Journal of Engineering Science and Technology
Vol. 20, No. 1 (2025) 31 - 49

PHYSICS ASTRONOMY LEARNING MEDIA BASED ON AUGMENTED REALITY (MAFIS-AR) TO IMPROVE STUDENTS CHARACTER

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Abstract

The purpose of this article is to explore and evaluate the effectiveness of AR-based media in astrophysics education for character development. The primary focus of this research is on how AR can enhance student engagement, creativity, and understanding of abstract scientific concepts. The research conducted is development research with the method in the research design based study (DBR) until the media development stage. The subjects in this study were students who would take the Astrophysics course. The results of this study are augmented reality (AR)-based learning media for the Astrophysics course in improving student character. The character that will be improved in the use of this media is religious (baiman) which is one of the mottos of the Banjar community (baiman, bauntung, and batuah). The results of the learning media study show that all aspects including learning, materials, visual and audiovisual, and software engineering are in the very good category based on the assessment of validators who are media, material, and language experts. In addition, the results of the limited class showed that MAFIS-AR received a positive response from students. The development of AR in physics education has several important roles, one of which is as a learning media for abstract materials in physics education, especially in Astrophysics courses.

Keywords: Augmented reality, Astrophysics, Character, MAFIS-AR, Physics education.

1. Introduction

The use of augmented reality (AR) technology in all aspects is inseparable from the tendency of generation Z who prefer audio-visual media. The presence of AR makes educational content more interesting and interactive, allowing students to see three-dimensional models and photo slideshows of various learning activities, from simple to complex, in real time [1]. The are many applications of AR in the learning process that can be seen from the large number of researchers' interest in these two fields. The Scopus database in 2024 showed 345 articles which are AR research in education with keyword change limited to AR and document type limited to article. The country that published the article is shown in Fig. 1. detailed information for analysis based on the Scopus database is explained elsewhere [2].

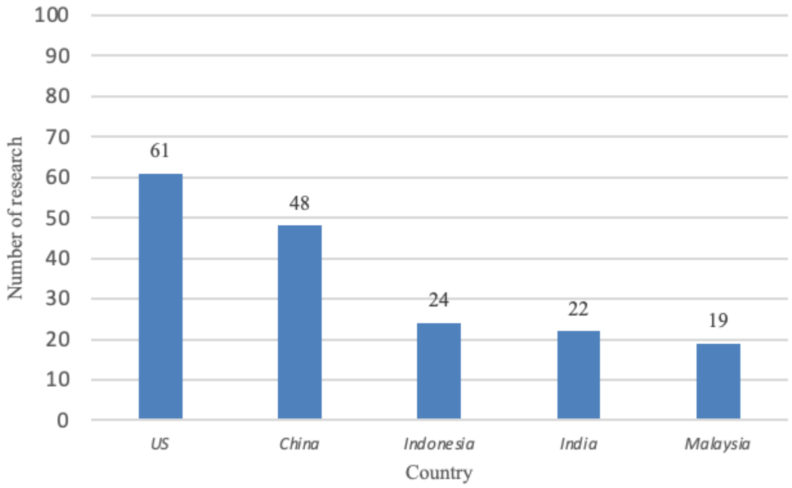


Fig. 1. The country published articles on AR and education.

Indonesia is the 3rd country to publish research about AR in education with 24 articles. There are 7 articles related to the use of AR in education to improve students' skills or learning outcomes [3-8]. AR shows great potential in education. This application is built using Unity game engine and Vuforia which mostly shows that the application reaches 89.5% for perceived usefulness and 86.33% for perceived ease of use [9]. One of the 7 articles is research on physics subjects. The Scopus database from 3 years ago showed studies related to AR and physics learning to improve the ability and skills of students [4, 10]. The integration of AR into educational frameworks, especially in the field of astrophysics, demonstrates the promising potential to enhance student engagement, creativity, and cognitive learning outcomes. AR enables students to visualize and interact with complex astronomical concepts in three-dimensional space, making it more engaging and effective compared to traditional teaching methods.

