

Development of Artificial Intelligence-Based Animated Flashcards to Enhance Understanding of Earth's Surface Change Concepts

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Article Info

Keywords:

AI-Based
Flashcards,
Animated Media,
Conceptual
Understanding,
Earth Surface
Changes, West Java
Geography.

ABSTRACT

Low conceptual understanding among students regarding earth surface changes in West Java's geographical context stemmed from limited learning media. Textbooks and two-dimensional images dominated the learning process, making it difficult for students to understand dynamic and abstract phenomena. This study aimed to develop AI-based Animated Flashcards and test their feasibility and effectiveness in improving students' conceptual understanding. The Research and Development (R&D) method was employed using the ADDIE model. The subjects consisted of 17 fifth-grade students. The research instruments included validation sheets for subject matter, language, and media experts, as well as a conceptual understanding test administered via pre-test and post-test. Validation results showed that the developed media achieved 98.5% from media experts, 98% from material experts, and 98% from language experts, categorizing it as highly feasible. The effectiveness test demonstrated an increase in the students' average score from 64.5 in the pretest to 88 in the posttest. The N-Gain analysis yielded a score of 76, falling into the high category. Thus, the AI-based Animated Flashcards on earth surface changes in West Java's geography were highly feasible and effective in enhancing student understanding.

Informasi Artikel

Kata Kunci:

Flashcard Berbasis
AI, Media Animasi,
Pemahaman
Konsep, Perubahan
Permukaan Bumi,
Geografis Jawa
Barat.

ABSTRAK

Rendahnya pemahaman konsep siswa pada materi perubahan permukaan bumi dalam konteks geografis Jawa Barat disebabkan oleh keterbatasan media pembelajaran yang digunakan dalam proses pembelajaran. Penyajian materi yang masih didominasi oleh buku teks dan gambar dua dimensi menyebabkan siswa mengalami kesulitan dalam memahami fenomena perubahan permukaan bumi yang bersifat dinamis dan abstrak. Penelitian ini bertujuan untuk mengembangkan media Flashcard Animasi Berbasis Kecerdasan Buatan (Artificial Intelligence/AI) serta menguji kelayakan dan efektivitasnya dalam meningkatkan pemahaman konsep siswa. Metode penelitian yang digunakan adalah Research and Development (R&D) dengan model ADDIE. Subjek penelitian terdiri dari 17 siswa kelas V. Instrumen penelitian meliputi lembar validasi ahli materi, ahli bahasa, dan ahli media, serta tes pemahaman konsep yang diberikan melalui pretest dan posttest. Hasil validasi menunjukkan bahwa media yang dikembangkan memperoleh persentase sebesar 98,5% dari ahli media, 98% dari ahli materi, dan 98% dari ahli bahasa dengan kategori sangat layak. Hasil uji efektivitas menunjukkan adanya peningkatan nilai rata-rata siswa dari 64,5 pada saat pretest menjadi 88 pada saat posttest. Analisis N-Gain memperoleh skor sebesar 76 yang termasuk dalam kategori tinggi. Dengan demikian, media Flashcard Animasi Berbasis AI pada materi perubahan permukaan bumi konteks geografis Jawa Barat dinyatakan sangat layak dan efektif digunakan untuk meningkatkan pemahaman konsep siswa.

Article History

Received : 30/06/2026
Revised : 12/07/yyyy
Accepted : 21/07/2026

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1. Introduction

Conceptual understanding is a key competency in the learning of Natural and Social Sciences (IPAS) under the *Kurikulum Merdeka* (Independent Curriculum). Students are expected not only to master facts but also to connect concepts with phenomena occurring in their immediate environment. One topic requiring a high level of conceptual understanding is changes to the Earth's surface, as this involves dynamic endogenous and exogenous processes that are difficult to observe directly (Sari et al., 2026). According to Piaget's theory of cognitive development, elementary school students are in the concrete operational stage; therefore, learning becomes more meaningful when abstract concepts are presented through experiences supported by visual, concrete, and interactive media (Alya et al., 2022). Consequently, the selection of learning media is a crucial factor in helping students build conceptual understanding.

