Development of Augmented Reality-Based Flashcard Instructional Media for Natural Science Learning in Madrasah Ibtidaiyah

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Keywords	**ABSTRACT**
Augmented Reality; Flashcard Instructional media; Natural Sciences Learning	Natural Science instruction at the elementary level of Madrasah Ibtidaiyah frequently encounters difficulties in delivering abstract concepts effectively, compounded by limited use of interactive media and consequent low student motivation. Therefore, this study aimed to develop and evaluate Augmented Reality (AR)-based flashcard learning media as an innovative solution to enhance student interest and conceptual understanding in elementary science education. The research employed a Research & Development (R&D) method using the ADDIE framework, which includes needs analysis, product design, product development, implementation, and evaluation. The findings indicate that the developed media positively influence students' interest in Natural Sciences learning. This was demonstrated by post-test scores that were higher than pre-test scores, showing an improvement in students' knowledge before and after the implementation of the augemented reality-based flashcard media.
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INTRODUCTION

In the current digital era, technology plays a crucial role in advancing scientific knowledge. Significant changes begin to appear when technology is integrated into learning processes. Technology transforms learning into a more accessible and practical activity. For example, technology increases access to education, allowing learning to take place anywhere without requiring direct physical interaction. This condition allows all segments of society to acquire the same knowledge regardless of geographical location or distance.

Technology also contributes to enhancing the quality of instruction through the continuous development of diverse instructional media and methods, thereby increasing students' interest and motivation to learn. Currently, the foundation of knowledge is no longer limited to teachers and textbook,[1] students can easily access various sources of knowledge through digital platforms, including those designed for Natural Science instruction. Natural Science constitutes an essential branch of knowledge as it encompasses

[1]Abdul Sakti, "Meningkatkan Pembelajaran Melalui Teknologi Digital," *Jurnal Penelitian Rumpun Ilmu Teknik* 2, no. 2 (2023): 212–19, https://doi.org/10.55606/juprit.v2i2.2025.

understanding of living organisms and their surrounding environment. According to Irsan, science education is crucial because it develops students' critical and logical thinking skills.[2]

Despite rapid technological advancement, substantial changes in educational practice remain limited. In reality, many students continue to achieve suboptimal learning outcomes. One primary contributing factor is the monotonous teaching persist in employing traditional methods that rely heavily on teacher-centered explanations and textbooks. This practice negatively affects students' interest and comprehension of instructional content. Consequently, innovative instructional innovation that incorporates interactive models or media is required to engage and motivate students, particularly in science education. Students require clearer visualization and conceptualization of learning content. One promising innovation is the implementation of augmented reality (AR)-based flashcard media.

Flashcards are commonly recognized as card-based learning media containing numbers or illustrations accompanied by explanatory text. Although widely utilized, conventional flashcards remain passive consisting merely of cards with textual and visual content but lacking interactive element facilitating minimal knowledge exchange between teachers and students. To address these limitations, integrating flashcards with augmented reality offers a promising interactive media innovation. According to Sari et al., Augmented Reality is a technology that combines real-world objects with virtual two- or three-dimensional images through mobile devices in real time.[3] Furthermore, Elvina et al. state that integrating flashcards with augmented reality provides a more authentic learning experience by allowing students to visualize learning content in three-dimensional form and rendering the learning process more meaningful.[4]

Previous studies on the use of flashcards in instructional reveal that, according to Rahman, flashcards effectively enhance students' motivation and retention of the instructional content studied.[5] Another view from Saputra et al, they highlight that flashcards help facilitate easier comprehension of learning content. [6] These perspectives form the basis for developing AR-based flashcard media for natural science instruction at the Madrasah Ibtidaiyah (Islamic elementary school) level. The interactive feature lies in the integration of AR technology into the flashcards; each card contains a barcode that, when scanned using a mobile device, displays content or images in two- or three-dimensional form.

