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Science Learning Innovation Using Augmented Reality Technology to Achieve Sustainable Development Goals (SDGs) through Increasing Students' Critical Thinking Abilities

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Abstract: This study aims to produce inquiry-based AR media that is feasible, practical, and effective to improve students' critical thinking skills which can ultimately achieve the SDGs goals in the aspect of mutual education. This study uses a 4D model development procedure. The subjects of this study were grade VIII students at one of the Mataram City Junior High Schools consisting of 3 classes. Data collection techniques used questionnaires, observation sheets and test instruments developed according to critical thinking indicators. Data analysis techniques used Aikens'V for feasibility testing, practicality percentage testing and normalized gain testing to test the hypothesis. Based on the results of the study, it was obtained that the Augmented Reality (AR) Media developed was included in the category of feasible and practical for use in science learning and could increase students' interest in learning. AR media supports students in the inquiry learning process. The use of AR media makes it easier for students to learn and provides fun and current things. Learning using AR media facilitates active and creative learning for pupils since it is supported by investigative activities.

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Introduction

Education in this modern era faces a major challenge in producing graduates who not only have extensive knowledge, but are also able to develop critical thinking skills needed to face the complexity of global challenges (Ramdani, et al., 2021). In an effort to achieve the Sustainable Development Goals (SDGs), education plays a role as one of the important pillars that can form a generation that cares about the environment, innovates, and is able to think critically (Tareze & Astuti, 2022). Sustainable development aims to improve the quality of life for both present and future generations. The Sustainable Development Goals (SDGs) are a set of 17 objectives for sustainable development (Purnamasari & Hanifah, 2021). Education for Sustainable Development (ESD) is one approach to achieving the SDGs (ESD).

The quality of education in Indonesia remains generally low (Nurfatimah et al.,2022). One of them is Indonesian students' insufficient critical thinking abilities (Saputri & Rinanto, 2018; Zubaidah et al., 2018). Saputra et al. (2019) discovered that students' critical thinking abilities remain inadequate, as evidenced by the symptoms of difficulties that dominate the outcomes of observations during the scientific learning process in the classroom. Teachers are not yet accustomed to designing technology-based learning devices (Hadisaputra, et al., 2019; Ramdani, et al., 2023). In fact, the use of information technology in learning plays an important role in improving the quality of learning (Maghfiroh, 2022). In addition, the

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availability of technology-based open materials in schools is still limited. Natural Science (IPA) learning is the main focus for developing students' understanding of natural phenomena and teaching how to use this knowledge to achieve sustainable development goals (Erlina, 2021).

Augmented Reality (AR) technology is one of the promising innovations in increasing the effectiveness of science learning. By integrating AR into learning, students can experience direct interaction with open materials, making learning more dynamic, and triggering the development of their critical thinking skills (Aripin & Suryaningsih, 2019). AR learning media is a media that combines images, videos, audio, and text into a real environment. AR media has the potential to attract and motivate students (Dewi & Sahrini, 2021). By using AR technology, objects that were previously two-dimensional will appear to be real and blend with the surrounding environment (Masri & Lasmi, 2018).

The use of AR in science learning can create a more comprehensive learning experience, where students not only understand concepts theoretically but can also observe, explore, and test these concepts in an environment similar to real conditions (Kanti, et al., 2022). In this way, learning is not only active and fun but also provides a foundation for the development of critical thinking skills needed to face complex challenges in the era of globalization. The integration of AR technology in science learning is expected to make a significant contribution to achieving the SDGs, especially those related to quality education, innovation, and climate change action. This effort is expected to create a generation that is not only skilled in science but also has a deep understanding of its impact on environmental sustainability and is able to produce creative solutions in facing future challenges.

AR media in this study displays visualizations of abstract concepts such as in the human digestive system material, one of the concepts displayed in a real and interactive way is the concept of the food processing process into the body. This AR media is also equipped with an inquiry learning phase and integrates critical thinking indicators into the media. This aims to train students to think critically through learning using AR media. This research is a new innovation because it is able to display abstract concepts between theory and practice, making it easier for students to understand complex science concepts. In addition, the application of AR in science learning not only enriches the learning experience, but also encourages students to analyze, evaluate, and create solutions to science problems that are relevant to global issues. This supports the achievement of science learning that is more contextual, meaningful, and oriented towards achieving SDGs, especially the goals of quality education and technological innovation.

