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Development of Augmented Reality-Based Digital Learning Media for Grade V Elementary School on the Topic of Food Chains

Milda Qothruntina Istmadelia[1*], Dewi Nilam Tyas[1]

[1]Department of Elementary School Teacher Education, Faculty of Education and Psychology, Universitas Negeri Semarang, Semarang, Indonesia.

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Corresponding Author:
Milda Qothruntina Istmadelia
milda.ismadelia@gmail.com

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Abstract: This research focuses on developing Augmented Reality (AR)-based digital learning media to enhance the learning outcomes. The research follows the Research and Development (R&D) model with the ADDIE development approach, aiming to create learning media that can improve students' learning outcomes in the topic of food chains. The material validation scored 89.5, while the media validation scored 87.5, indicating that the media is deemed suitable for use. The normality test on a large scale yielded results of 0.99 and 0.21, signifying normal data distribution. Furthermore, the t-test results on a small scale were 0.00, and the N-Gain test on a large scale scored 71%. The normality test on a small scale yielded results of 0.55 and 0.42, indicating normal data distribution. The t-test on a small scale resulted in 0.01, and the N-Gain test on a small scale scored 84%, categorizing the effectiveness of Augmented Reality-based digital learning media on the topic of food chains as moderate. Based on the research findings, it can be concluded that an effective AR-based digital learning media on the topic of food chains has been successfully created to enhance the learning outcomes of fifth-grade students at Kasepuhan 02 Elementary School in Batang.

Keywords: Augmented reality; Education; Learning media; Learning outcomes

Introduction

Science and technology from year to year experience very rapid development. The era of Revolution 4.0 is characterized by the development of the internet and digital technology that makes everything connected without borders (Javaid et al., 2024; Lee et al., 2018; Mukri et al., 2019). There are many discoveries in the field of technology and the sophistication of communication tools that make it easier for users to do their daily work. This development is not only felt in the field of technology and information but in other fields such as industry, and science, and the field of education is no exception, in this field, it can be seen from several changes in the curriculum system (Laksana, 2021). Curriculum changes are made in accordance with the demands of the times, where a new curriculum is currently being implemented, namely the independent curriculum (Pamorti et al., 2024).

In the world of education, many teachers do not utilize technology so the learning activities carried out are less interesting for students. This makes learning less effective. Based on this, the world of education really needs innovation and presents technology that can support the learning process. One of the innovations that can support learning activities is to use of learning

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media. Media is the key to creating interaction in the learning process (Fitri & Erita, 2023). Currently, the development of technology-based learning media is being intensively applied in the world of education (Wardoyo et al., 2021).

According to Mubarok et al. (2021), learning media can be interpreted as a supporting tool in the teaching and learning process, namely anything that can be used to stimulate the thoughts, emotions, attention, and skills of students, so as to facilitate the learning process. Learning media is a tool that can help convey learning material (Fatayan et al., 2023). Rahayu & Wulandari (2024) added that learning media is anything that can be used as a tool to convey information to recipients to encourage students' mindset, interest, and enthusiasm to create effective learning. Based on some of the above definitions, it can be concluded that learning media is a means that can be used to stimulate thoughts, emotions, and attention so that it can create effective learning.

According to Hartono et al. (2020), learning media used during lessons can captivate students. In addition, learning media are also able to arouse student curiosity and stimulate student activeness in learning (Safitri et al., 2023). By using learning media, it will create fun learning. In addition, the existence of media in learning is able to become a bridge between teachers and students (Febriyanti et al., 2021). By using learning media, the teaching and learning process will run effectively and efficiently (Anjarani et al., 2020). Therefore, the role of learning media today is very important. The provision of dynamic learning media and methodologies will provide enthusiasm and dialog in developing students' potential optimally. With the development of an increasingly advanced digital world, if utilized optimally, it will have a significant influence on the pattern of interaction between teachers and students. Teachers are expected to create technology-based learning media (Cheng & Tsai, 2019).

Based on the results of interviews that have been conducted by researchers with teachers at SD Negeri Kasepuhan 02 Batang, it is found that the learning system used by teachers to students who tend to use conventional learning. Conventional learning that is theoretical in nature using static images or blackboards still occurs. This is still possible if school facilities are not adequate to visualize certain materials. Food chain learning materials delivered by teachers to students also only use lecture techniques so that students become passive. This will lead to a lack of motivation for students to be able to learn the learning material delivered by the teacher. In addition, the learning media on food chain material used is still in the form of printed images only. The result is that students feel bored and bored and unsatisfactory results are obtained. This is by obtaining data on the science value of class V Food Chain material with an average value of the provisions of the Minimum Criteria value of 70. class V meets the kkm is 10 out of 35 students, which means that only 25 students reach the Minimum Criteria value.

