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Development of Augmented Reality Learning Media Based on Spatial Thinking Skills

Mei Vita Romadhon Ningrum *
Geography Education, Mulawarman University,
Samarinda, 75123, Indonesia
mei.vita@fkip.unmul.ac.id
**Corresponding Author*

Ummi Saadah Ardianna
Geography Education, Mulawarman University,
Samarinda, 75123, Indonesia
ummisaadah08@gmail.com

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Abstract— Fire is one of the most common disasters, and the denser the population, the higher the risk of fire. One area that has a high fire potential is the densely populated city of Samarinda. One way to mitigate or prevent fire hazards is by utilizing the learning process at school, especially in geography subjects. The purpose of this research is to produce augmented reality media design based on spatial thinking skills on fire disaster mitigation material and to determine the feasibility of using augmented reality learning media based on spatial thinking skills in geography subjects. This research is development research, where the developed media is tested to material experts and media experts before being tested on students. Data analysis used qualitative and quantitative methods, with quota sampling techniques. The results showed that the product in the form of 3D Augmented Reality (AR) learning media application named 'AR Fire Mitigation' can be used on smartphones. This application is offline and does not require internet access. This product is also equipped with a supporting book that contains 2D and 3D images with explanations for each material. The supporting book discusses fire disaster mitigation materials, including the characteristics of fire-prone and non-fire-prone areas, the impact of fires, types of fires, classification of fires, mitigation during a fire, causes of fires, fire disaster mitigation scenarios, and conditions of residential and land fires. The learning media developed is considered feasible based on the average results of user trials of 88.92%, so that the learning media products and supporting books produced are categorized as feasible.

Keywords— Learning Media, Spatial Thinking, Geography Subject, Augmented Reality

I. INTRODUCTION

Residential fires have become the most frequent disaster in Samarinda City. According to data from the Samarinda City Fire Department (2023), residential fire incidents in Samarinda have experienced a significant increase. In 2020, there were 282 fire incidents, 240 incidents in 2021, and approximately 227 incidents in 2022. This year, the number of incidents increased by 20 to 247. Fires in residential areas are the most dominant type of fire, with 71 incidents caused by gas leaks, electrical short circuits, and other factors.

One fact in the field proves that fire disasters affect all groups, including the large number of child fatalities, which is a loss that needs attention (Aini et al. 2022). Government policies and public awareness about disaster management at the pre-disaster stage are very lacking. Past disaster experiences have always resulted in significant material losses and fatalities. These incidents indicate a lack of knowledge and application in daily activities regarding mitigation and preparedness for disasters. To reduce the resulting losses, good fire disaster mitigation is needed. (Rohmah et al, 2020) Stated that mitigation is a series of efforts made to minimize the risk and impact of disasters, through infrastructure development and providing awareness and the ability to face disasters. Disaster management will be better if integrated into the education sector, because education is one of the determining factors in disaster risk reduction activities. This integration can start early on with students from kindergarten to high school (Sadewa, Andreswari, and Erlansari 2019). Disaster education is necessary because school students are a vulnerable group that is a priority in disaster management due to the weaknesses of students' psychological aspects and understanding of disaster risk factors (Nurrohim and B. Kharisma 2023). Disaster education is provided at the senior high school level and integrated into the geography subject in the material on disaster mitigation and adaptation. Teaching disaster mitigation from the beginning will increase students' ability to be vigilant before a disaster, self-rescue, and know what activities can and cannot be done after a disaster (Aini et al. 2022).

Students find it easier to understand the material when there are illustrations to analyze objects in physical form, so a medium is needed that can present more realistic disaster mitigation education (Ismowati et al, 2023). Education through educational media is carried out by utilizing technology. One development of learning media that is still new is learning media using Augmented Reality (AR) which is one of the technologies in the field of interaction (Ningsih, Rusdiana, and Rudini 2019). The optimization of disaster mitigation education media using

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Augmented Reality as an information technology-based learning media can attract interactive learning interest so that it is expected to facilitate disaster education. Augmented Reality or in Indonesian called augmented reality is a technology that combines two-dimensional and three-dimensional virtual objects into a three-dimensional real environment and then projects these virtual objects in real time. (Lee et al. 2012) Stated that augmented reality has the potential to increase the efficiency of academic education and training by providing information at the right time and place and offering rich content by generating 3D images. Based on the results of observations, it shows that the learning media used in the material on disaster mitigation and adaptation in SMA Negeri 1 Samarinda uses media that is still less flexible, which uses a learning system only through explanations that are centered on the teacher and by utilizing the available media in the school such as material books, pictures, and PowerPoint, thus it is not very interesting and students also find it difficult to understand the content of the material given. A very minimal explanation of the material content delivered can cause students to have a poor understanding of the material and find it difficult to solve problems with the material given.