A related previous study conducted by Ilafi entitled "Development of an Augmented Reality-Based Interactive Module Assisted by Assemblr on the Solar System Topic for seventh-grade junior high school *(Madrasah Tsanawiyah).*" The interactive module developed in that study received positive responses from seventh-grade students met the criteria for effective learning media. Its relevance to the present research lies in the shared use of AR technology in science education. The key difference is the medium employed; the previous study utilized a module, whereas the current research develops flashcards. Based on this overview, the research problem is formulated as follows: how valid and effective is the

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[2]Irsan Irsan, "Implemensi Literasi Sains Dalam Pembelajaran IPA Di Sekolah Dasar," *Jurnal Basicedu* 5, no. 6 (2021): 5631–39.

[3]Indah Purnama Sari et al., "Introduction to Building Space Using Augmented Reality as a Learning Media," *Hello World Jurnal Ilmu Komputer* 1, no. 4 (2022): 209–15.

[4]Tri Elvina, Dian Miranda, and Lukmanulhakim Lukmanulhakim, "Pengembangan Flashcard Tematik Berbasis Augmented Reality Anak Usia 5-6 Tahun," *Jurnal Edukasi* 2, no. 1 (2024): 57–61, https://doi.org/10.60132/edu.v2i1.256.

[5]Annisa Mayasari Nafsiah Hafidzoh Rahman, "Penggunaan Flash Card Sebagai Media Pembelajaran Interaktif Untuk Meningkatkan Penguasaan Materi Tarkib Bahasa Arab" 10, no. 1 (2025): 49–62.

[6]Domi Saputra et al., "Penggunaan Media Flashcard Dalam Pembelajaran Bahasa Arab Untuk Penguasaan Kosa Kata," *Jurnal AS-SAID* 2022, no. 1 (2022): 127–37.

developed AR-based flashcard learning media? Accordingly, the objectives of this study are to determine the validity and effectiveness of the developed media so that it can be appropriately implemented in the instructional process.

RESEARCH METHOD

This study employed the Research and Development (R&D) method with ADDIE framework (Analysis, Design, Development, Implementation, and Evaluation). The researchers selected the ADDIE model because it provides a systematic, sequential, and logical flow suitable for educational media development.

This study used several data collection techniques, namely direct observation, interviews, and questionnaires. Direct observation enabled the researchers to examine student engagement during classroom learning activities. Interviews were conducted to obtain feedback on the effectiveness of the developed media. Questionnaires were distributed for data analysis purposes, particularly to assess the validity of the developed media and identify user responses, which included both teachers and students. The research instruments consisted of two main validation sheets; content expert validation and media expert validation, both designed to assess the feasibility of the learning media. Qualitative analysis was applied to interpret data obtained from observations and interviews, whereas quantitative analysis was used to process questionnaire responses and results from material and media expert validation.

The level of validity from material and expert validation was calculated using a 5-point Likert Scale (1 = very poor, 5 = very good). Validity percentage was determined using the following formula:

$$V = \frac{\sum F}{N} \times 100\%$$

Description:

V = Validity percentage
$\sum F$ = Total score obtained
N = Maximum possible score

The resulting validity percentage was interpreted according to the media validity criteria proposed in table 1.[7]

Table 1. Validity Criteria

Percentage Score	Validity Level
P ≤ 20%	Not Valid
21% < P ≤ 40%	Less Valid
41%< P ≤ 60%	Sufficiently Valid
61% < P ≤ 80%	Valid
80%< P	Very Valid

In addition to validity analysis, user response test was conducted based on questionnaires to teachers and students after using the augmented reality-based flashcard media. User response were measured on a 5-point Likert scale 1= strongly disagree, 5= strongly agree). Practicality percentage was calculated using the same formula:

[7]Amrita Dewi and Mintohari, "Pengembangan Multimedia Interaktif Terraksa Materi Bumi Dan Antariksa Berbasis Web Untuk Meningkatkan Hasil Belajar Kognitif Siswa Kelas Vi," *Jpgsd* 12, no. 1 (2024): 2516–29, https://ejournal.unesa.ac.id/index.php/jurnal-penelitian-pgsd/article/view/59106.

$$V = \frac{\sum F}{N} \times 100\%$$

Description:

V = Presentase kepraktisan Percentage of practicality

$\sum F$ = Score obtained

N = Maximum score

The resulting percentage were then matched with the practicality criteria for learning media adapted, [8] as shown in able 2.