Innovation in learning media on digital-based food chain material is a solution to existing problems. The development of technology is increasingly advanced, and integrating technology into learning media is interesting in the learning process carried out by teachers to students. Digital learning media can refer to graphical and interactive representations of an ecosystem or food community in virtual or digital form. This learning media can illustrate the correlation or relationship between trophic organisms and energy flow in the new ecosystem in the learning process. These results can overcome some of the obstacles that arise and can certainly improve student learning outcomes and understanding of the food chain. One of the efforts that can be made is by applying augmented reality technology when delivering learning materials related to food chains.

Currently, educators are always trying to involve technology-based media in the world of education (Amirahma & Setyasto, 2024). One of the latest interesting technology-based media is augmented reality media. Augmented Reality (AR) is a technology that combines digital elements with the real environment, creating an interactive experience that enriches user perception. Augmented Reality is a technology that combines 2D or 3D virtual objects and then projects them in real-time (Hutahaean et al., 2022). Students become active when learning takes place because the media is supported by 2D and 3D images that feel very real (Liang et al., 2023; Listiyani et al., 2021; Zhao et al., 2023). From some of the above opinions, it can be concluded that Augmented Reality (AR) is a digital technology that can be projected into the real world.

The utilization of AR technology also has a positive impact on the attractiveness of learning. Augmented Reality (AR) can provide a more interactive and interesting learning experience for students (Hidayat et al., 2022). The same thing was also conveyed by Egaji et al. (2022), AR can strengthen student motivation to learn new things and improve educational realism-based practices. According to Khoiriyah (2021), AR-based learning media can facilitate students' understanding of the material being taught. This is in line with the opinion of Mardiyah et al. (2020) which states that AR can increase student involvement in learning. In the world of education, AR creates a dynamic and interactive learning environment, providing opportunities for educators to deliver material in relevant innovative ways. Juwita et al. (2021) added that AR is very effective for improving learning experiences, especially in

education. Augmented Reality media certainly has many advantages, among others: more complex, can be used in general, depicting objects that feel real, cheap, and easy to use. However, it also has the disadvantage that it requires a lot of memory when making media (Prananta et al., 2024).

Previous research conducted by Jannah & Atmojo (2022) with the title "Digital Media in Empowering 21st Century Critical Thinking Skills in Science Learning in Elementary Schools". The results showed that the forms of digital media innovation in empowering 21st-century critical thinking skills in science learning in elementary schools include: digital educational games, videos, YouTube, PowerPoint, Macromedia/Adobe Flash, digital comics, e-books, flipbooks, augmented reality, virtual reality, educational websites, educational television, and educational applications, such as the teacher's room, quipper school, and smart class.

In another study by Qorimah et al. (2022) with the title "The Need for Augmented Reality (AR) Based Learning Media Development on Food Chain Material. The results of this study indicate that the concept in the analysis of food chain material is 12.5% concrete and 87.5% abstract. Based on field studies of teachers and students in learning using learning media using image media, students are less interested because the images are less colorful. Teachers and students also need to improve the use of media, one of which can use AR media to make it interesting. For that Augmented Reality (AR) media is needed on food chain material.

Similar research was also conducted by Syarif et al., (2022) with the title "Development of Science Learning Media Based on Food Chain Puzzle and Augmented Reality". The results showed that Puzzle media and Augmented reality on the food chain material of the rice field ecosystem can make learning effective and interesting and can improve students' understanding and skills in understanding the food chain material of this rice field ecosystem. Educators can also achieve the target learning objectives to be achieved. Based on the results of material expert validation, it gives a value of 82% with a category worth using, linguists give a value of 75 with a category worth using and media experts give a value with a category of 85 with a category very worth using. Research that has been conducted also shows that the application of Augmented Reality technology can improve students' understanding and motivate their learning (Chang et al., 2024; Fidan & Tuncel, 2019; Yasin & Utomo, 2023).

From some of the research that has been done Augmented Reality (AR) is one of the innovations in the field of technology that is interesting so that it can increase students' understanding and motivation to learn. Based on this background exposure, researchers aim to develop Augmented Reality-based digital learning media to improve student learning outcomes on food chain material in grade five elementary schools.