Through the analysis of existing media, researchers found that the media used in learning disaster mitigation and adaptation, such as textbooks, pictures, and PowerPoint presentations, still have many shortcomings. Not all materials are presented using textbooks, pictures and PowerPoint, making it less interesting for students. As an educator, it is necessary to develop a learning media in educating about disaster mitigation as a form of effort to provide important value to knowledge, understanding, and utilization of technology in overcoming when a disaster occurs. Therefore, researchers developed augmented reality learning media on disaster mitigation and adaptation materials with fire disaster mitigation sub-materials. The advantages of augmented reality media that researchers want to develop are augmented reality media based on spatial thinking skill where the concept of geography learning is not far from spatial thinking skill, and the concept of learning spatial thinking skill is very useful for students in everyday life, so that students not only memorize but more easily understand and master the material, and provide clearer meaning to the learning material, so as to improve the shortcomings of the previous learning media. Geography learning, especially on disaster mitigation material, has not utilized much technology, especially mobile-based technology. While shit experience-based learning, students can easily understand and absorb the information conveyed, and can store memories about disaster mitigation accurately, so that they can act quickly when a similar event occurs. This is due to the experience gained by students during the learning process.

Based on the above problems, this research was conducted to develop augmented reality learning media design based on spatial thinking skills in geography lessons and to determine the feasibility of augmented reality learning media based on spatial thinking skills in geography lessons. The purpose of this research is to know the design of learning media development and to know the results of the feasibility of augmented reality learning media based on spatial thinking skills in geography lessons.

Several previous studies have explained that in learning that is useful and close to everyday life, practical learning is one way for students to have meaningful experiences of it. However, due to time and resource constraints as well as technological advancements, it is not difficult for teachers to bring students to experience events according to the material taught through augmented reality. Maharani, Romadhona, and Masnuna (2023) explains that students have a better understanding with AR technology compared to students who learn disaster mitigation without using AR. Then Nistrina (2021) also supports this statement where AR technology allows students to directly experience events related to the theory taught so that they can easily understand the situation and act according to the instructions. However, the application of augmented reality has primarily focused on disaster mitigation, particularly natural disasters. Therefore, this research develops augmented reality media based on spatial thinking skills on disaster mitigation material, specifically focusing on fires that often occur in big cities like Samarinda.

II. RESEARCH METHODS

This research is development research that refers to qualitative and quantitative approaches. This media development research adapts the model developed by Brog & Gall,1989) as a reference at each stage of development. The development stages of this model consist of ten steps first research studies and information gathering, second research planning, the initial product development, then initial product trial, then main product revision, main field trial, operational product revision, and operational trial, final revision, end dissemination and implementation of the final product. Procedurally, the stages of developing augmented reality media refer to the steps put forward by the expert and are simplified according to the needs of the researcher. Therefore, the stages of this development only adopted seven steps, namely research studies and information gathering, research planning, initial product development, validator trials, User trials, product revision, final product.

In this study, researchers used the quota sampling technique, which is a sample selection method by setting a certain amount as a target that must be met in sampling from a population that has been determined by the researcher with a total of 20 students.

The data collection technique obtained in the development of this learning media is quantitative data obtained from the results of the trial of learning media products on students and qualitative obtained from media expert validators and material experts. Data collection instruments in this development using open questionnaires and closed questionnaires are given to

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material expert validators, and media expert validators. It aims to revise the products developed according to the validator's suggestions. Closed questionnaires are given to students in which they measure the feasibility level of the product developed. The questionnaire is also the basis for developing a product.

This development of research data analysis technique consists of qualitative data and quantitative data. Qualitative data is based on media expert validators and material expert validators in the form of suggestions and responses. The suggestions and responses were not analyzed. Suggestions and responses from validators will be directly used for revision of learning media products. While quantitative data comes from students. Quantitative data is analyzed with descriptive percentage technique. The descriptive percentage technique is by converting quantitative data into a percentage from which will then be interpreted into a qualitative sentence.

To calculate the feasibility of learning media products, it is obtained using the formula (1):

$$p = \frac{\sum X}{\sum Xi} \times 100\% \quad (1)$$

Information (1)

P = Research Presentation

$\sum x$ = The total number of respondents' answers in one aspect

$\sum Xi$ = Total ideal score

100 = Constant

The conclusions that have been reached are based on the research classification as shown in table 1.

Table 1. Assessment Classification

Classification	Score (%)	Feasibility Assessment
A	81-100	Suitable
B	61-80	Moderately suitable
C	<60	Unsuitable

(Modification, Akbar 2013)

III. Results and Discussion

This research and development resulted in a product form of an augmented reality application and a supporting book for learning media in high school geography. The augmented reality application is a type of digital learning media that can be used on smartphones, supported by a supporting book for the application to display 3-dimensional objects. The application of the development model in the development of this media as a reference at each stage of development, including research studies and information gathering, research planning, product development, validator testing, user testing, product revision, and final product.