Based on learning media theory, media serve as a means to convey information, thereby enhancing students' attention, motivation, and comprehension. Flashcards are a suitable medium for elementary school students because they present information through simple visuals and text, facilitating the processes of memorization and conceptual understanding (Febriyanto & Yanto, 2019; Desfrida et al., 2023). However, conventional flashcards have limitations when it comes to depicting dynamic phenomena, such as the processes that alter the Earth's surface (Aqrahah et al., 2024). Advances in Artificial Intelligence (AI) enable the evolution of flashcards into media that integrate images, animations, audio, and video, allowing abstract concepts to be visualized in a more concrete, interactive, and engaging manner (Fajriati et al., 2024; Pratama et al., 2025). Furthermore, incorporating the geographical context of West Java aligns with the contextual learning approach, which emphasizes the connection between learning material and students' real-life experiences, thereby making the learning process more meaningful (Mas'ad et al., 2024).

Various studies indicate that the use of animation and flashcards can enhance learning motivation, student engagement, and conceptual understanding compared to conventional media (Susilo & Mareta, 2021; Kurnia et al., 2025; Hasyati et al., 2024). However, research on Artificial Intelligence (AI)-based animated flashcards that integrate the geographical context of West Java into lessons on changes in the Earth's surface remains limited. Most studies have focused primarily on media development or feasibility, while research regarding their effectiveness in improving conceptual understanding among elementary school students remains scarce (Pangestu, 2021). School observations further reveal that instruction is still dominated by lecture methods and textbook usage, with approximately 40% of students failing to achieve the expected level of conceptual understanding; consequently, there is a need for learning media capable of visualizing the material in a more concrete and interactive manner.

2. Research Method

This study employs the Research and Development (R&D) method using the ADDIE model, as follows.

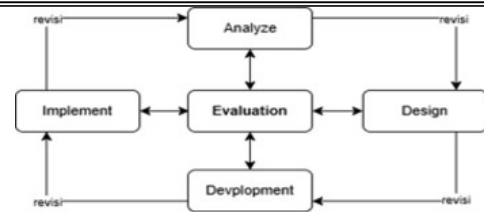


Figure 1. ADDIE stages

The ADDIE model was selected because it provides a systematic framework for developing, validating, and evaluating learning media (Sugiyono, 2021). The study was conducted with fifth-grade students. The research subjects included subject matter experts, media experts, a fifth-grade teacher, and the students themselves. Testing was carried out in stages comprising limited trials and field trials to determine the feasibility and effectiveness of the Artificial Intelligence (AI)-based animated flashcard media, which focused on the topic of Earth's surface changes within the geographical context of West Java. Research data were collected through observations, interviews, expert validation questionnaires, teacher and student response questionnaires, and conceptual understanding tests. Media validity was analyzed using the percentage of expert validation scores and interpreted based on feasibility criteria. Media effectiveness was analyzed using the N-Gain test to measure the improvement in students' conceptual understanding following the use of the developed learning media (Ramadhani & Izzati, 2023).

3. Results and Discussion

Based on the results of this study, the research involved several stages, as follows:

3.1. Analyze

This study focuses on the topic of Earth's surface changes for fifth-grade elementary students. Observations and teacher interviews revealed that instruction was dominated by lectures, textbooks, and static images. Consequently, the presentation of material failed to dynamically visualize the processes of Earth's surface changes, resulting in approximately 40% of students failing to achieve the expected level of conceptual understanding. Furthermore, students struggled to grasp abstract concepts such as tectonism, volcanism, erosion, and sedimentation because these phenomena cannot be directly observed.

These findings align with Piaget's theory of cognitive development, which posits that elementary school students are in the concrete operational stage and thus grasp concepts more easily when presented through visual, concrete, and interactive media. Therefore, instruction relying solely on verbal explanations and two-dimensional images was insufficient to fully facilitate the students' knowledge construction process. A needs analysis further indicated that teachers required instructional media that were user-friendly, engaging, and capable of integrating technological advancements into the learning process. This aligns with instructional media

theory, which states that media serve as tools for information delivery, thereby enhancing student attention, motivation, and comprehension. To address these needs, Artificial Intelligence (AI)-based animated flashcards were developed, combining text, illustrations, animations, audio, and video within the geographical context of West Java. Integrating this local context is intended to help students link concepts of Earth's surface changes to phenomena in their immediate surroundings, thereby making the learning experience more meaningful.