Table 2. Media Practicality Criteria

Percentage Score	Practicality Level
P ≤ 20%	Not Practical
21% < P ≤ 40%	Less Practical
41%< P ≤ 60%	Sufficiently Practical
61% < P ≤ 80%	Practical
80%< P	Very Practical

RESULTS AND DISCUSSION

Research Findings

The study was conducted at MI Raudlatul Hasan Kareng Kidul, Wonomerto District, Probolinggo Regency, involving 20 fifth-grade students as the experimental subjects. The development process followed the ADDIE model with following stages:

The first stage was the Analysis phase. Researchers performed direct classroom observation of the Natural Science learning process in the fifth-grade at MI Raudlatul Hasan Kareng Kidul, Wonomerto, Kabupaten Probolinggo. This observation aimed to identify school needs and served as the foundation for developing appropriate, targeted learning media that aligned with both curricular objectives and the actual requirements of students and teachers. The observation results revealed that the science learning process remained inadequate. Instruction was predominantly teacher-centered, with teachers relying on conventional lecture methods without the support of any learning media. Many students lots focus during explanations and showed low interest due to the monotonous teaching approach. When teachers posed questions about the material that had just been explained, the majority of students strangled to provide correct answers.

Natural Science is a subject that contains essential content in elementary education that requires suitable media to visualize concept clearly.[9] Based on the analysis of the observed teaching practices, researchers concluded that students' lack of enthusiasm toward science stemmed primarily from the teacher remaining the sole source of knowledge without the integration of engaging media. Consequently, researchers decided to develop augmented reality (AR)-based flashcard learning media expected to enhance students' understanding and learning interest.

The second stage was the Design phase. The initial design of the learning media was developed based on the analysis results obtained in the field. The media were deigned to match identified needs so that instructional objectives and effectiveness could be achieved. The researchers designed the flashcard using Canva software. Three-dimensional objects were created with Assmblr Edu software, producing scan able barcode (QR codes) that could be accessed via smartphones equipped with a scanning feature. Each AR-based flashcard

[8]Dewi and Mintohari.

[9]Siti Dahlia Rahanyamte, "Cara Guru Mengvisualisasi Materi Sains Kaitanya Dengan Peningkatan Kualitas Pemahaman Siswa," 2025, 112–18.

measured 10,5cm x 14,8cm, a size intended to attract students' attention. The flashcards also contained clear, easy to understand textual explanations of material. The appearance of the developed media is presented in Figure 1, 2, and 3.

Figure 1.Flashcard Instructional Media Design

Figure 2. Front View of the Instructional Media

Figure 3. Instructional Media in Use

Each complete AR-based flashcard package also included a user guidebook to facilitate effective use of the media. The guidebook comprised the following components: (1) a preface, (2) product identification, (3) definition of AR flashcards, (4) learning objectives of the media, (5) instructions for use, (6) closing remarks, and (7) creator profile.

The third stage was the Development phase. The media underwent expert validation by both media and content experts to ensure high quality before implementation.[10] Researchers revised the product according to all validator suggestions and comments to improve the overall quality of the learning media.

The media expert validation aimed to examine the quality and feasibility of the instructional media. The validation was conducted by a lecturer from Institute Ahamad Dahlan Probolinggo who specialized in instructional media. The instrument consisted of 14 statements covering four aspects: (1) design and display (4 items), (2) functionality and interactivity (4 items), (3) media content quality (3 items), and (4) ease of use (3 items). Results are displayed in Table 3.