Research Method

This research process is referred to as research and development. This study approach adheres to the 4D development model (define, design, develop, and disseminate) (Thiagarajan 1974) (Thiagarajan, 1974). This study focuses on creating Augmented Reality (AR) media that incorporates local expertise and is realistic and practical for use in scientific education. The subjects of this study were grade VIII students from one of Mataram City's junior high schools, which had three courses. Expert lecturers and media specialists complete a validation form to validate the learning gadget. Furthermore, the validator is expected to offer a general assessment and recommendations for the AR media that has been generated, as well as whether the instructional materials that have been created may be considered legitimate or invalid. Teachers' and students' answers to learning using AR media are collected using a validation questionnaire and a questionnaire sheet. Using the validation % formula, the amount of validity is ascertained by analyzing expert validation data.

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Results and Discussion

The development stage, which includes validity testing, is the emphasis of this study's 4-D model. The define and design phases are the initial steps in creating Augmented Reality (AR) content that incorporates local knowledge. A literature study and content analysis are conducted at the define step. This section determines a variety of things, including the equipment required, the quantity of instruments created, the kind of instrument used, and the material—specifically, the Human Digestive System. Additionally, student analysis, task analysis, concept analysis, and learning target descriptions are carried out. The major goal of the design stage is to create prototype devices for test preparation, media selection, and format selection. AR media products use an inquiry learning model. According to Eggen and Kauchak (2012), guided inquiry learning consists of many broad processes, including orientation, problem formulation, hypothesis submission, data collection, hypothesis testing, and conclusion formulation. The goal of these phases is to underline the importance of answering the numerous difficulties offered in the instructional materials created. In addition to construction of learning activities according to the syntax of the learning model. Inquiry learning attempts to give students with a method for developing intellectual talents (thinking skills) through a reflective thinking process.

During the design stage, researchers compile AR material using flowcharts and storyboards. Then, gather supporting resources like photographs, videos, animations, and images. Following the flowchart and storyboard, all collected resources are entered into the unity software application. The purpose of creating flowcharts and storyboards is to offer an overview of the form and content of the e-book display. Researchers use flowcharts and storyboards to turn AR material into a comprehensive product using Unity. The AR media product's outcomes are then packaged as an application and incorporated into the learning process as a product design. AR media also has a user guide function, which helps students comprehend the media being created. AR media has been enhanced with critical thinking skill indicators, guided inquiry phases, and local knowledge notions. Figure 1 shows the outcomes of the creation of an integrated inquiry-based e-book for character education.

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Figure 1. AR Media Home Page

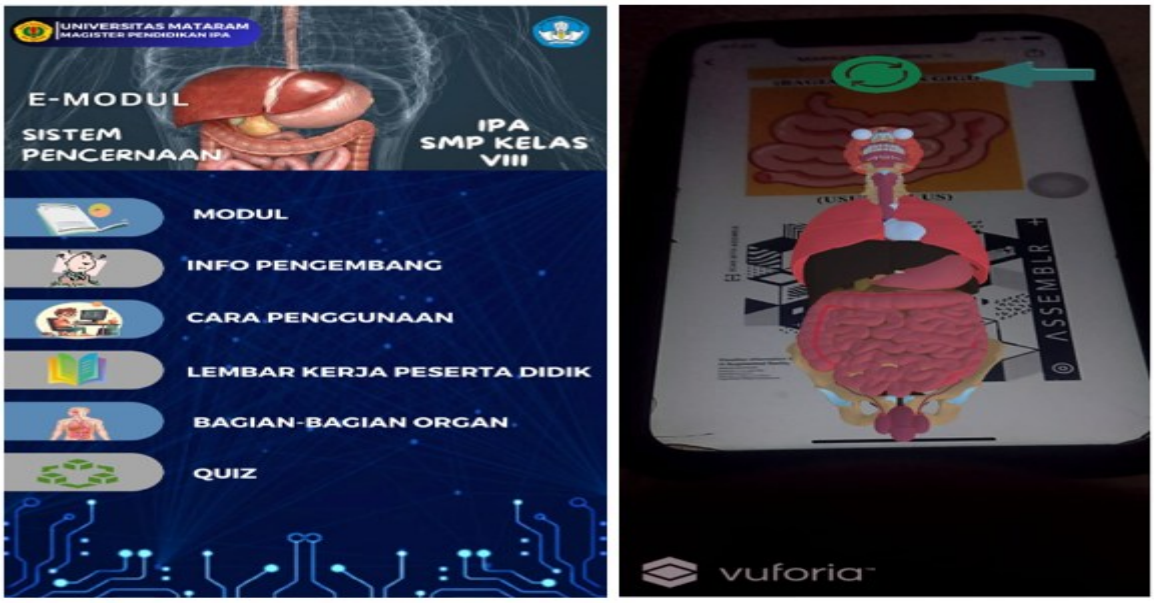

Figure 2. AR Media Content Page

This inquiry-based augmented reality (AR) content was built using previously created flowcharts and storyboards. The flowcharts and storyboards were made as images to help with the process of generating AR material. At this point, supporting resources such as hosting and domains, photos, backdrop creation, movies, sound effects, button icons, and learning animations were gathered. At this stage, critical thinking skills instruments were also developed. Figure 3 shows the validation findings for AR media.