Recent research indicates that using AR in education can improve students' abstract reasoning skills and enhance their satisfaction and academic achievement [11]. AR also offers students the opportunity to manipulate virtual objects, which can deepen their understanding and retention of scientific concepts [12]. Previous studies have shown that AR-based media in astrophysics education can address the challenges of visualizing celestial objects and their interactions, which are often difficult to grasp through conventional methods. Developing AR teaching materials, such as models of the solar system, significantly boosts student motivation and interest in science [13]. This is supported by findings that AR can cater to diverse learning needs, including those of students with learning disabilities, by making abstract concepts more accessible and understandable [14]. Furthermore, AR enriches the learning experience by creating an inclusive and adaptive environment for all students. Additionally, AR plays a role in enhancing the emotional and motivational aspects of learning. Research highlights that AR not only aids cognitive development but also addresses affective factors, creating a more holistic educational experience [15]. AR engages students emotionally, which is crucial in fields like astrophysics where curiosity drives inquiry. Thus, AR can be a valuable tool in modern educational practices, allowing students to learn and interact with complex scientific concepts more deeply and comprehensively.

This study aims to explore and evaluate the effectiveness of AR-based media in astrophysics education for character development. The primary focus of this research is on how AR can enhance student engagement, creativity, and understanding of abstract scientific concepts. The scope includes analysing various studies related to the use of AR in education and measuring its impact on learning outcomes and character development in the context of astrophysics. The novelty of this research lies in its systematic approach to integrating AR technology into astrophysics education with a specific focus on character development. Unlike previous studies that primarily assess the impact of AR on cognitive or motivational aspects alone, this research specifically evaluates how AR can influence various dimensions of student character, including creativity, empathy, and scientific attitude. The hypothesis of this study is based on the premise that AR, with its ability to create interactive and immersive learning experiences, can significantly enhance student engagement and understanding in the field of astrophysics. AR is considered an effective tool for supporting diverse learning styles and special needs, thus helping all students, including those with learning disabilities [14]. Therefore, this hypothesis suggests that AR not only improves cognitive learning outcomes but also contributes to holistic character development in students.

2. Literature Review

2.1. Augmented reality

AR technology integrates the real world with virtual elements in a three-dimensional environment and displays virtual objects directly and instantaneously. Using AR allows physics material to be transformed into three-dimensional objects. Thus, students can interact directly with these objects. In addition, this technology makes the learning process more flexible, interesting, and interactive, which in turn creates active learning for students. A variety of technologies and approaches are used throughout the world to provide better support for the teaching and learning process. One of these approaches is the use of AR which is currently gaining momentum throughout the world [16].

To support the present study, analysis using a literature database has been done. Detailed information on the way how to do a literature survey is explained elsewhere [17-19]. Based on the Scopus database in 2024 in the US, there are 68 studies related to the use of AR in education. The use of AR in the educational sector is mostly used by medical students. AR has the potential to provide unique experiences for students, especially in the teaching of science subjects [14]. The second country conducting research on AR in the education sector is China. There are 48 articles related to this research. AR research in China is more varied than in the US. AR research in the US does not include physics learning, while in China there are studies that discuss the application of AR in physics learning. Research was conducted on learning media regarding the Doppler effect material [20]. Indonesia is the third country to research the relationship between AR and education, after observing 24 existing documents, it turns out that there is no use of AR in physics learning. Further analysis was carried out on the Google Scholar database. The database shows a lot of research regarding the application of AR for education in Indonesia. The use of AR in learning has been widely used and proven to be able to improve student learning outcomes. Table 1 shows some reports on AR that can improve students' skills. Although AR technology has proven effective in improving learning, student achievement and motivation also need to be considered in developing technology-based learning [21].

Table 1. Some reports on AR for improving students' skills.