The results of this analysis served as the basis for determining the product's characteristics during the design phase, including material selection, flashcard content development, the creation of AI-based animations, and the presentation of examples of Earth's surface changes relevant to the geography of West Java.

3.2. Design

The design phase was conducted based on the results of a needs analysis to create AI-powered animated flashcards tailored to the characteristics of fifth-grade elementary school students. During this stage, the team formulated learning objectives, content regarding Earth's surface changes, the material presentation flow, the media's visual design, and the research instruments used to assess the media's feasibility and effectiveness. The content was developed in alignment with the Learning Outcomes (CP), Learning Objectives (TP), and Learning Objective Flow (ATP).

The media was designed as digital flashcards integrating text, illustrations, QR codes, and AI-generated animations. Each card presents a single key concept accompanied by a visual illustration, a brief explanation, and access to an animated video via a QR code scan. This presentation aims to provide students with a learning experience that is more concrete, interactive, and easy to comprehend. The visual design also prioritizes the use of simple colors, typography, and layouts to suit the cognitive characteristics of elementary school students.

The media design is grounded in instructional media theories emphasizing that presenting information through a combination of visual and verbal elements can enhance student attention, motivation, and understanding. Furthermore, Piaget's theory of cognitive development suggests that students in the concrete operational stage grasp concepts more easily through visual representations and tangible learning experiences. Consequently, AI-powered animation was selected to visualize Earth's surface changes processes that are difficult to observe directly while the geographical context of West Java was utilized to make the learning experience more contextual and meaningful.

At this stage, research instruments are also developed, comprising validation sheets for subject matter and media experts, questionnaires to gauge teacher and student responses, and a test to assess conceptual understanding. These instruments are

designed to gather data on the media's feasibility, practicality, and effectiveness prior to its implementation in the subsequent stage.

3.3. Development

At this stage, validation by a media expert aims to gather input including information, critiques, and suggestions to refine the AI-based animated flashcard media being developed, ensuring it becomes a higher-quality and more suitable product. The validator in this study is a media expert competent in the fields of instructional media development and educational technology.

The objective of this development is to produce AI-based animated flashcard instructional media that meets suitability criteria and is ready for implementation in the learning process; the results of the media expert validation are presented in Figure 2.

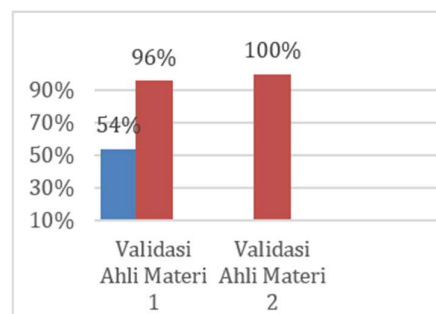


Figure 2. Graph results for both media

Based on these results, the AI-based animated flashcard media designed to enhance conceptual understanding of Earth's surface changes within the geographical context of West Java achieved a score in the 81%–100% range, meeting the "Highly Feasible" criterion. An initial validation score of 97% was obtained; following revisions based on the media expert's feedback, a second validation yielded a score of 100%. The resulting average score of 98.5% ("Highly Feasible") indicates that the developed AI-based animated flashcard media is highly suitable for practical application and requires no further revision.

Regarding the subject matter experts, the process aimed to gather information, constructive criticism, and suggestions for improvement to enhance the quality and feasibility of the developed AI-based animated flashcards. The validation process involved two experts: Subject Matter Expert 1 (an academic) and Subject Matter Expert 2 (an education practitioner). The assessment instrument was designed to evaluate all components integrated into the AI-based animated flashcards. The resulting data is presented in the diagram shown in Figure 3.