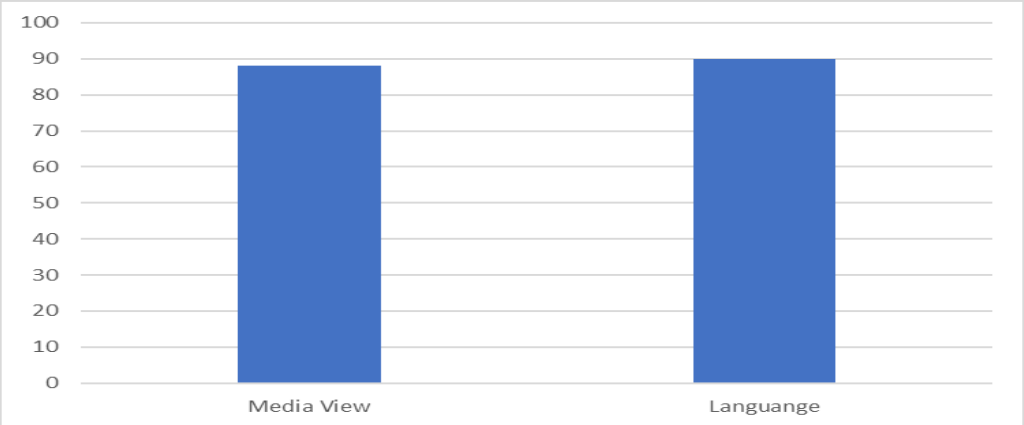

Figure 3. Augmented Reality (AR) Media Validation Results

Figure 3 illustrates that the overall average validity value of AR media is 89%, with extremely valid criteria. When evaluated individually, the Display Quality component had an average validity value score of 88% with extremely valid criteria, while the Language aspect received an average score of 90%. This demonstrates that the AR media generated may be utilized effectively in scientific education. According to Saadah and Suhartini (2017), components of content quality and aims include correctness, significance, completeness, balance, attractiveness, fairness, and fit to the student's circumstances. The findings of this study are corroborated by the findings of Dewi and Anggaryani (2020), who discovered that creating physics learning media with Android-based augmented reality on Optical Instrument Material is possible for use as a learning medium.

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These findings indicate that the AR media given has the potential to pique students' interest in learning more thoroughly independently through the virtual environment, resulting in student independence in learning (Wati, 2021). Instructional quality is related to ease of use of media, assistance in learning, teaching flexibility, evaluation quality, and motivation quality (Susilo et al., 2017). Validity of Results This means that AR media provides flexibility for deeper learning (Rahmawati & Susilowibowo, 2020) and facilitates student learning (Fitri & Ardipal, 2021). These results indicate that the features on AR media function well and are easy to use. Data on the practicality of learning using AR media collected through student and teacher responses to science learning using inquiry-based AR media are presented in Tables 1 and 2.

Table 1. The Percentage of Student Responses

Respondents	The attractiveness of inquiry-based AR media	Ease of Use	The role of inquiry-based AR media in the learning process	Average
Students	83%	80%	75%	79.3%
Criteria	Very practical	Practical	Practical	Practical

Table 2. The percentage of teacher responses

Respondents	Content Quality and Purpose	Quality of Learning and Instructional	Average
Teacher	82%	84%	83%
Criteria	Very practical	Very Practical	Very Practical

According to Tables 1 and 2, the average proportion of teacher and student answers to all areas of learning have practical requirements, implying that inquiry-based AR media in scientific learning falls into the practical category.

This learning media can be used independently. This media is also developed complete with instructions for use to guide students in carrying out learning. The material created is also as appealing to pupils as possible in order to encourage them to participate in learning. Some students believe that using e-learning resources is enjoyable. Yilmaz (2017) also stated that student satisfaction and motivation affect learning outcomes. Augmented reality (AR) is a technology that converts virtual things, either two-dimensional or three-dimensional, into a real-world environment that is displayed simultaneously (Utami et al., 2021). AR can be used via mobile phones using the Android operating system. This is because the Android system will support strategies in the learning process in the digital era used by teachers today. AR as a learning medium may be utilized to make the learning process more dynamic and enjoyable, hence improving students' critical thinking abilities (Retnaningtiyas et al., 2021).