A. Research Study and Information Gathering

The study began with a research study and data collection. An analysis of the problems and weaknesses of the media was carried out. The problem identified was that the teaching process for the sub-material of fire disaster mitigation was less than optimal due to the learning media used during the teaching process, where teachers only used books, images, and PowerPoint presentations. The researcher analyzed that the learning media used was still less interesting and difficult to understand for students because of the lack of explanation of the material presented, and the learning media used was also less attractive so that students were less active in geography learning. Based on these things, which eventually caused students' focus during learning to be less, and the learning carried out to be passive. These problems indicate that a learning process requires interesting and innovative media. However, its implementation in school learning is still lacking. Based on the conditions and problems that have been found, the researcher developed augmented reality-based spatial thinking skill learning media for the sub-material of real fire disaster mitigation in the student's environment.

B. Research Planning

The planning stage involves designing the development of a learning media product. This research has four stages: determining competencies, determining product user targets, determining research instruments, and collecting data. The first stage is determining competencies, which aims to limit the material on the media to be developed. The material analyzed is the material on disaster mitigation and adaptation. The selection of this material is based on the independent curriculum geography learning module, which the researcher then breaks down the material topics according to the learning material with the sub-material of fire disaster mitigation, which is then linked to indicators of spatial thinking skills. For material topics in learning media, as shown in table 2.

Table 2. Material Topics in Learning Media Products

Learning	Spatial Thinking	Topic Augmented reality media material

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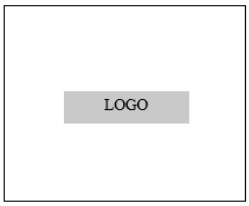
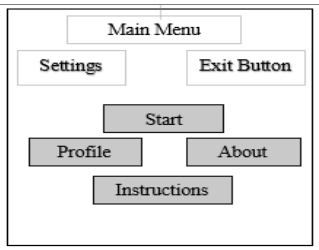
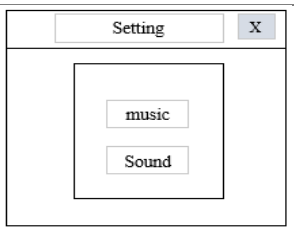
materials	Skill Indicator	
Introduction		1. Understanding disaster mitigation and adaptation 2. Definition of Fire 3. The difference between fire disaster mitigation and fire disaster risk
The sub materials of fire mitigation are in accordance with the spatial thinking skill indicators	1. Comparison	1. Characteristics of places prone to fire and characteristics of places not prone to fire
	2. Aura	2. Impact of fire
	3. Region	3. Type of fire
	4. Hierarchy	4. Classification of fires
	5. Transition	5. Mitigation when a fire disaster occurs
	6. Analogy	6. Conditions of residential and land fires
	7. Patter	7. Cause of fire
	8. Association	8. disaster mitigation scenarios

The second stage is determining the target users of the product. At this stage the researcher determines the target users of the learning media products developed in accordance with the basic competencies of high school, namely analyzing disaster mitigation and adaptation. At this stage the researcher chose to test the product in class XII on the grounds that students had previously studied related material in class XI so that students could understand much more about the material. The third stage is determining the research instrument at this stage the instrument used to collect data is an open questionnaire and a closed questionnaire. Open questionnaires are given to expert validators while closed questionnaires are given to students. The last stage is data collection, this stage researchers collect the data needed in the development of learning media. The data is in the form of illustrations and animations in both 2D and 3D, as well as other materials needed in making applications and supporting books. The data is used as a form of visualization and model of the description text used in learning media and supporting books.

C. Product Development

At this stage it is the stage of developing the product starting from installing the supporting application first. This stage is carried out the creation and modification of supporting components in the form of background images, application logos, button icons 3D models, material displays, and marker images. Object creation follows the references in the 8 materials that have been compiled during the literature study. After the components are prepared, the development continues with the creation of a program using the unity software, the result of which is an application that can be installed. The storyboard and flowchart design will be realized with the implementation of programming codes. After all the unification is successful, naming the AR application developed under the name AR fire disaster mitigation is carried out. The following is a storyboard and flowchart of the initial design of the 'AR fire disaster mitigation application' as shown in table 3 and figure 1.