Method

This research uses quantitative research using the Research and Development (R&D) method. Development of research models with ADDIE (Analysis, Design, Development, Implementation, and Evaluation). The research data used consists of research and development data, and the data sources include observations, interviews conducted with the school principal, fifth-grade homeroom teacher, students, experts, and questionnaire results. Data collection techniques include interviews, questionnaires, documentation, and tests. This research was conducted at SD Negeri Kasepuhan 02 Batang Regency. The research period began on January 10 and continued until the data requirements for compiling this research were met. The population in this study consisted of all students at SD Negeri Kasepuhan 02, Batang Regency. The number of samples to be taken includes all class V students of SD Negeri Kasepuhan 02 Batang. In analyzing the data, the Validity Test, Reliability Test, Normality Test, Homogeneity Test, T-Test, and N-Gain Test were used.

Result and Discussion

Table 1. Test of normality

	Kalmogorov-Smirnov			Shaopiro-wilk		
	Statistics	df	Sig.	Statistic	df	sig.
Prettest	0.136	30	0.168	0.941	30	0.099
Postest	0.143	30	0.122	0.954	30	0.217

Table 1 shows the results of the normality test for the pretest and posttest scores using the Shapiro-Wilk test. The normality testing criteria are considered normal if the significance value is > 0.05, indicating the normal distribution of data. Conversely, if the significance value is < 0.05, the data is considered not normally distributed. From the above data, it is evident that the normality test results for the pretest and posttest scores show a normal distribution.

T-Test

Table 2. Paired Samples Test

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% confidence interval of the difference Lower	Upper	t	df	Sig (2-tailed)
Pair 1: Pre Test – Post Test	-38.400	11.530	2.105	-42.705	-34.095	-18.242	29	.000

Table 2 shows based on the results of the test for the difference in mean values between the pretest and posttest, it is shown that the sig (2-tailed) is 0.000. After comparing with sig (2-tailed), which is 0.000 < 0.05, the null hypothesis (Ho) is rejected. Therefore, it can be concluded that there is a significant difference in the learning outcomes of students using Augmented Reality-based Food Chain learning media.

N-Gain Test

Table 3. Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NGain	30	0.43	1.00	0.7173	0.13808
Valid N (listwiss)	30				

Table 3 shows, based on the table of N-Gain test results, it is obtained that the N-Gain score is 0.7173 or 71%, which falls into the moderate category. In this case, it indicates that the use of Augmented Reality-based digital learning media on the food chain material is effective.

T-Test

Results of Small-Scale Testing

Normality Test

Table 4. Test of normality

	Kalmogorov-Smirnov			Shaopiro-wilk		
	Stastic	df	Sig.	Statistic	df	sig.
Prettest	0.184	6	0.200	0.927	6	0.554
Postest	0.208	6	0.200	0.907	6	0.425

*. This is a lower bound of the true significance

Table 4 show presents the outcomes of the normality test for the pretest and posttest scores using the Shapiro-Wilk test. The normality testing criteria consider the data to be normal if the significance value is > 0.05, indicating a normal distribution. Conversely, if the significance value is < 0.05, the data is considered not normally distributed. The data above demonstrates that the results of the normality test for both pretest and posttest scores indicate a normal distribution

Table 5. Paired Samples Test

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% confidience interval of the difference Lower	Upper	t	df	Sig (2-tailed)
Pair 1: Pre Test – Post Test	-38.400	11.530	2.105	-42.705	-34.095	-18.242	29	.000

Table 5 shows, based on the Results of the Mean Difference Test between Pretest and Posttest. Table 5 shows that the significance value (2-tailed) is 0.001. Upon comparing this value with the significance level (2-tailed) of 0.05, since 0.001 < 0.05, the null hypothesis (H0) is rejected. Therefore, it can be concluded that there is a significant difference in the learning outcomes of students using augmented reality-based digital learning media on the food chain material.

N-Gain Test

Table 6. Descriptive Statistic

	N	Minimum	Maximum	Mean	Std. Deviation
NGain	6	.71	1.00	.8463	.13133
Valid N (listwiss)	6				

Table 6 indicates that the N-Gain score obtained is 0.8463 or 84%, falling into the moderate category. In this context, it suggests that the use of augmented reality-based digital learning media on the food chain material is effective.

Discussion

The development of augmented reality-based digital learning media on the food chain material is

carried out using the ADDIE development model, which stands for Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model is a systematic approach to the development of learning media that involves several stages to achieve optimal results.