No.	Title	Result	Ref.
1	Analysing the effective use of augmented reality glasses in university physics laboratory courses for the example topic of optical polarization	There is an increase in student motivation after learning to use AR. However, AR does not show any achievement in student cognitive. Thus, it is necessary to design AR content to challenge the existing meta-analysis in physics education.	[22]
2	Development of augmented reality integrated teaching materials to improve the critical thinking ability of gen z-students at primary school level	There is a significant difference between the pretest and posttest results which shows the influence of the application of AR-based teaching materials on the critical thinking abilities students in the learning subject of organ systems.	[23]
3	The use of augmented reality to improve students' geometry concept problem-solving skills through the stem approach	This research shows that AR media is effective in improving students' abilities in solving problems on geometric concepts with a moderate level of difficulty using the STEAM approach. The results of this research conclude that integrating ARM media with STEAM learning can improve problem solving abilities in geometric concepts.	[24]
4	The effectiveness of augmented reality in learning vector to improve students' spatial and problem solving skills	The AR module has a significant influence on students' problem solving and spatial skills, as shown by an increase in students' average scores on the pretest and posttest. Learning using AR is more effective than conventional methods because students are generally taught using conventional modules	[25]

Table 1 (continue). Some reports on AR for improving students' skills.

No.	Title	Result	Ref.
5	Development of augmented reality-based interactive multimedia to improve critical thinking skills in science learning	The use of interactive multimedia based on AR improves students' critical thinking abilities compared to before they used it.	[26]
6	Augmented reality for cultivating computational thinking skills in mathematics completed with literature review, bibliometrics, and experiments for students.	AR media plays an effective role in improving students' computational thinking skills in secondary schools. These results indicate that AR technology in mathematics education can create a new teaching approach.	[27]
7	Development of augmented reality application for exercise to promote health among elderly	The results of research on the effectiveness of AR for physical exercise to improve health in the elderly.	[28]
8	Application of augmented reality technology with the fuzzy logic method as an online physical education lecture method in the new normal era.	AR has been developed in the basic physics practical tutorial Sound Wave Resonance which makes students feel comfortable and easy to understand the material.	[29]

2.2. Astrophysics course

The astrophysics course is an elective course in the 4th semester with course outcomes in the form of students being able to apply and utilize science and technology in the field of physics education and being able to adapt to situations faced in solving physics education problems. This is one of the important subjects for students [30]. There are some learning subjects in the Astrophysics course, including (i) introduction, (ii) miracles of the Al-Qur'an, (iii) the Miracle of Human Creation, (iv) the Miracle of the Working Principles of the Human Heart, (v) The Miracle of the Working Principles of Human Lungs, (vi) The Miracle of the Working Principles of the Human Brain, (vii) The Wonders of the Working Principles of the Human Skeleton, (viii) The Wonder of the Creation of the Universe, (ix) The Wonder of the Balance of the Universe, (x) The Miracle of Planet Earth's Balance, (xi) Wonders of Physics Technology, (xii) Other miracles around humans, and (xiii) Facts about Nature's Journey to the Afterlife. The material chosen to be developed in this research is The Wonder of the Balance of the Universe. The materials include (i) the natural constant, (ii) the size of the moon, earth, and sun, and (iii) the distance between the sun and earth.

The development of AR-based physics learning media (MAFIS-AR) in the Astrophysics course because this material is abstract and cannot be presented in class. The material that will be developed in technology-based media is The Wonder of the Balance of the Universe. MAFIS AR will be integrated with the values of the Qur'an. The choice of the Qur'an to build religious character is the majority of the population of South Kalimantan is Muslim. Figure 2 shows the application of MAFIS AR media in astrophysics courses.