Table 3. AR Fire Disaster Mitigation Application Storyboard

No	Name	Design and Description
1.	Splash Screen	 Description: 1. When entering the application, the first splash screen will display the application branding logo. 2. Then the second splash screen displays the logo of the application created
2.	Main Menu	 Description: 1. In the top corner there is a writing that indicates that you are on the main menu 2. In the upper left corner, there is a settings menu that functions as a music and sound regulator 3. In the upper right corner, there is a button to exit the application. 4. There are buttons in the middle, namely the start menu, profile, about, and instructions
3.	Menu Setting	 Description: 1. When pressing the settings button on the main menu, the screen will change as shown above.

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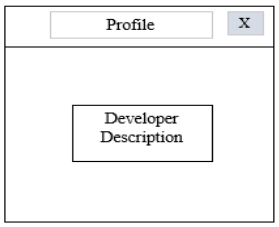
2. On this page contains a display of the music and sound menu in this application
3. In the right corner there is a home button to the main page

4. Profile Menu



Description:
1. When pressing the profile button on the main menu, the screen will change as shown above
2. This page contains the profile of the developer
3. In the top right corner, there is a home button to the main menu

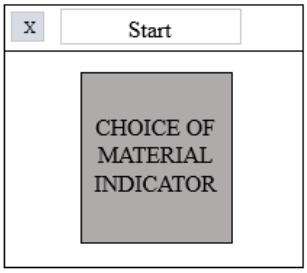
5. Instructions Menu

Description:
1. When pressing the hint button on the main menu, the screen will change as shown above
2. This page contains instructions for using the application
3. In the top right corner, there is a home button to the main menu

6.7 About Menu

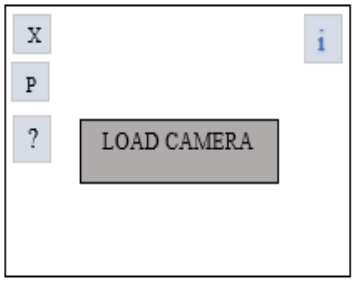
Description:
1. When pressing the about button in the main menu, the screen will change as shown above
2. This page contains a brief description of the Augmented Reality application.
3. In the upper right corner, there is a home button to the main menu

7. Start Menu



Description:
1. When pressing the start button on the main menu, the screen will change as shown above
2. On this page contains a choice of material according to the indicators that will use Augmented Reality.
3. In the upper left corner there is a back button to the main menu

8. AR camera



Description:
1. When pressing one of the buttons in the material menu, the screen display will change as shown above and the camera will be activated.
2. In the top right corner there is a summary description of the material
3. In the upper left corner, there is a home button to the main menu
4. Below the left of the home menu there is a music and sound settings button
5. Then below the left there is a button (?) which contains instructions

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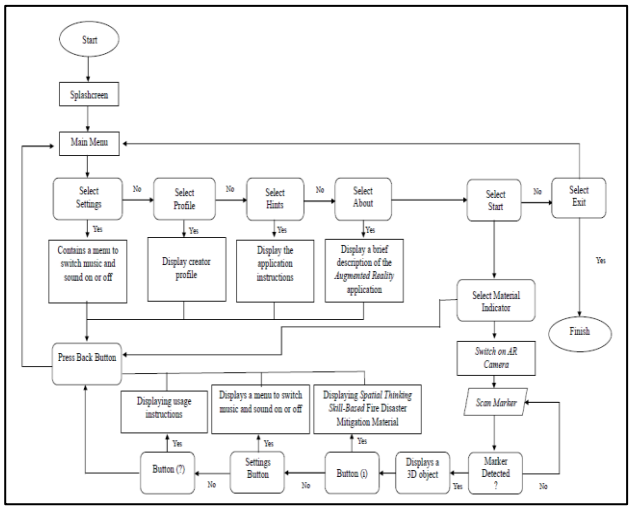

Figure.1. AR Fire Disaster Mitigation Application Flowchart

D. Validator Trials

At this stage, it is the validation stage of the learning media, which is carried out by 2 expert validators who are experienced in their respective fields. The validators are material experts, Mr. Yaskinul Anwar, S.Pd., M.Sc., and media experts, Mrs. Dewi Rosita, M. Kom, both the subject and media experts have considerable expertise in the field of education. Both are active lecturers who have written numerous books and developed interactive learning materials and media that have proven to be highly effective. This stage obtains suggestions from expert media validators and expert material validators by using a number of pre-defined criteria to examine different aspects of the product (Nassereddine, Veeramani, and Hanna 2022). In table 4, A detailed description of the feedback received from each type of validator is provided in the product validation data. The feedback was in the form of suggestions for improvements to specific components of the product, such as improvements to examples in the materials, image quality, definitions in the materials and clarity of information.