Table 3. Media Expert Validation Results

Aspect	∑F	N	Percentage	Criteria
Design and Appearance	18	20	90%	Very Valid
Functionality and Interactivity	18	20	90%	Very Valid
Media Content Quality	13	15	86%	Very Valid
Ease of use	13	15	86%	Very Valid
Average	62	70	88%	Very Valid

The media expert validation showed consistent scores across all aspects. The design and appearance aspect obtained a percentage score of 90%, categorized as very valid. The functionality and interactivity aspect also received 90%, falling into the very valid category. The media content quality score 86%, which is likewise categorized as very valid, and the ease-of use aspect scored 86%, also in the very valid category. The average scores across all the aspects was 88% (very valid category), indicating that the AR-based flashcard media met

[10]Hayyu Annaafi Warida Putri and Gallant Karunia Assidik, "Integrasi Media Pembelajaran Berbasis Android Untuk Meningkatkan Keterampilan Menyimak Siswa Pada Fase D," *Jurnal Onoma: Pendidikan, Bahasa, Dan Sastra* 10, no. 2 (2024): 2173–89, https://doi.org/10.30605/onoma.v10i2.3714.

the criteria for implementation in learning activities. Nevertheless, the validator provided several recommendations for improvement; (1) enlarging the flashcard size to better suit elementary school students and (2) developing a detailed user guidebook for teachers and students in operating the media. These recommendations formed the basis for revising the final design to improve the quality of the learning media before its implementation.

The content expert validation aimed to ensure that the learning media met the expected standard of content quality. The content validation was conducted by a lecture at Institute Ahmad Dahlan who teaches elementary science education. The validation instrument contained 16 statements assessing three aspects: (1) content accuracy (11 items), (2) language use (2 items), and (3) presentation (4 items). The results are presented in Table 4.

Table 4. Content Expert Validation Results

Aspect	∑F	N	Ppercentage	Criteria
Content	47	55	86%	Very Valid
Language Use	10	10	100%	Very Valid
Presentation	20	25	80%	Valid
Average	**77**	**90**	**85%**	**Very Valid**

Although scores varied across aspects, the overall average reached 85%, placing the product in the "very valid" category. The content quality aspect obtained 86%, categorized as very valid. The language use aspect achieved a perfect score of 100%, placing it in the very valid category, while the presentation aspect received 80%, categorized as valid. These findings indicate that the content presented in the instructional media meets the required standards and is suitable for implementation in learning process.

The user validation aimed to assess the practicality of the AR-based flashcard media when used in the classroom. The user validation sheet was completed by the fifth-grade teacher who teaches Natural Science subject at MI Raudlatul Hasan, Kareng Kidul, Wonomerto, Kabupaten Probolinggo Regency. In the user validation stage, the assessment components consisted of 11 statements covering four aspects: (1) Content Suitability (4 items), (2) design and display (2 items), (3) ease of use (2 items), and (4) functionality and interactivity (3 items). The validation was scored using quantitative data, which were subsequently converted into percentages. The calculation results of the user validation scores are presented in Table 5.

Table 5. User Validation Results

Aspect	∑F	N	Ppercentage	Criteria
Content Suitability	17	20	85%	Very Practical
Design and Appearance	9	10	90%	Very Practical
Ease of Use	8	10	80%	Practical
Functionality and Interactivity	14	15	93%	Very Practical
Average	48	55	87%	Very Practical

The results of the user validation showed relatively consistent percentages across all assessed aspects. The content suitability aspect received by 85%, categorized as "very practical." The design and appearance aspect achieved 90%, also categorized as "very practical." The ease of use aspect received 80%, which is interpreted as "practical." The functionality and interactively aspect achieved the highest score of 93%, categorized as "very practical". The overall average percentage was 87%, placing the media in the "very practical" category. These findings indicate that the instructional media developed in this study are

practical for classroom use and have strong potential to support instructional activities effectively from the teacher's perspective.

Student response questionnaires were administered to evaluate the attractiveness and perceived effectiveness of the media after students used the AR flashcards in class. The questionnaire was completed by 20 fifth-grade students at MI Raudhlatul Hasan. The results are presented in Table 6.

Table 6. Student Response Results

Aspec	∑F	N	Ppercentage	Criteria
Content Suitability	253	300	84%	Very Practical
Design and Appearance	402	500	80%	Practical
Functionality and Interactivity	257	300	85%	Very Practical
Average	912	1100	82%	Very Practical

Students' responses produced an overall average of 82%, which corresponds to the "very practical" category. This finding indicates that the AR-based flashcard media were perceived as highly attractive, easy to use, and effective by the students themselves.