Augmented reality-based digital learning media on the topic of food chains was tested on fifth-grade students at SD Negeri Kasepuhan 02 with the aim of improving students' learning outcomes in the Food Chain material. This goal aligns with the need to enrich teaching methods to be more engaging and effective for students, especially in understanding abstract concepts such as food chains.

The first stage in developing augmented reality-based digital learning media on the food chain topic is the analysis phase. In this stage, field conditions are analyzed through observations and questionnaires to assess the needs of teachers and students. Observations are conducted to gain direct insights into the classroom conditions and learning environment of the students, while questionnaires are used to collect information about the needs and expectations of both teachers and students regarding the developed learning media.

Figure 1. Illustrates the design of augmented reality-based digital learning media

Figure 2. Design of augmented reality-based digital learning media.

Figure 3. Design of augmented reality-based digital learning media

The results from the observations and questionnaires are then analyzed to serve as a reference in the development of the media. This analysis helps researchers gain a deeper understanding of what is needed by teachers and fifth-grade students at SD Negeri Kasepuhan 02 Batang. Thus, the development of the media can be tailored to better suit the needs and characteristics of the students while supporting the achievement of the set learning objectives. This analysis also aids in identifying potential issues or obstacles that may arise during the development and implementation of the learning media.

The second stage in the development of digital learning media based on augmented reality for the food chain material is the design stage. This stage involves planning the learning media based on the identified needs of teachers and students through the analysis in the previous stage. In the design stage, the media development team will intricately plan how the learning media will be created and implemented. This includes selecting content, lesson structure, and teaching strategies, as well as designing the interactive interface that will be used in the media.

The design of learning media must take into account various factors such as student characteristics, learning objectives, as well as technical capabilities, and the availability of devices to be used. A good design will ensure that the learning media can provide an effective and engaging learning experience for students, thus enhancing their understanding of the taught subject matter.

The third stage in the development of digital learning media based on augmented reality for the food chain material is the development stage. This stage is the process of creating Augmented Reality media from the components that have been designed and arranged in the previous stage into a cohesive and functional whole. In this stage, the development team will use the Assmblr Edu application or another suitable application to design and develop Augmented Reality media according to the previously planned layout and design. This process involves creating the content to be displayed in the media, setting up the interface interactions, and testing the functionality of the media to ensure that all components work well and meet the desired requirements.

The development of digital learning media based on Augmented Reality for the food chain topic requires a profound understanding of Augmented Reality technology and the ability to design and develop content that can provide interactive and engaging learning experiences for users. With proper development, this learning media is expected to enhance the learning outcomes of students in understanding complex subjects such as the food chain. The fourth stage in the

development of digital learning media based on augmented reality for the food chain topic is implementation. In this stage, the developed learning media will be applied or implemented in the actual learning process for the 5th-grade students at SD Negeri Kasepuhan 02 Batang.

The implementation of this learning media is carried out by introducing and using the media in the classroom learning activities. Teachers will utilize the augmented reality-based digital learning media for the food chain topic to enhance the delivery of the lesson on the food chain in a more interactive and engaging manner. During implementation, teachers need to ensure that the learning media is used effectively according to the set learning objectives. Students should also be given the opportunity to interact with the media so that they can better understand the concepts being taught. The implementation of augmented reality-based digital learning media on the food chain material is expected to improve student's learning outcomes and help them better understand the concept of the food chain in a more enjoyable manner.

The fifth stage in the development of augmented reality-based digital learning media for the food chain material is evaluation. Evaluation is carried out to assess the feasibility of the developed learning media by subject matter experts and media experts. The purpose of this evaluation is to determine the extent to which the learning media can meet quality standards and whether it is suitable for use in the learning process. Evaluation is carried out using various methods and evaluation instruments that are suitable for the characteristics of the developed learning media. Subject matter experts will evaluate the content presented in the learning media, while media experts will evaluate the technical aspects and presentation of the media.

The results of this evaluation will provide an overview of the strengths and weaknesses of augmented reality-based digital learning media on the food chain. The evaluation results will also serve as input for making improvements or refinements to the learning media to make it more effective and efficient in supporting the learning process of students. After the development stage of the media and the media is available, the next step is to test the feasibility of the media that will be used in the learning process. Expert testing is carried out in two stages, namely media expert testing and material expert testing.