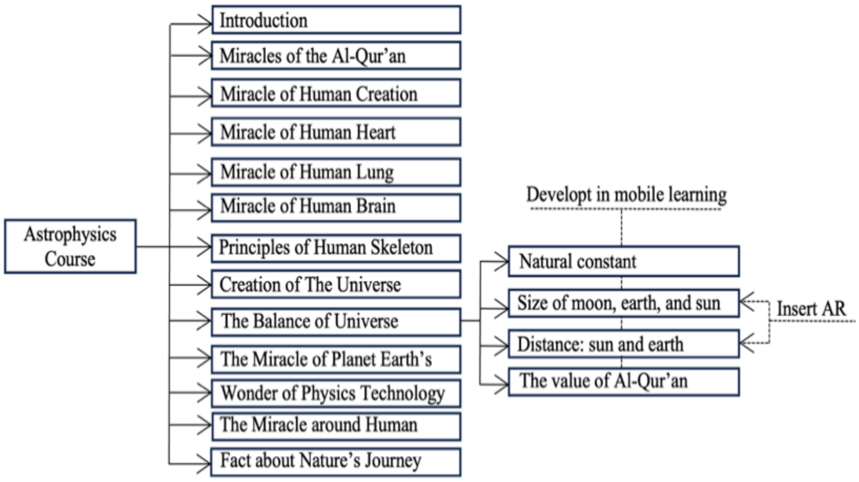


Fig. 2. MAFIS AR application in astrophysics course.

AR is applied to the material The Balance of the Universe. There are three materials in this topic, including (i) natural constant, (ii) the size of the moon, earth, and sun, and (iii) the distance between the sun and earth, while the values of Al-Qur'an are the instillation of religious character values. The material on physical constants includes natural constants and astronomical data on celestial and terrestrial objects. Some examples of natural constants are the speed of light, electron charge, gravity, Planck's constant, Bozman's constant, Avogadro's number, and so on. Astronomical data of celestial bodies and the earth includes scientific information obtained from observations and research on celestial objects and natural phenomena that occur on earth. this data is very important in the study of astronomy, astrophysics, and earth sciences. some examples of astronomical data are planetary mass, planetary radius, orbital radius, and orbital period. The second material is the size of the Earth, sun, and moon. The material on the size of the earth contains the diameter of the earth, the mass of the earth, the acceleration of gravity of the earth, and the period of the earth's revolution around the sun. The material on the size of the moon contains the diameter of the moon, the mass of the moon, the gravitational acceleration of the moon, the distance of the moon from the earth, and the revolution of the moon. The material on the size of the sun contains the diameter of the sun, the mass of the sun, the general constant of the sun's gravity, and the distance from the sun to the earth. The differences between the three celestial bodies are shown in Fig. 3.

The third material is the calculation of the distance between the sun and the earth. The technique for estimating the distance between the Earth and the sun can be done using the estimation method shown in Fig. 4. By knowing the speed of microwaves (the speed of light = 3×10^8 m/s) and the separation distance between the sun and Venus with the separation angles alpha and beta, then using trigonometry techniques, the distance between the sun and the earth can be determined as 1 Au = 1.5×10^8 km. Figure 5 shows a visualization of the calculation of the distance between the sun and the earth in MAFIS AR.

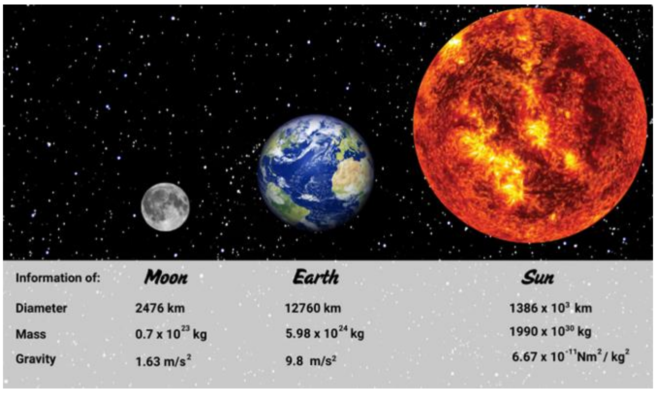


Fig. 3. Size of moon, earth, and sun.

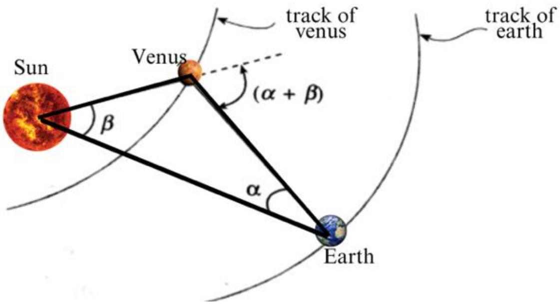


Fig. 4. Calculation of the distance between the sun and the earth.