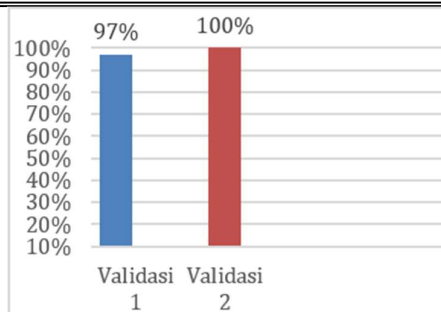


Figure 3. Subject matter expert's graphical results

Based on the assessment by language experts as shown in the diagram of the trial results used to determine linguistic validity and suitability the findings are presented in Figure 4.

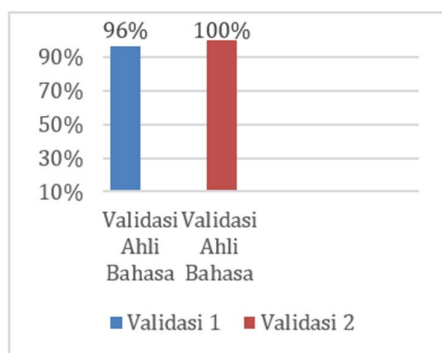


Figure 4. Linguist assessment results

Based on the linguistic validation results for the development of AI-based animated flashcards designed to improve students' conceptual understanding of Earth's surface changes within the geographical context of West Java a score of 96% was achieved during the first validation. Following revisions, the score rose to 100% in the second validation. These results yield an average score of 98%, which falls within the 81%–100% range, meeting the "Highly Suitable" criterion and indicating the material is ready for use without further revision.

3.4. Implementation

At this stage, the instructional media product having been validated and deemed suitable by experts underwent direct field testing during classroom instruction. Implementation took place on May 25, 2026, involving 17 fifth-grade students. The participants were regular students possessing typical cognitive abilities, with no specific impediments to grasping or comprehending the lesson material. The entire instructional flow was aligned with the previously developed Deep Learning Lesson Plan (RPM).

The lesson began with the teacher setting the stage to foster a conducive learning environment. This phase included greeting the class, checking the

cleanliness of the area around the students' seats, and flexibly arranging the desks to facilitate effective group discussion. Once the class was ready, the session proceeded with a group prayer led by the class monitor, followed by the teacher taking attendance. To instill a sense of nationalism, the students were guided in singing the national anthem, "Indonesia Raya."

Before entering the core material, the teacher distributed a multiple-choice pre-test to assess students' prior knowledge of changes in the earth's surface. Following the pre-test, the teacher provided a refresher session with an icebreaker themed "Ready to Learn" to improve students' focus and concentration. This preliminary phase concluded with the teacher conveying the learning objectives: to enable students to identify factors causing changes in the earth's surface, analyze the correlation between natural phenomena and natural disasters, and evaluate their negative impacts on life and the surrounding environment, particularly as relevant to the geographic context of West Java. Entering the core activity, the learning strategy was implemented through a problem-based learning model or Problem-Based Learning (PBL). The first step began with student orientation to the problem, where the teacher presented a visualization of a natural disaster along with prompting questions using PowerPoint and Canva. Through this presentation, the teacher stimulated students' critical thinking skills through an interactive question and answer session regarding the causality of flooding, the mechanisms of changes in the earth's surface that trigger disasters, and their impact on society. Students then formulated hypotheses or tentative answers based on their existing knowledge.

To regain students' focus before the group activity, the teacher provided a break with an icebreaker called "Tepuk Energi" (Enthusiastic Applause). Next, students were organized into five small, heterogeneous groups of five. Each group received a Student Worksheet (LKPD) as a guide.

During the group investigation phase, the teacher provided an orientation on the procedures for using "FANABUMI," an innovative digital learning tool consisting of AI-based animated video flashcards. Working in their respective groups, students collaborated to observe the visual stimuli on the cards and scan the Quick Response (QR) codes using their mobile device cameras. This scanning process directed students to AI-generated animated videos that visually illustrated various geographical phenomena, including the earthquake in Cianjur, the eruption of Mount Tangkuban Perahu, the tornado in Bogor, the flash flood in Ciletuh, the landslide in Cisarua, and the tsunami in Pandeglang.

