease of access to this technology is a challenge, especially for educational institutions that have limited technological infrastructure. The quality and relevance of AR content is also a crucial aspect, as content that does not match the curriculum or is not interactive enough can reduce the effectiveness of learning [101]. As a result, AR technology developers must ensure that the content delivered through the AR platform genuinely aligns with learning goals and enhances students' comprehension of the subject matter.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 5: 2027-2045, 2025
DOI: 10.55214/25768484.v9i5.7371

Apart from technical factors, the individual characteristics of students also play a crucial role in determining how effective AR is in enhancing the learning process. Every student possesses a unique learning style, and not all students are equally comfortable adopting new technologies in their learning process [102]. The level of digital literacy, previous experience with AR-based technology, and preference for certain learning methods can affect how much students feel motivated by AR-based learning [103, 104]. Students who prefer text-based learning may take longer to adapt to AR-based learning environments compared to those who are more familiar with digital technology [105]. Therefore, a more personalised approach to AR implementation can help accommodate these differences and ensure that all students get the maximum benefit from this technology.

The effective of AR in education relies not only on technical aspects and individual student traits but also on the backing of educators and institutions [106-108]. Many educators still face challenges in integrating AR into teaching methods due to limited training and understanding of this technology [109]. Therefore, educational institutions need to provide training programmes and curriculum development that support the effective use of AR to suit students' academic needs. Furthermore, social interaction and collaboration are crucial in enhancing learning interest through AR. This technology is not only advantageous for individual learning but can also be utilized in team-based activities, such as group projects and interactive simulations [35, 110]. This can improve students' cooperation, communication and confidence in understanding concepts more deeply.

5. Conclusion

Based on the results and analysis, this study concludes that: (1) the augmented reality-based social studies laboratory was developed using the Borg & Gall model. The development process involved eight stages: analyzing the needs of the social studies laboratory, creating an AR-based social studies laboratory, validating the product, conducting limited trials, revising the product, finalizing the development results, performing experimental tests, and disseminating the product. (2) The augmented reality-based social studies laboratory is both feasible and effective for educational use, as confirmed by evaluations from material and media experts. In the material aspect, it scored 88.70, meeting the criteria of feasible/very effective. In the media aspect, it scored 90.00, also meeting the criteria of feasible/very effective. (3) The augmented reality-based social studies laboratory developed in this study has a meaningful and positive effect on enhancing students' interest in learning.

Lecturers can use augmented reality-based social studies laboratories to help provide students with conceptual understanding and train scientific research skills. Suggestions for further researchers, so that they can develop materials or other things that are not yet in this research to be better, for example development in the form of virtual reality (VR).

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Acknowledgement:

The author would like to thank the Institute for Research and Community Service (LP2M) of Maulana Malik Ibrahim State Islamic University Malang for funding and supporting this research through research grants. This research is funded by the Indonesian Ministry of Religious Affairs worth IDR 62,000,000 through the BOPTN Research program in 2024, in accordance with DIPA No. 025.04.2.2: DIPA 025.04.2.423812/2024.

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Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 5: 2027-2045, 2025
DOI: 10.55214/25768484.v9i5.7371