Table 4. Product validation data

No	Comments and Suggestions	Action
1.	validator material a. Improvements in several examples in each indicator b. Add data and images to the material	a. Refinement of examples of material indicators b. Add data and images to the material
2.	Media validator a. Improvements to the instructions for use in the application b. Adding material points to the application c. Improves the clarity of 3-dimensional objects	a. Additional instructions for use on media b. adding material points to the application c. improves the clarity of 3-dimensional objects

In particular, the criteria used by the expert validators reflected the overarching objectives of educational media development. These included clarity and consistency of content within the supplementary book, correspondence between 3D objects and content, and overall media development alignment with educational content (Huang et al, 2022).

The validation process rigorously examined products against a comprehensive set of criteria covering content accuracy and media presentation. These criteria were carefully designed to ensure that educational media not only meet high quality standards but also suit the educational needs. To ensure a thorough understanding of the media's strengths and areas for improvement, feedback from both expert validators and end users was analyzed in detail (Susmei Rindantiya et al2024).

Further details on the validation criteria and the scope of the user trials highlighted the comprehensive approach taken to assess the feasibility of the educational media. In addition to the technical aspects of the augmented reality application, the educational effectiveness of the supplementary textbook was also assessed (Mustaqim 2016).

E. User Trials

The trial stage conducted on students aims to measure the level of suitability of the developed learning media. When conducting media trials, students are invited to observe and analyze the material given by using the 3D objects displayed and reading several examples in the supporting book. The application of concepts and theories contained in the "AR Fire Mitigation" media also provides a new experience for students in learning fire mitigation based on spatial thinking skills, thus creating a memorable and unforgettable learning experience for students (Ahmad Munarun 2024).

The data presentation includes a comprehensive display of results from the product trial, including validation results from expert validators and results from student user trials. This approach ensures that the feasibility of learning media is assessed from different perspectives (Christopoulos et al. 2021). The data obtained from the trial is quantitative data. The data obtained is then analyzed by looking at the feasibility assessment table. The results of the score analysis was then analyzed in qualitative sentences. Assessment of learning products conducted by students using a closed questionnaire. The data obtained from this questionnaire is quantitative data. This questionnaire instrument consists of 3 categories with a total of 20 statements. The

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following is a description of each aspect of the assessment:

1. Instructions for use

Indicators in the aspect of instructions for use there are 3 statement items. Assessment data on the assessment aspect is shown in table 5.

Table 5. Explanation of The Results of The Assessment of Instructions for Use

No	Assessment Aspect	Score (%)	Feasibility Assessment
1.	Instructions for use on the media are easy to understand	91,25	Suitable
2.	The sentence structure and language are easy to understand	88,75	Suitable
3.	The sentences and images in the steps for using learning media are very clear	92,5	Suitable
	average	90,83	Suitable

Based on table 5 the average score obtained in the assessment aspect of the user guide was 90.83%, which falls into the 'suitable' category. The highest score was obtained in statement number 3, which states that the sentences and images in the steps of using the learning media are very clear. This is because during the use of the learning media, it was collaborated with the use of a supporting book or guide, complete with steps both on the learning media and the supporting book. Thus, this makes it easier for users to use this learning media. Conversely, statement number 2 received the lowest score of 88.75%. This is because the sentences and language used were still confusing for students, so they need to be revised. Cahdriyana and Richardo (2016) the development of instructional media, particularly updated models, should prioritize the clarity of user instructions. Clear instructions are essential for the successful implementation of such media. The more explicit the instructions, the more effective the learning medium becomes.

2. Material

There are 12 statements on the material aspect. Assessment data on each aspect of the assessment is shown in table 6.

Table 6. Explanation of Material Assessment Results

No	Assessment Aspect	Score (%)	Feasibility Assessment
1.	This augmented reality learning media explains a concept using illustrations related to everyday life	91,25	Suitable
2.	By using augmented reality media, I can find out the characteristics of fires in residential areas	85	Suitable
3.	After using this augmented reality media, I was able to find residential areas prone to fire disasters in Samarinda City	91,25	Suitable
4.	By using this augmented reality media, I can understand the impact of fire	93,75	Suitable
5.	After using this augmented reality media, I can find out how to save myself when a fire disaster occurs in a safe place	83,75	Suitable
6.	This augmented reality learning media helped me understand the material on types of fires and fire classification	91,25	Suitable
7.	By using this augmented reality media, I understand mitigation material when a fire disaster occurs and disaster mitigation scenarios	82,5	Suitable
8.	After using this augmented reality learning media, I can find out the patterns of settlements that are prone to fire	85	Suitable
9.	This augmented reality learning media helps me understand the conditions of housing and land fires	82,5	Suitable
10.	By using this augmented reality media, I understand the causes of fires	93,75	Suitable
11.	The existence of augmented reality learning media can provide me with motivation to study fire disaster mitigation and adaptation	85	Suitable
12.	Augmented reality based on spatial thinking can test understanding of fire disaster mitigation	81,25	Suitable
	Average	87,18	Suitable