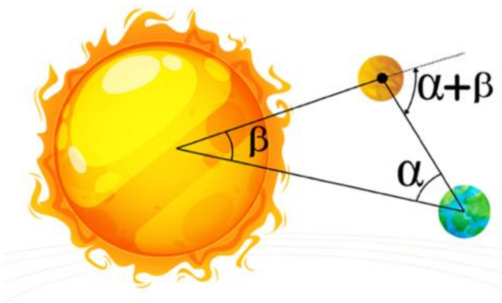


Fig. 5. Distance between the sun and the earth.

In addition to calculating the distance between the sun and the earth, in this material, students are also trained to calculate the distance between the earth and the moon, calculate the radius of the earth, calculate the distance of stars from the earth, calculate the period of revolution of planets, and so on. The fourth material is the verse of the Qur'an which is the instillation of character values for students. Through the first to third material, the verse of the Qur'an shows that God created everything with the right calculation and balance. Some of the surahs of the Quran that are displayed include (i) QS. Al Furqan-2, (ii) QS. Al-Hijr-21, (iii) QS. Al

Qamar-49, (iv) QS. Yuunnus-5, (v) QS. Yaasin-40, (vi) QS. Ar-Rahman-5,7, (vii) QS. Al-Mulk-3, and (viii) QS. Al-Qashash-68.

MAFIS-AR in this material was developed by collaborating with the use of technology-based media and learning models to instil character values in students. Collaboration between the use of media and the correct learning model will result in achieving learning goals and improving student skills. A good and consistently carried-out learning process will produce good character patterns for students [31].

2.3. Student's character

Character and learning outcomes describe aspects of achieving very important competencies at school [32-35]. One effort to improve character is to provide religious lessons in the learning process. Religious education plays an important role in preventing someone from committing actions that are prohibited by religious teachings. The application of Islamic education aims to increase devotion to Allah SWT, while noble morals are a reflection of the faith adhered to by each individual. Therefore, a combination of faith and piety within a person can keep them away from destructive behaviour, slander, and actions detrimental to society, which also have the potential to endanger the unity and unity of the nation in the future. Habits that are carried out consistently will form a person's good character [14].

Character values in students can be trained by linking typical phenomena that exist in the surrounding environment which are known as local wisdom. Indonesia is one of the countries that prioritizes local wisdom to be included in the learning process. One of the local wisdoms in Indonesia in South Kalimantan is covering the wetland environment. The wetland environment in South Kalimantan instils the character of wasaka for all South Kalimantan people. Wasaka's character is a value that can be instilled in students and becomes the life motto of the people of South Kalimantan. Wasaka symbolizes a figure who is hardworking, does not give up easily, has strong determination and commitment, and is responsible for completing the efforts he has made to achieve his goals.

The other characters inherent in the Banjar people are baiman (religious), bauntung, and betuah. In line with the wetland environment that instills character values, Indonesia is a country that instills character values as competency achievements for students based on Pancasila values known as the Profil Pelajar Pancasila (Pancasila Student Profile). Profil Pelajar Pancasila includes (i) religious, piety, and good morals, (ii) global diversity, (iii) mutual cooperation, (iv) creativity, (v) critical reasoning, and (vi) independence.

3. Method

This research has used design-based learning (DBR) to design MAFIS AR. The procedure has 4 steps, including 1) identification and problem analysis, (ii) designing MAFIS AR, (iii) developing MAFIS-AR, and (iv) reflection. The subject in this study is physics education students who take the course Astrophysics. There is some material in the astrophysics course. MAFIS-AR consists of materials: (i) natural constant, (ii) the size of moon, earth, and sun, (iii) the distance between the sun and earth.