Students used the information obtained from the "FANABUMI" tool as a reference during group discussions to complete all the instructions on the Student Worksheet (LKPD). Throughout the activity, the teacher actively monitored progress, provided guidance to groups facing difficulties, encouraged peer tutoring, and conducted authentic assessments of student engagement and group

collaboration. The following table presents the assessment results for the Student Worksheet (LKPD) based on scores obtained during the discussion activity. This assessment aimed to determine the extent to which students had grasped the material. These scores subsequently served as the basis for the data presented in Table 1.

Table 1. Scores from Student Worksheet (LKPD) discussion – Assessment Table

No.	Group Name	Score	Grade	Everage
1	Group 1	72	75	92,6
2	Group 2	96	100	
3	Group 3	90	94	
4	Group 4	90	94	
5	Group 5	96	100	

Following the discussion phase, the process moved on to the development and presentation of the work. Each group took turns presenting the results of their student worksheets (LKPD) to the class. The teacher acted as a facilitator and moderator, ensuring the presentations proceeded in an orderly and interactive manner while allowing other groups to offer feedback or ask questions. To acknowledge the students' active participation, the teacher led the class in giving a "Thumbs-Up Clap" to the groups that had presented. Once all groups had finished their presentations, the teacher provided clarification and confirmation regarding any material that appeared not to be fully understood by the students.

The following table presents the scores from the student performance assessment conducted during the learning activity. These assessment results provide an overview of the students' work throughout the learning process.

The following table presents the scores from the assessment of student performance during learning activities. These assessment results serve as an overview of student performance throughout the learning process. This can be seen in Table 2.

Table 2. Performance Assessment Scores (Presentation)

No.	Group Name	Score	Grade	Everage
1	Group 1	14	87,5	92,5
2	Group 2	15	93,75	
3	Group 3	15	93,75	
4	Group 4	15	93,75	
5	Group 5	15	93,75	

The core phase concluded with the measurement of learning outcomes through the distribution of a final self-assessment instrument (post-test) consisting of 21 multiple-choice questions based on Higher Order Thinking Skills (HOTS). Students completed the instrument individually and honestly within the allotted time limit.

The learning activity concluded with a closing phase. The teacher conducted a brief oral evaluation to review the material learned. Under the teacher's guidance, students collectively formulated the conclusion that the earth's condition is dynamic and

constantly changing, making understanding natural signs crucial for disaster mitigation. The learning session concluded with a reflection on the learning process, a relaxed icebreaker to relax students' psychological well-being, a presentation of the material plan for the next meeting, and a solemn prayer.

A summary of student attitude assessments during the learning process and group work activities can be seen in Table 3.

Table 3. Student Assessment Summary

No	Indicator/Aspect	Scale			
		(4)	(3)	(2)	(1)
1	Citizenship	88%	6%	6%	0%
2	Collaboration	82%	6%	12%	0%
3	Creativity	76%	18%	6%	0%
4	Communication	76%	18%	6%	0%

Based on observations made during the learning process, the student attitude assessment instrument generally indicates highly positive outcomes. In the citizenship dimension, the majority of students fell into the highest category, achieving 88% on scale 4, while scales 3 and 2 were evenly distributed at 6% each. Furthermore, regarding the collaboration dimension, student attitude mastery was also dominated by scale 4 (82%), followed by scale 2 (12%) and scale 3 (6%).

An identical distribution was observed in the creativity and communication dimensions; both aspects recorded 76% on scale 4 and 18% on scale 3, with only 6% of students falling into scale 2. The low proportion of students at the lower evaluation levels combined with the absence (0%) of results at scale 1 across all attitude dimensions serves as strong empirical evidence that the implemented learning media successfully internalized character values inclusively and equitably among all students in the class.