The average score obtained in the material assessment aspect was 87.18%, which falls into the 'suitable' category. The highest scores were obtained in statements number 4 and number 10 with scores of 93.75%, also falling into the 'suitable' category. This means that students, by using augmented reality media and its supporting book, can understand the material on the impact and causes of fires. The lowest score was obtained in statement number 12, which concerns the spatial thinking-based augmented reality's ability to test understanding of fire disaster mitigation. In this respect, the score obtained was 81.25%. This means that students still do not fully understand how to study fire disaster mitigation and adaptation. (Hasiru, Badu, and Uno 2021) It is important to note that the initial use of a new learning medium may not yield significant results immediately. However, repeated application can enhance student abilities in accordance with the medium's

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development goals. Based on this, the current scores are not definitive, indicating areas for improvement.

3. 3-Dimensional Objects

The next indicator is the 3-dimensional object on the learning media developed. The aspect of 3-dimensional object instructions has 5 statements. Table 4.3. Assessment data on each aspect is shown in table 7.

Table 7. Explanation of The Results of 3D Object Assessment

No	Assessment Aspect	Score (%)	Feasibility Assessment
1.	The design presented in this augmented reality learning media is interesting	95	Suitable
2.	The content in augmented reality based on spatial thinking is equipped with images that match the material	95	Suitable
3.	The 3-dimensional objects displayed are clearly visible	90	Suitable
4.	The 3-dimensional objects in fire disaster mitigation and adaptation material are easy to understand	83,75	Suitable
5.	There are many features (beneficial capabilities) in this application so that I don't get bored studying material on fire disaster mitigation and adaptation	80	Moderately Suitable
	Average	88,75	Suitable

The average score obtained in the assessment aspect of 3D objects was 88.75%, which falls into the 'suitable' category. The highest scores were obtained in statements number 1 and number 2 with scores of 95%, also falling into the 'suitable' category. This means that the design presented in the augmented reality learning media and the content in the spatial thinking-based augmented reality, equipped with images that match the material displayed on the learning media, is attractive and easy for students to understand. (Sari, Soepriyanto, and Wedi, 2020) Students are more likely to be engaged with learning materials that incorporate 3D elements, Pralisaputri K R, Heribertus, and Chatarina (2016) There is a discernible tendency among students to be more engaged with learning materials that utilize three-dimensional visualizations. The lowest score was obtained in statement number 5 with a score of 80% and falls into the 'quite suitable' category. This means that this learning media still does not have many features in this application, making it boring to learn about fire disaster mitigation and adaptation This is in line with research (Aji et al. 2018) state effective interactive learning media necessitates a comprehensive suite of features to accommodate the varied requirements of learners. (Ramdani, Nugraha, and Hadiapurwa (2021) Similar to the way TikTok has successfully accommodated diverse user needs through its extensive feature set, educational media should strive to provide a comprehensive range of functionalities to meet the varied learning requirements of its users.

Based on the assessment of each aspect of the assessment that has been described above both in terms of instructions for use, material and 3-dimensional objects, as an average score of >81% is obtained so that it is included in the feasible category for each aspect of the assessment by students is shown in table 8.

Table 8. Results of Product Trial by Learners

No	Assessment Aspect	Score (%)	Feasibility Assessment
1.	Instructions for use	90,83	Suitable
2.	Material	87,18	Suitable
3.	3D object	88,75	Suitable
	Average	88,92	Suitable

Table 8 above states that the results of student's assessment of the learning media obtained an average of 88,92%. Based on this, the students' assessment of the learning media is included in the feasible category.

F. Product Revision

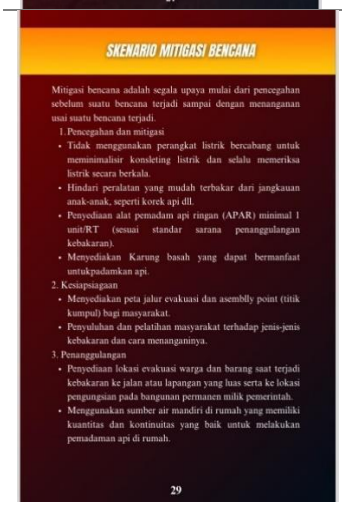
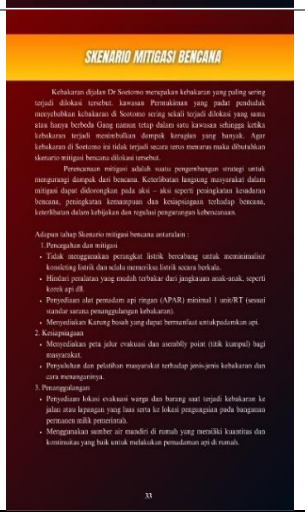
Product revision was carried out in 2 stages, namely based on the validation results from media expert validators and material experts in the form of comments and suggestions, as well as questionnaire assessments, suggestions and input from students. The results of the application product display and AR book before and after revision are shown in tables 9 and 10.