Media expert testing is conducted to evaluate the technical aspects and presentation of the developed learning media. The media experts will assess the extent to which the media can provide an interactive and engaging learning experience for students. They will also evaluate whether the media is easy to understand and use by students and to what extent the media meets good design standards in the development of learning media.

The material expert will assess the accuracy, meaningfulness, and usefulness of the content presented in the learning media. Material experts will evaluate whether the content accurately supports the set learning objectives. They will also assess whether the presented content can be well understood by students and is relevant to the taught subject matter.

The results of the feasibility test by material and media experts will provide an overview of the extent to which the developed augmented reality-based digital learning media on the food chain topic can be used in the learning process. The results of this feasibility test will serve as a basis for making improvements or refinements to the learning media, ensuring its effectiveness in supporting the students' learning process. The results of the feasibility test by material and media experts are outlined as follows.

Results of Material Expertise Feasibility Data

The results of the feasibility evaluation by material experts indicate that the augmented reality-based digital learning media on the food chain topic is suitable for use in the learning process. This evaluation was conducted using a validation instrument sheet consisting of 15 questions covering five assessment aspects: material accuracy, suitability for students' thinking levels, alignment with learning content, linguistic appropriateness, and the accuracy and utility of the media. The assessment was conducted using a Likert scale with scores ranging from 1 to 4, where a score of 1 indicates poor, 2 is fair, 3 is good, and 4 is excellent. The assessment results showed that the material experts gave a positive response to this learning media, with an average score of 89.5%.

Therefore, the augmented reality-based digital learning media on the food chain topic is deemed suitable for use in teaching by material experts. This evaluation indicates that the media exhibits accuracy in content, alignment with students' cognitive levels, appropriateness of instructional content, and linguistic alignment, as well as good or excellent accuracy and utility of the media. Consequently, this learning media can serve as an effective alternative in supporting the learning process in the classroom.

Based on the results of the normality test for the large-scale, the obtained values are 0.99 and 0.217, indicating that the data is normally distributed. Additionally, for the t-test on the small-scale, the result is 0.000, and the N-Gain test on the large-scale yields a score of 71%. Regarding the normality test for the small-scale, the results are 0.554 and 0.427, signifying that the data is normally distributed. The t-test for the small-scale produces a result of 0.001, and the N-Gain test for

the small-scale obtains a score of 84%, indicating a moderate category, signifying that Augmented Reality-based digital learning media for the food chain material is effective.

Results of Media Expert Feasibility Data

The evaluation results by media experts indicate that the augmented reality-based digital learning media on the food chain topic is suitable for use in the teaching process. This assessment was conducted using a validation instrument sheet consisting of 16 questions covering four assessment aspects: media aspects, display aspects, usability aspects, and usefulness aspects.

The assessment was conducted using a Likert scale with a scoring range from 1 to 4, where a score of 1 indicates poor, 2 is fair, 3 is good, and 4 is excellent. The evaluation results indicate that the media expert gave a positive response to this learning media, providing an average score of 87.5%.

Therefore, the digital learning media based on augmented reality for the food chain material is deemed suitable for use in learning by the media expert. This assessment indicates that the media has good media aspects, an attractive display, easy usability, and high utility. Consequently, this learning media can be considered an effective alternative in supporting the learning process in the classroom.

Table 7. Material Validation

Assessment Aspect	Score
Feasibility Percentage (NP)	89.50
Qualification Feasibility	Feasible

The material expert validation assessment obtained a score of 89.5. the results obtained from material expert validation can be categorized as decent.

Table 8. Media Validation

Assessment Aspect	Score
Feasibility Percentage (NP)	87.50
Qualification Feasibility	Feasible

Media expert validation assessment obtained a score of 87.5. the results obtained from media expert validation can be categorized as Feasible.

Conclusion

The Augmented Reality-based digital learning media was successfully developed using the ADDIE model, which stands for analysis, design, development, implementation, and evaluation. The development of Augmented Reality-based digital learning media utilized the Assembler Edu software. The results of the research on Augmented Reality-based digital learning media for the food chain material are valid or suitable for use in the classroom learning process. This is evident from the data obtained in the media validation and material validation tests, which scored 8.75 and 8.95, respectively. Therefore, the learning media is considered valid and suitable for use.

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Author Contributions

The main author, M.Q.I contributed to the research, product development, data analysis, and article writing. The second author, D.N.T supervisor in research activities to article writing.

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Conflict of Interest

In this case, there are no conflicts of interest reported.

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