According to Martín et al. (2010), AR-based interactive multimedia's 3D interaction features help pupils quickly grasp topics. Furthermore, the technology provided enables students to engage with the physical world electronically rather than physically, which is very useful in scientific education (Budiarti et al, 2020). The use of AR technology on mobile devices allows for the creation of new sorts of applications and services that can improve the quality of scientific instruction (Yanti & Sari, 2021). AR-based media makes it easier and more enjoyable for elementary school teachers to learn. AR also enables for the exploration of more in-depth teaching approaches, particularly in primary school science education. However, many teachers have not implemented this teaching method in scientific education. Students do not actively participate in learning because learning is still centered on the teacher. Lectures, Q&A , and assignment is the method used.

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Augmented reality can also promote social and cognitive activities, motivation, and critical thinking by emphasizing physical movement, allowing students to be active learners and teachers to experiment with new learning strategies (Amiruddin et al, 2022; Anshori et al, 2021). In addition, the results of previous studies have proven that augmented reality is effective in helping students achieve conceptual understanding, both abstract concepts and complex concepts (Rahayu et al, 2018; Aditia et al, 2022). Furthermore, education in the contemporary period accelerates instructors and students' integration of technology to attain 21st century abilities, which are quickly developing. AR in learning offers several benefits for attaining learning success since it contains engaging material, namely a multimodal presentation that encourages students to actively participate in learning. This exhibit helps pupils visualize abstract material ideas in concrete ways.

AR content can include text, photos, movies, and 3D objects. This can help people listen, develop new vocabulary, and learn different languages (Arti & Ikhsan, 2020). Furthermore, AR is a technology that uses a computer webcam, camera, or even special glasses to bring data from the virtual world into the actual world (Choirudin et al., 2020). AR is used as a learning medium in a variety of ways, including Student Worksheets (LKS), game-based, e-modules, and apps, as well as for performing practicums. However, in every learning media used there will be advantages and disadvantages. According to (Siahaan et al., 2019) the advantages of augmented reality are: 1) the learning media used becomes more interactive, 2) displays real objects in a virtual state, 3) can be widely implemented in various media and 4) easy to operate. While the disadvantages of augmented reality as a learning medium are: 1) sensitive to changes in perspective, 2) the selection of augmented reality as a learning medium is still rarely used, and 3) takes time in the manufacturing process.

AR is an interactive technology that combines actual and virtual elements to create a three-dimensional (3D) object that can be viewed on the user's smartphone device. Augmented Reality works by detecting images or photographs known as markers using a cellphone or smartphone camera. When used, augmented reality-based learning media is supposed to help teachers offer more entertaining teaching materials. This learning medium can also serve as a substitute for appropriate media since it can present biology lessons that are thought to be challenging for students to comprehend in a contextual setting. In addition to theoretical instruction, augmented reality applications can display images with eye-catching displays, animations, videos, and other content. This can increase student learning outcomes by encouraging students to be more creative and active as well as by improving their comprehension of the course. It is strongly advised that teachers employ augmented reality-based learning materials to enhance their students' learning results since, according to research by Halidi et al. (2015), students enjoy using them because they encourage greater student participation in the learning process. Additionally, this medium aids pupils in organizing and remembering the knowledge included in the educational materials they have been given.

Augmented Reality provides benefits to teachers and students in learning. The advantages or benefits of learning using Augmented Reality include students becoming easier to learn, because students prefer to do it directly or practice rather than just giving theory. The internet substantially aids instructors and students in finding learning resources to use during the learning process. The teaching and learning process using Augmented Reality media is more interesting, for example by displaying images or sounds so that students are more enthusiastic about learning. Whatever it is, there are usually positive and negative impacts, without exception the learning process using technology. The negative impacts of learning using technology are as follows; the learning process can only take place in schools

with complete equipment, for schools that do not have complete technological equipment, they will be left behind, and students from graduates of these schools will have difficulty if they enter secondary schools in big cities with complete technological equipment. Students frequently prefer to play games during class rather than actively participating in the teaching and learning process. such that pupils are unable to focus and comprehend the lessons being taught (Harliawan et al., 2014).

Conclusion

Based on the research findings, the Augmented Reality (AR) medium produced was deemed practicable and practical for application in scientific education, with the potential to boost students' enthusiasm in learning. AR media supports students in the inquiry learning process. The use of AR media makes it easier for students to learn and provides fun and current things. Learning using AR media encourages pupils to learn actively and creatively since it is accompanied with exploratory tasks.

Recommendation

Recommendations for schools can use Augmented Reality (AR) learning media as an innovative learning resource in learning. Recommendations for further research to use AR media integrated with local wisdom and SDGs to improve the quality of learning.

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