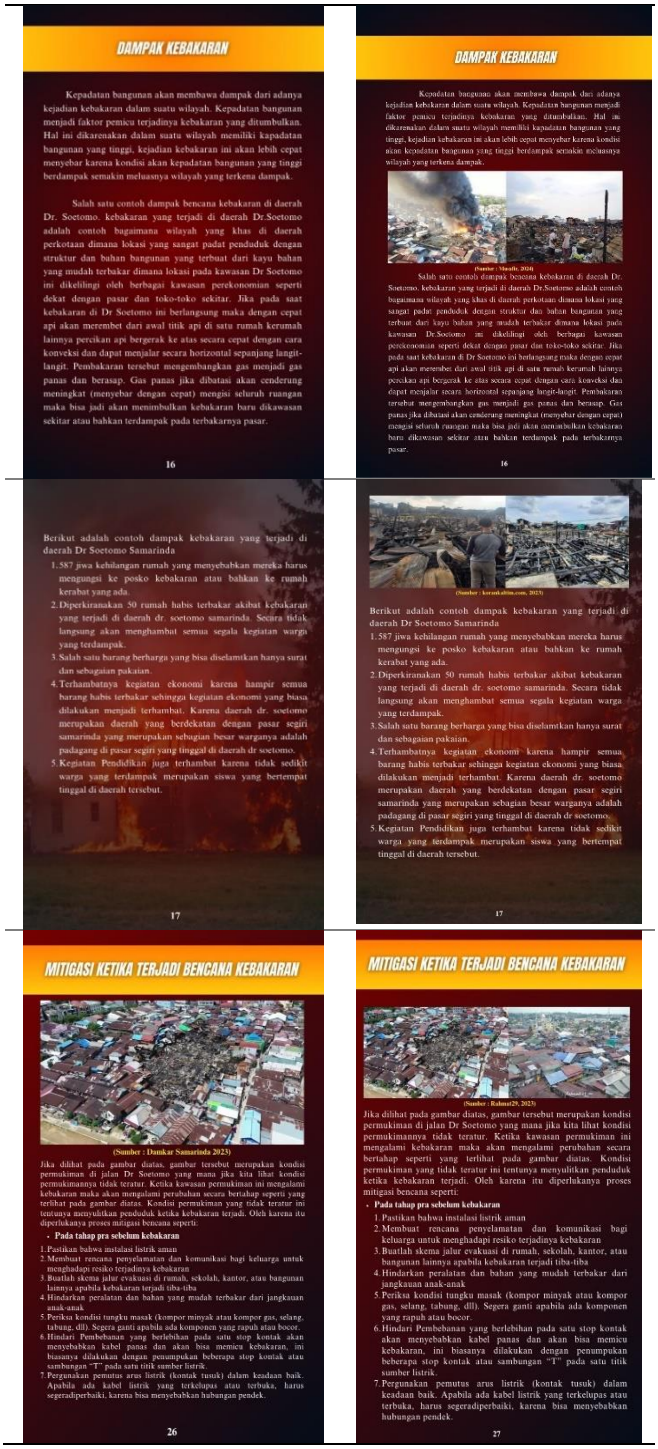
Table 9. GUI Before and After Improvements to The Application

GUI Before Revision	GUI After Revision
Added a hint icon to the application menu	
	
Added material points to the application	
	
3D Object Clarity Improvements	
	

Ningrum, M. V. R., & Ardianna , U. S. (2025). Development of Augmented Reality Learning Media Based on Spatial Thinking Skills. TEPIAN, 6(1). 1-12. https://doi.org/10.51967/tepian.v6i1.3172

Table 10. GUI Before and After Repairs in Supporting Books

GUI Before Revision	GUI After Revision
Improvements to the example in several material indicators	
	
	
	
Adding data and images to the material	



The validators make suggestions for the improvement of the quality of the media by following the suggestions of the media experts and the material experts as well as the students for various things that need to be changed or added (Badryatusyahryah et al., 2020). Various inputs have been made until the learning media developed becomes feasible without revision, so this learning media continues with the trial of products that have been completed and improved both in the form of changes and additions.