The implementation stage involved testing the AR-based flashcard media in Natural Science lesson on the topic "*Bumiku Sayang, Bumiku Malang* – Subtopic A: *Bumi Berubah"* (Earth Changes) with 20 fifth-grade students at MI Raudlathul Hasan Karenag Kidul, Wnomerto, Probolinggo Regency. A one-group pretest-posttest design was adopted to measure the effectiveness of media by comparing students' conceptual understating before and after its use.

At the first meeting, a pretest was administered to assess students' prior knowledge.[11] The AR flashcards were then applied across three subsequent teaching sessions. Photographs of the implementation process are shown in Figure 4-6.

Figure 4. Implementation of Instructional Media

Figure 5. Implementation of Instructional Media

After the implementation phase, a post-test was administered to measure changes in students' understanding following the use of the media. The normality test results for the pre-test and post-test scores are presented in Table 7.

[11]Ashimatul, Wardah, Al Mawaddah et al., "The Effect of Using Quizizz Learning Media on Student Learning Outcomes in Mathematics Subjects through Online in Elementary Schools," *Journal Basicedu* 5, no. 5 (2021): 3109–16.

Table 7. Normality Test Result for Pre-Test and Post-test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pretest	.132	20	.200*	.963	20	.602
postest	.240	20	.004	.751	20	<,001

The pre-test and post-test data were analyzed using the Shapiro-Wilk normality test because the sample size was fewer than 50. The results in Table 7 show that the pre-test data were normally distributed. Meanwhile, the post-test score had s significance value of 0.602 (≥ 0.005), indicating that the pre-test data were normally distributed. Meanwhile, the post-test score had a significant value of < 0.001 (≤ 0.05), indicating that the post-test data were not normally distributed. Based on these results, the researcher selected the Wilcoxon Signed-Rank Test as an alternative to the paired-sample t-test. [12]

Table 8. Wilcoxon Ranks

Ranks

			N	Mean Rank	Sum of Ranks
postest - pretest	Negative Ranks		0[a]	.00	.00
	Positive Ranks		18[b]	9.50	171.00
	Ties		2[c]		
	Total		20		

a. postest < pretest
b. postest > pretest
c. postest = pretest

Table 9. Wilcoxon Test Statistics

	postest - pretest
Z	-3.766[b]
Asymp. Sig. (2-tailed)	<,001

[12]Tiara Cahaya Putri, Yatti Sugiarti, and Gilang Garnadi Suryadi, "Pengembangan Media Pembelajaran Video Praktikum Untuk Meningkatkan Hasil Belajar Peserta Didik," *Edufortech* 6, no. 2 (2021), https://doi.org/10.17509/edufortech.v6i2.39292.

The Wilcoxon Test was used to compare the pre-test and post-test scores. The negative ranks indicate the number of students whose scores decreased from pre-test to post-test,[13] the positive ranks indicate the number of students whose score increased, and the ties indicate students whose scores remained the same.

The test results showed 0 negative ranks, 18 positive ranks, and 2 ties, indicating that none of the 20 students experienced a decline in scores, and only two students obtained the same score on both test. The remaining 18 students showed improvement. The mean rank and sum of ranks also demonstrated an increase, with values rising from 9.5 to 171, indicating a positive shift in student performance.

The test statistics in Table 9 show that the hypothesis tested was: H0: There no significant difference between the pre-test and post-test results, and H1: There is a significant difference between the pre-test and post-test results. The decision rule states that if the significance value is < 0,005, the alternative hypothesis (H1) is accepted; otherwise, H0 is accepted. Based on the Wilcoxon test, the significant value obtained was 0.001< 0.005, meaning H0 is rejected, and H1 is accepted.