4. Results and Discussion

4.1. Identification and problem analysis

Astrophysics is an elective subject in the physics education master's study program. Astrophysics studies objects in the sky and their behaviour. Astrophysics courses are elective courses. This course is expected to provide a foundation of knowledge and broad insight as well as a strong belief for students in God, as a provision for life in society, both as individuals, educators, and as civilized creatures of God. Thus, they can be responsible for natural resources and the environment in carrying out their religious obligations and their caliphate duties on earth. Students are expected to have a general knowledge base about physics and technology based on the Al-Qur'an. Thus, they can think, behave, and act Islamically in understanding themselves and their environment as creatures and realizing the greatness and majesty of God, their creator. In the era of digital, the learning system in universities especially in Indonesia has shifted to digitalization based on e-learning. The Covid-19 pandemic has overhauled the education system in Indonesia. Thus, learning in higher education now uses an online model by utilizing information technology. AR is a type of e-learning that can make abstract material real. AR can be applied in various ways in formal and non-formal education. Teachers can prepare attractive visual tools to increase students' learning motivation. The application of AR in the educational sector can encourage students to create AR elements related to the material being studied. By creating their content, students become more active in the learning process and develop skills and competencies at a higher level [36].

In the astrophysics course, a learning module based on Al-Qur'an values has been developed, but it is only applied via flip pdf. As time goes by, it is necessary to update the media. One way is to use AR to make abstract celestial objects visible. Based on this, AR-based learning media was developed for the astrophysics course which is expected to be able to train students' religious character.

4.2. Learning media design

MAFIS-AR's design is that apart from using barcodes for celestial objects and the distance between the sun and the earth, it also takes the form of an APK that can be run on the smartphone. This will add new information for the teaching and learning process [37, 38]. The flowchart for the MAFIS AR design is shown on Fig. 6.

MAFIS-AR is made using unity and vuforia. On the first page, four menu options will appear, namely learning materials, AR, developers, and exit. The learning material menu contains five menus of celestial body balance materials. The first menu contains natural constants which explain the physical constants used in astrophysics. The second menu regarding the size of celestial bodies includes radius, mass, rotation period, and revolution. The third menu contains data on calculating the distance between the sun and the earth based on physics concepts. The fourth menu contains verses from the Qur'an related to astrophysics, aimed at instilling religious character in students.

In the second main menu, there is an AR menu that aims to visualize AR on astrophysics material. In this section, there are three menus for running AR, namely: (i) the size of the sun, earth and moon, (ii) the distance between the sun and earth, and (iii) the solar system. The menus use barcodes to display AR. Some of these barcodes are shown in Table 2. The third menu from the main menu is developer. This menu contains information about the application developer. The last menu on the main menu is the exit menu. This menu functions to exit the MAFIS-AR application.

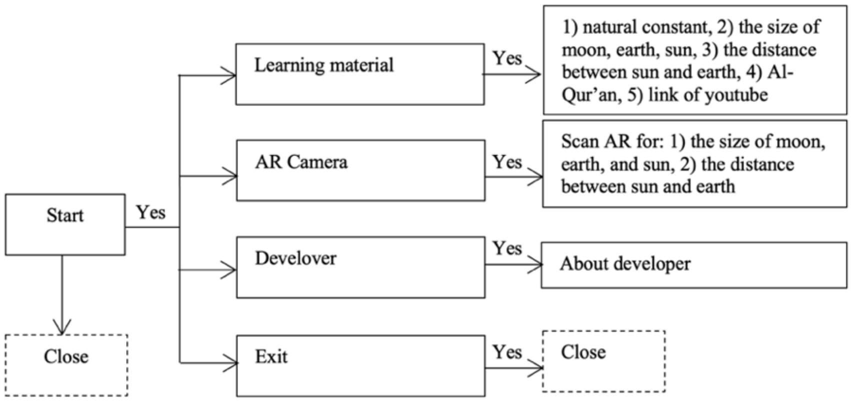


Fig. 6. Flowchart of MAFIS-AR.

4.3. Developing MAFIS-AR

MAFIS-AR was created using Unity and vuforia. Figure 7 shows the one of development stages using these two applications using Unity and showed the arrangement of assets and layouts in Unity.

Fig. 7. Development MAFIS-AR using Unity and Vuforia.

Unity is an application that is usually used to develop games, but in education also used to develop learning media. In Unity, several MAFIS-AR layouts are created according to the flowchart in Fig. 8. MAFIS-AR was built to form an apk that can be run on a smartphone. Figure 8 shows the MAFIS-AR icon that is installed on the smartphone.