Ningrum, M. V. R., & Ardianna , U. S. (2025). Development of Augmented Reality Learning Media Based on Spatial Thinking Skills. TEPIAN, 6(1). 1-12. https://doi.org/10.51967/tepian.v6i1.3172

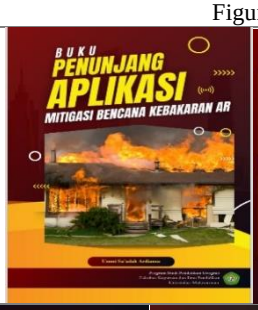
G. Final Product

The final stage is the stage after getting valid criteria from media expert validators and material experts and getting feedback on the feasibility level of learning media products from users, namely students. This stage is the production stage that produces the final product in the form of augmented reality based spatial thinking skill learning media. the results of product development are shown in table 11 and table 12.

Table 11. Finished Product AR Fire Disaster Mitigation Application

Figure	Information
	Display of the AR Fire Mitigation initial menu that has been installed on the smartphone
	Menu display on the logo  This menu contains profiles of learning media creators
	Menu display on the logo  This menu contains instructions for using the AR Fire Mitigation application combined with supporting books
 	Menu display on the logo  This menu contains several indicator options for the material, where when we point the camera at the supporting book, the material has been packaged in augmented reality (3D) form.
	Menu display on the logo  This menu contains brief information on augmented reality fire mitigation applications

Table 12. Finished Product of AR Application Support Book

Figure
      

This research has successfully developed two main products, namely learning media applications and supporting books. The learning media application is an augmented reality (3D) tool called AR Disaster Mitigation, which is used on smartphones that are unique in their educational usefulness (Suciliyana and Rahman 2020). This application requires 237MB of memory and a 5MP rear camera to run. This application is offline and does not require an internet connection. The AR book itself has 41 pages from the cover to the bibliography, which consists of a cover introduction, product description, application features and instructions for use. Then in the materials section there are 8 materials, each of which has a picture made as a marker. The size of the book is 23cm x 15.5cm (UNESCO standard). Learn more about AR disaster preparedness education to bring geographic concepts to life and provide students with a new, real-world and interactive learning experience (Alfitriani et al,. 2021).

During the development and testing phase, the AR disaster relief application and accompanying book faced several challenges, particularly delays in capturing 3D images, which were still bugs in the application. Given these obstacles, it is clear that addressing or mitigating these issues in the future can significantly improve product reliability and user experience (Cao et al. 2023).

The benefits of this AR disaster mitigation application and accompanying book have an impact on the learning process by making abstract geographical concepts more

interesting and easier to understand. (Syahputra et al,. 2016). The advantages of augmented reality are that students can see the whole process of phenomena or concepts from different angles, which can help develop students' spatial intelligence (Guntur et al. 2020).

The Disaster Mitigation AR app and accompanying book have been rigorously evaluated and received a suitability score of 88.92% from media and material experts. This high level of conformity underscores the effectiveness of the product as an educational tool, which has been validated by student trials. Feedback from these trials suggested further improvements in the development of the augmented reality application, such as the addition of more and varied material features (Mada Raharja and Suharto 2024).

One of the challenges encountered in developing this augmented reality-based learning media was the limited availability of suitable augmented reality applications. Free applications often have restricted premium features, necessitating the use of paid versions for more comprehensive functionalities. This resulted in significant development costs due to the need for more complete paid features. Moreover, while free applications could be used, the limited selection of images and tools available restricted the complexity of the developed media, hindering its ability to fully meet the needs of learners. The instructions for using the developed media were deemed to be insufficiently explicit and somewhat confusing for some students. Although this aspect was mentioned in the research findings, more in-depth revisions and analysis of its impact are required to ensure better user comprehension.

Based on revisions from material and media experts, the final AR media is as presented in the table above. The application of this learning media has received a positive response from students, with students considering the features to be very helpful in the learning process. However, a limitation of this study is that the learning media was only applied to observe student feedback and was not implemented in depth to compare the results of learning without using AR technology and with using AR technology. Therefore, this study only presents student responses to the existing media and does not show the effectiveness of using AR media itself.

IV. Conclusion

The development of this augmented reality-based learning media, utilizing spatial thinking skills, has resulted in two products: an application and a supporting book. The product in the form of an augmented reality (3D) learning media application, named AR fire mitigation, can be used on smartphones. This application is offline, thus requiring no internet connection for use. The supporting book, measuring 23cm x 15.5cm (UNESCO standard), consists of 2D and 3D images with explanatory notes for each material. This supporting book discusses fire disaster mitigation materials, including characteristics of fire-prone and non-fire-prone areas, the impact of fires, types of fires, fire classification, mitigation during a fire disaster, causes of fires, fire disaster mitigation scenarios, and conditions of residential and land fires. The developed learning media is deemed suitable based on the average results of user trials at 88.92%, thus the resulting learning media product and supporting book are categorized as suitable.

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