These results indicate that the students' pre-test scores were lower than their post-test scores. This finding demonstrates that the developed AR-based flashcard media effectively enhanced students' conceptual understanding of Science, particularly in the topic *"Bumiku Sayang Bumiku Malang."*

During the implementation of the AR-based flashcard, the researcher encountered several challenges. First, the three dimensional animations required a slightly longer loading time due to weak internet connectivity. To overcome this issue, the researcher switched from Wi-Fi to mobile data, which provided a more stable connection. Second, several students experienced difficulties using the AR media because they were nor accustomed to such technology. To address this, the researcher provided repeated explanations until all students understood how to operate the media. Third, there was a limitation in the availability of mobile devices, as students were not allowed to bring smartphones to school. Therefore, the researcher divided the students into several groups, and each group took turns using a smartphone to access the AR flashcard media.

In the final stage, an evaluation of the learning media was conducted following the validation assessments by the media and content experts. This evaluation aimed to improve and enhance the effectiveness and overall quality of the developed media. according to the media expert validator, the learning media were sufficiently well-designed to be tested in the classroom. The media were easy to use, visually appealing, and aligned with current technological developments. However, several revisions were recommended, including enlarging the flashcard size from 6 x 9 cm to A6 (10,5 x 14,8 cm). Additionally, the researcher was advised to develop a user guidebook to assist teachers and students in operating the media more effectively.

After implementing the media across three learning sessions, the teacher who used the AR-based flashcard media reported feeling greatly assisted, as the media represented a new and innovative tool that had not been previously available. The media effectively supported the teacher in motivating students to engage with the learning process, particularly in Natural Science lesson that require clear conceptual visualization. The learning process became more effective, as students were significantly more active than usual. The presence of the guidebook also enabled to teacher to integrated the media seamlessly into instruction.

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[13]Maharani Dewi Masitoh and Arief Cahyo Utomo, "Pengembangan Media Pembelajaran Macromedia Flash Berbasis Kearifan Lokal Untuk Meningkatkan Keterampilan Berpikir Kritis Di Sekolah Dasar," *Jurnal Kependidikan* 13, no. 2 (2024): 2535–48, https://jurnaldidaktika.org.

Discussion

Instructional media represent a key strategy for enhancing student learning motivation.[14] In the current digital era, technology integration is widely utilized to foster innovative and creative learning environments that stimulate students interest.[15] Among numerous technological advancements in education, augmented reality stands out as particularly promising. The present study developed AR-based flashcard media specifically tailored for elementary Science instruction, using the fifth-grade semester 2 topic "*Bumiku Sayang, Bumiku Malang – Earth Change and Natural Disasters."* The flashcards covered various natural disasters, complete with definitions, causes, impacts, 3D visualizations, and sound effects.

The media were constructed using Assemblr Edu (for 3D object creation) and Canva (for card design). Each package consisted of physical flashcards containing images, textual explanations, and scan able barcodes that triggered 3D models and audio when viewed through a smartphone, accompanied by a detailed user guidebook. The design intentionally incorporated vibrant colors, sound, and interactive 3D elements aligned with elementary students' developmental interests to maximize engagement and long-term retention.

After the development process was completed, the researcher conducted media and content expert validation to assess the quality and feasibility of the media before implementation. Once the media met the required validity criteria, experimental trials were conducted involving teachers and students. The researcher administered pre-test to measure the effectiveness of the learning media before and after its implementation.

Table 9. Students' Pre-Test and Post-Test Scores

No	Student Code	Pre-test	Post-test
1.	AM	40	100
2.	AMY	60	80
3.	AZF	70	100
4.	ANF	40	70
5.	BAN	60	90
6.	EA	30	30
7.	LS	80	100
8.	MAQ	90	100
9.	MA	10	30
10.	MI	40	70
11.	MR	30	60
12.	NAS	60	100
13.	NFS	90	100
14.	RI	30	30
15.	RA	40	100
16.	SJ	60	90
17.	SM	50	90
18.	SMI	50	80
19.	SN	70	100
20.	SR	60	100

[14]Nur Khosiah, "Strategi Guru Kelas Dalam Meningkatkan Literasi Membaca Siswa Di Mi Misbahut Tholibin Leces - Probolinggo," *AL IBTIDAIYAH: Jurnal Pendidikan Guru Madrasah Ibtidaiyah* 4, no. 2 (2023): 116–27, https://doi.org/10.46773/ibtidaiyah.v4i2.779.