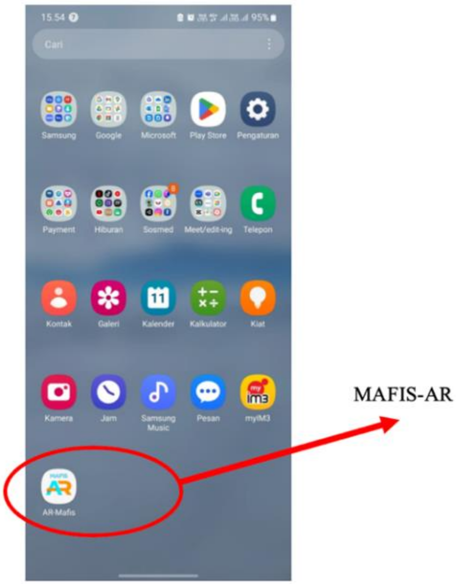


Fig. 8. MAFIS-AR on smartphone.

The MAFIS-AR application that has been installed on a smartphone. This application can run on Android and iOS systems. Table 2 shows the appearance of MAFIS-AR when run on a smartphone. Table 3 shows the barcode used in the AR scan. There are 3 barcodes used according to the flowchart in Fig. 1. One of the AR scan results in the AR Cam menu is shown in Fig. 9.

Table 2. MAFIS-AR in smartphone.

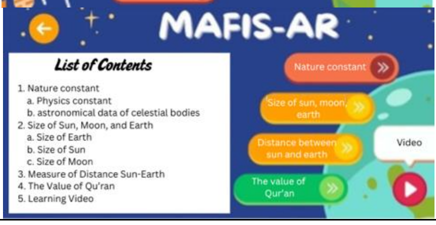
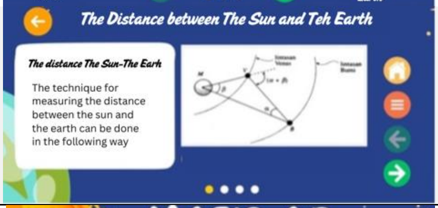
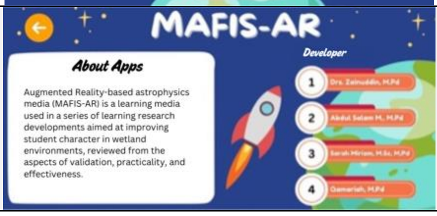
<table>
<tr><th>Appearance in smartphone</th><th>Information</th></tr>
<tr><td>
</td><td>The first screen enters the MAFIS-AR application</td></tr>
<tr><td>
</td><td>Main menu:
(i) Learning material, (ii) AR-Cam, (iii) About developer, and (iv) Exit</td></tr>
<tr><td>
</td><td>Learning Materi: (i) natural constant, (ii) the size of the moon, earth, and sun, (iii) the distance between the sun and the earth, (iv) the value of Qur'an.</td></tr>
</table>

Table 2 (continue). MAFIS-AR in smartphone.

Appearance in smartphone	Information
	Learning material of natural constant, there are 2 scenes in this part.
	Learning material of size of the moon, earth, and sun, there are 3 scenes in this part.
	Learning material of distance between sun and earth, there are 3 scenes in this part.
	Scene of AR Cam, there are 3 menus for AR scan.
	Scene about information of developer

After being developed, the next step is the MAFIS-AR validation process by 5 validators using a validation questionnaire. The validation questionnaire uses a Likert scale with the highest value being 5 and the lowest value being 1. Validators consist of media experts, material experts, and language experts. The validation result show in Table 3.

Table 3. MAFIS AR validation results.