Classroom observations indicate that the use of AI-based animated flashcards effectively internalized the *Profil Pelajar Pancasila* (Pancasila Student Profile) character traits in students. The majority of students achieved optimal scores on the attitude assessment instrument. These findings suggest that a team-based learning method supported by student worksheets (LKPD) and AI-based animated flashcards is effective in stimulating students' communication, collaboration, and critical thinking skills. These capabilities were evident as students solved contextual problems through structured and supportive group collaboration.

During the lesson's concluding phase, the educator guides students in synthesizing information and drawing collective conclusions regarding the topic of Earth's surface changes within the geographical context of West Java. To assess the effectiveness of the AI-based animated flashcards and the overall success of the learning process, students are instructed to complete a post-test. The evaluation proceeds with the educator providing feedback, accompanied by a reflection session to

explore students' responses and impressions regarding the use of this digital medium. This entire sequence of instructional activities concludes with a joint prayer. Based on the previously established calculation formulas and criteria tables, a detailed summary of the data including pre-test and post-test scores, N-Gain values, and achievement categories for each student in class V is presented in Table 4.

Table 4. Student Pretest and Posttest Results

Criterion	Score	
	Pretest	Posttest
Number of Students	17	17
Highest Score	86	100
Lowest Score	43	76
Everage	64,5	88
N Gain Category	0,76 High	

The data obtained from the students' pre-test and post-test measurements were subsequently converted into a graph to provide a more comprehensive visualization of fluctuations in learning achievement. The detailed distribution of the score improvements is presented in Figure 5.

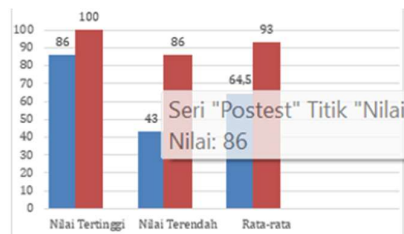


Figure 5. Student pre-test and post-test learning scores

Data analysis results indicate a significant improvement in students' conceptual understanding following the classroom implementation of the learning product. Prior to the intervention, the students' average initial proficiency score (pre-test) was 64.5. However, after the media product was optimally applied, the average learning outcome score (post-test) rose significantly to 88. To measure the degree of effectiveness and the significance of this improvement, testing was conducted using the Normalized Gain (N-Gain) index formula. Quantitative calculations yielded an average N-Gain score of 0.76. This decimal index value indicates that the improvement in students' conceptual understanding at the class level falls within the "High" category ($g > 0.70$).

Furthermore, converting this decimal index into a percentage yields an N-Gain value of 76%. Based on the effectiveness interpretation criteria, this achievement falling within the $>76\%$ range indicates that the intervention instrument meets the "Effective" criterion. This improvement is supported by the distribution of individual performance among the 17 students; the majority successfully met the minimum

mastery targets and demonstrated a positive score gain between their initial and final proficiency levels. Thus, it can be concluded that the development of AI-based flashcard media focused on the topic of Earth's surface changes within the geographical context of West Java was successful and demonstrated a high level of effectiveness in optimizing cognitive learning outcomes and conceptual mastery among elementary school students.

The successful improvement of students' learning outcomes and conceptual understanding is inextricably linked to the quality of the classroom interventions implemented by the educator. Data from the Learning Implementation Observation Table indicate that the entire planned instructional sequence was executed flawlessly, achieving a 100% completion rate across all stages—from the introductory and core activities to the concluding phase.

This high level of implementation consistency contributed significantly and directly to the effectiveness of classroom instruction. During the introductory phase (100%), the educator successfully established learning readiness and effectively facilitated the activation of prior knowledge (apperception), thereby fostering students' cognitive focus from the very beginning of the session. Subsequently, the efficient delivery of material and the integration of AI-based animated flashcards were fully realized during the core learning activities (100%), enabling active student participation through structured group collaboration. The success of this phase was further reinforced by the concluding activities (100%), which proceeded according to the planned timeline and included synthesis exercises, a final evaluation (post-test), and periodic reflection.

The maximum achievement (100%) recorded in the learning implementation observation serves as empirical evidence confirming that the surge in average cognitive scores and the "High" N-Gain category achieved by the students were driven by the educator's adherence to systematic, measurable, and accountable learning process standards within the classroom.