[15]Tiara Genisa et al., "Pemanfaatan Teknologi Digital Dalam Meningkatkan Minat Belajar PPKn Siswa Di Sekolah Dasar," *Jurnal Bintang Pendidikan Indonesia* 3, no. 2 (2025): 218–27, https://doi.org/10.55606/jubpi.v3i2.3826.

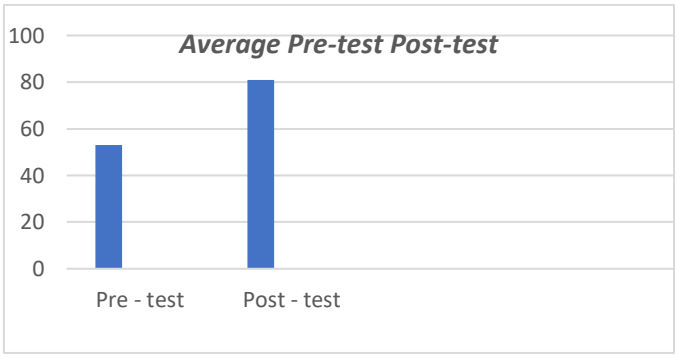

Figure 9. Average Pre-Test and Post-Test Scores

Referring to the pre-test and post-test results presented above, there was a clear and significant difference in students' learning outcomes before and after the implementation of the AR-based flashcard instructional media. This improvement occurred because students developed a better understanding of the content and experienced more meaningful learning when using the AR flashcard media. The media enabled teachers to explain Natural Science content more effectively through discussion-based or project-based learning approaches. The integration of AR technology made the learning process more engaging and interactive, which contributed to improved student comprehension.

The student responses obtained through the questionnaire further supported these findings, indicating an increased level of interest due to the immersive three-dimensional features embedded in the media. this shows that the developed instructional media were effective and aligned with the perspective that[16] "*The teacher's role as director and actor determines the class's tone, choosing between scary stories or exciting adventures*" emphasizing that enjoyable learning that enjoyable learning depends on the teacher's ability to create an engaging classroom environment.

This research is also consistent with findings from previous studies, such as *The Impact of Augmented Reality-Based Learning Media on Students' Digital Literacy Skills: A Study on Junior High School Students,* which demonstrated that AR media improved students' digital literacy competencies.[17] Another literature review study also reported that the use of AR in Natural Science subject for elementary school had a positive effect by improving students' learning outcomes.[18]

Beyond increasing instructional effectiveness, the implementation of AR-based media also enhanced student engagement and participation. [19] When the AR media were introduced,

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[16]Mochamad Desta Pradana and Yusuf Olawale Owa-Onire Uthman, "Development of Aqidah Akhlak Learning Media 'Board Game Based on Education Fun on the Theme of Commendable Morals (E-Fun A2M)' for High School Students," *Assyfa Learning Journal* 1, no. 1 (2023): 25–36, https://doi.org/10.61650/alj.v1i1.9.

[17]Risnawati et al., "The Impact of Augmented Reality-Based Learning Media on Students' Digital Literacy Skills: A Study on Junior High School Students," *Journal of Educational Technology and Learning Creativity* 2, no. 1 (2024): 63–70, https://doi.org/10.37251/jetlc.v2i1.1415.

[18]Dkk Widya Mufidatul 'Ula, "Efektivitas Penggunaan Augmented Reality (Ar) Dalam Meningkatkan Hasil Belajar Siswa Sd Pada Mata Pelajaran Ipa: Literature Review," *Sustainability (Switzerland)* 11, no. 1 (2025): 1–14, http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI.