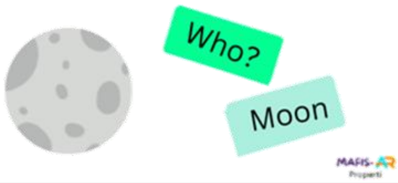
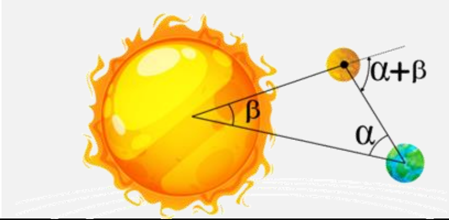
Aspect	Average score	Category
Learning process	4.60	Very good
Learning material	4.65	Very good
Visual and audio	4.64	Very good
Software engineering	4.57	Very good

The average results for each aspect are in the very good category. Meanwhile, the overall average score is 4.61, which is in the very good category. This shows that MAFIS AR is very good for use in learning astrophysics in the learning process, learning material, visual and audio, and software engineering. In the learning process aspect, the value is 4.60, which is in the very good category. This shows that the learning material is following the learning achievements of astrophysics. The assessment on the second aspect is the learning material aspect. The learning material aspect has a value of 4.65, which means it is in the very good category. This shows that in the following sections: (i) the concept of the material is appropriate, (ii) the description of the material is appropriate, (iii) the language used is appropriate, and (iv) there are no double meanings in the sentences. The assessment on the third aspect is audio and visual.

The results show that this aspect has a value of 4.64, which means it is in the very good category. These results show that: (i) the layout proportions are good, (ii) the colour proportions are good, (iii) the background selection is good, (iv) the font selection is good, (v) the font size selection is good, (vi) the navigation buttons are attractive, (vii) the navigation button display is consistent, (viii) the animation movement is attractive and smooth, (ix) the animation is following the material, and (x) the supporting images are following the material. The assessment of the fourth aspect is software engineering aspect, obtained a value of 4.57, which is in the very good category. This shows that: (i) MAFIS-AR operation is easy, (ii) instructions for using the media are clear, (iii) MAFIS-AR is an interesting work, (iv) MAFIS-AR provides innovations in classroom learning, (v) the MAFIS-AR program runs smoothly, and (vi) MAFIS-AR is in line with current developments. During small class tests, students were enthusiastic and gave positive responses to MAFIS-AR. Students also listen carefully to the verses of the Al-Qur'an. MAFIS-AR is a technology-based learning media for astrophysics courses which is expected to be able students' religious character in a wetland environment. Figure 9 shows that the application of MAFIS-AR when scanning barcodes. Table 4 shows some barcodes in MAFIS-AR.

Fig. 9. One of the AR scan results in the AR Cam.

Table 4. Barcode in the MAFIS-AR.

Barcode	Information
	Barcode to display AR containing information about the sun
	Barcode to display AR containing information about the earth
	Barcode to display AR containing information about the moon
	Barcode to display AR containing information about the distance of the sun and earth including the revolution and rotation of the earth

4.4. Reflection

Although the average validation results are in the very good category. There are several comments and suggestions from validators. Some of the comments are: (i) At moving animation speeds, whenever possible use a scale consistent with the actual values, and (ii) there should be a start page with instructions for using the application. Suggestions from validators are used as revisions to the MAFIS-AR application before being disseminated in the next research. Improvements according to the validator's suggestions have been made, including making the barcode more visible. Thus, when scanned the AR application runs smoothly. Technology-based interactive learning media and character education have proven to be significantly effective in improving learning outcomes [39, 40]. AR is an alternative to traditional distance learning that can be accessed anytime and anywhere [41]. The implications of implementing AR in learning can also help teachers optimize the use of media and other learning approaches. One of them is the use of STEM using AR media [42]. Finally, this study adds new information for the teaching and learning process, especially for physics subjects as reported elsewhere [43-48].

5. Conclusion

MAFIS-AR is a technology-based learning media for astrophysics courses which is expected to be able students' religious character. The character values instilled are religious characters. MAFIS AR was developed using the DBR development method. There is some material in the astrophysics course. MAFIS-AR consists of materials: (i) natural constant, (ii) the size of the moon, earth, and sun, and (iii) the distance between the sun and earth. MAFIS-AR validation results in a very good category, and it can be used to train students' religious character.

Acknowledgment

Thanks are due to the Universitas Lambung Mangkurat which funded this research through a competitive grant with contract number 1374.118/UN8.2/PG/2024.

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