Based on these results, the data regarding learning implementation recorded by the observer can be visualized in the following diagram.

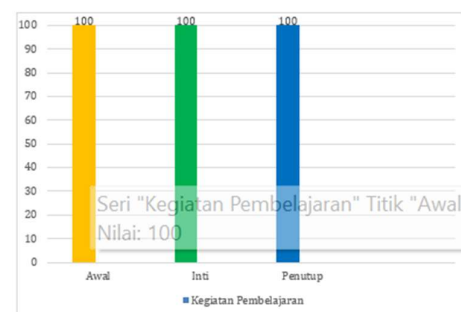


Figure 6. Research Observer Results

Data indicates that the quality of the implemented actions fully met all planning indicators, achieving a 100% implementation rate—classified as "Excellent." Out of 25 observational aspects comprehensively covering the introductory, core, and concluding phases, not a single instructional aspect was overlooked (0%). This maximum level of success was significantly driven by the systematic flow of the implemented instruction. During the initial phase, the effectiveness of the action was bolstered by the educator's readiness in establishing the classroom environment and the precise administration of the pre-test. Subsequently, in the core phase, deep subject-matter mastery supported by AI-based animated flashcards optimized the intervention process. This sequence was then rounded out in the concluding phase through precise time management that facilitated both periodic reflection activities and the administration of the final evaluation (post-test).

3.5. Evaluation

The data obtained from these responses serve as the basis for addressing the research questions, which encompass the development process of AI-based animated flashcards covering the topic of Earth's surface changes within the geographical context of West Java; the product's feasibility tested under field conditions evaluated in terms of subject matter, visual design, learning content, and linguistic readability; and an overview of the media's use in enhancing students' conceptual understanding in elementary schools.

The following table presents the results of teacher responses regarding the use of AI-based animated flashcards in instruction.

Table 5. Teacher response results

Indicators/ Aspects	Evaluation		
	Score Achieved	Maximum Score	Percentage (%)
Media Presentation	10	10	100%
Understanding of Material	8	10	80%
Media Appearance	8	10	80%
Language	5	5	100%
Media Effectiveness	15	15	100%
Final Total	46	50	92%

Based on the teacher response assessment, a score of 92% was obtained. This figure falls within the 81%–100% interval, placing it in the "Strongly Agree" or "Excellent" category. These quantitative findings factually indicate that the developed AI-based animated flashcard media is highly suitable as a tool to support digital learning. Utilizing this media can optimize cognitive learning outcomes and students' mastery of concepts, particularly regarding the topic of Earth's Surface Changes within the geographical context of West Java.

Based on the student response assessment, a score of 90.35% was obtained. This figure falls within the 81%–100% interval, placing it in the "Strongly Agree" or "Excellent" category. These quantitative findings factually indicate that the developed AI-based animated flashcard media is highly suitable as a tool to support digital learning. Utilizing this media can optimize cognitive learning outcomes and students' mastery of concepts, particularly regarding the topic of Earth's Surface Changes within the geographical context of West Java.

4. Conclusion

Based on the research findings and discussion, it can be concluded that this development research successfully produced a new learning medium: AI-based animated flashcards covering the topic of Earth's surface changes within the geographical context of West Java for fifth-grade elementary students. Regarding theoretical feasibility, the developed medium was rated highly suitable based on expert evaluations, achieving scores of 98.5% from media experts, 98% from subject matter experts, and 98% from language experts. Beyond its theoretical validity, the medium proved highly practical and elicited a very positive response from both teachers and students during classroom implementation.

Furthermore, regarding empirical effectiveness, the use of these AI-based animated flashcards significantly improved the students' conceptual understanding. This was evidenced by a striking increase in the average student score rising from 64.5 in the pre-test to 88 in the post-test and reinforced by an N-Gain score of 76, placing it in the high-index category. The integration of AI-driven animated visualizations successfully made abstract geological processes concrete, while the use of West Java's local geographical context fostered a science learning process that was more relevant, meaningful, and contextual for the students.

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