[19]Thania Carolline and Abd. Mu'id Aris Shofa, "Penerapan Media Card Education Output Untuk Meningkatkan Keterlibatan Aktif Siswa SMP Pada Materi Mengapresiasi Kebudayaan Lokal," *Journal of*

students showed high levels of enthusiasm, as the technology was new to them. Throughout the learning process, students actively interacted with the 3D objects embedded in the media. Their increased interest and engagement directly contributed to the improvement of their learning outcomes, as reflected in the pre-test and post-test scores. These results are consistent with the premise underlying this study: interactive learning significantly influence students' interest in learning, particularly in Natural Science content, where students require clear visualization of concepts and content.

.The theoretical foundation of this study is grounded in constructivism and multimedia learning theory. According to constructivism, students construct their cognitive understanding through learning experiences supported by instructional media.[20] In the context of augmented reality (AR) use, particularly in Natural Science learning. Students are able to expand their own knowledge through interactive engagement, as they directly interact with the objects being studied. This interaction strengthens the role of AR in instruction because AR effectively facilitates the constructivist learning process.

Meanwhile, Mayer's multimedia learning theory asserts that the combination of visual, audio, and animation elements can enhance students' memory retention. In the AR-based flashcard media developed in this study, students were able to improve their conceptual understanding of Science because the media integrated these three essential components.[21]

The development of learning media offers substantial benefits for students; however, certain limitations remain despite the media being validated as effective and feasible for classroom use. One limitation is that teachers still need to allocate time to design or create models that match the instructional content. The platforms used to develop the AR media also lacked ready to made instructional content, requiring teachers to prepare the content themselves before using it for instructional purposes. Therefore, further development of AR applications will be necessary to include more comprehensive materials and design features aligned with the elementary curriculum, enabling teachers to create learning media more efficiently and flexibly.

Another limitation lies in the duration of the study, which was conducted over only three sessions. This limited timeframe prevented the researcher from assessing the long-term effects of using the AR-based learning media. Additionally, the sample size was restricted to a single school, which limits the generalizability of the findings. Future research will need to involve larger and more diverse samples, as well as longer implementation periods, to better understand the sustained impact of AR-based learning media in Science education

CONCLUSION

Based on the overall findings of this development study, it can be concluded that the augmented reality (AR)-based flashcard learning media are feasible and highly suitable for implementation, particularly in Natural Science instruction at the Madrasah Ibtidaiyah (Islamic elementary school) level. Media expert validation yielded an average score of 88%, corresponding to the "very valid" category. Content expert validation produced an average score of 85%, also classified as "very valid." Taken together, these results confirm that the

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[20]Rahma Violla and Reno Fernandes, "Efektivitas Media Pembelajaran E-Booklet Dalam Pembelajaran Daring Untuk Meningkatkan Hasil Belajar Siswa Pada Mata Pelajaran Sosiologi," *Jurnal Sikola: Jurnal Kajian Pendidikan Dan Pembelajaran* 3, no. 1 (2021): 13–23, https://doi.org/10.24036/sikola.v3i1.144.

[21]Siti Rosidah and Kata Kunci, "Penerapan Media Augmented Reality Dalam Meningkatkan Pemahaman Materi Ibadah Di MIS Bachrul Huda," *Jurnal Pendidikan Kolaboratif* 1, no. 1 (2024): 520–25.

media fully satisfy validity and quality requirements for classroom use. Teacher (user) practicality validation during the implementation stage returned an average score of 87%, placing the media in the "very practical" category and indicating strong effectiveness in real instructional settings. Student response questionnaires revealed an overall average of 82%, again in the "very practical" category, demonstrating that the media successfully captured students' interest and enhanced engagement. Posttest scores were significantly higher than pretest scores (Wilcoxon $p < .001$), providing clear evidence of improved conceptual understanding and knowledge acquisition after the intervention. At the evaluation stage, all recommendations provided by the media expert validators were incorporated through final revisions, further elevating the quality, usability, and visual appeal of the product. In summary, the developed AR-based flashcard instructional media meet stringent criteria of validity, practicality, attractiveness, and pedagogical effectiveness. They represent an innovative, creative, and impactful alternative instructional tool capable of transforming conventional science teaching at the elementary school/madrasah ibtidaiyah into a more interactive, motivating, and meaningful learning experience.

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