

IMPLEMENTING DEEP LEARNING THROUGH JOINT PUPPET MEDIA: INSIGHT FROM HUMAN MOVEMENT SYSTEM LEARNING IN ELEMENTARY SCIENCE EDUCATION

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ABSTRACT

Science learning regarding the human movement system in elementary schools requires connecting abstract concepts with concrete experiences. This study aims to describe the implementation of a deep learning approach using *Boneka Sendi* media at SD Negeri 02 Ngringo, focusing on its planning, implementation, evaluation, teacher obstacles, and adaptive strategies. A descriptive qualitative method was used, involving a sixth-grade science teacher as the informant. Data were collected through observations, in-depth interviews, and documentation, then analyzed using the Miles and Huberman interactive model. *Boneka Sendi* was successfully integrated into the learning sequence through the principles of mindful, meaningful, and joyful learning. Students actively observed and manipulated the media, enabling them to explain joint mechanisms in their own words, connect joint functions to daily activities, and understand simple joint disorders. Challenges regarding the limited number and durability of the media were effectively managed through group division, turn-taking, and usage guidance. The novelty of this research lies in integrating concrete media with deep learning principles and teachers' adaptive strategies, moving beyond its function as a mere teaching aid. Ultimately, successful deep learning implementation relies on well-integrated learning design, active student engagement, and the teacher's ability to manage facility limitations.

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INTRODUCTION

Science education (IPA) at the elementary school level, which is incorporated into the IPAS subject, has a strategic position as a foundation for developing students' scientific literacy, curiosity, and scientific attitudes. BSKAP Decree Number 046/H/KR/2025 states that the objectives of science learning are to develop students' understanding of scientific concepts

and process skills to understand natural phenomena, as well as to build scientific attitudes toward environmental conservation. However, the reality of science learning in Indonesia still reveals fundamental problems. Various studies show that science learning approaches implemented in elementary schools tend to remain conventional, dominated by lectures, and teacher-centered: (1) teacher-centered learning limits active student participation (Wahyuni & Baniati, 2025), while (2) book-focused learning often makes students less interested and less engaged in science learning (Prabowo, 2022).

Curriculum adjustment in Indonesia represents an adaptation to current developments and global competency demands. After several curriculum changes, the government introduced the Merdeka Curriculum in 2022 as a form of national educational reform (Herman et al., 2023). The implementation of the Merdeka Curriculum is considered to have positive impacts by making learning more flexible and student-centered, while providing space for the development of students' interests, talents, independence, and creativity (Ulfadhilah, 2024). This is expected to increase students' motivation and willingness to learn, as well as help them develop skills that are more relevant to future needs (Arsyad et al., 2024). The Merdeka Curriculum emerged as an answer to the challenges of the previous curriculum, which was considered unable to adequately meet global developments and students' needs (Muliawan, 2024).

The Merdeka Curriculum includes graduate profile dimensions as a direction for shaping the characteristics of Indonesian students. The graduate profile consists of eight main dimensions: faith, citizenship, critical reasoning, creativity, collaboration, independence, health, and communication, which are explicitly stated in Permendikdasmen Number 10 of 2025 as competency standards to be achieved through deep learning. The deep learning approach focuses on deep conceptual understanding, the development of higher-order thinking skills, and the formation of 21st-century competencies that integrate the six 6C dimensions (character, citizenship, collaboration, communication, creativity, and critical thinking) (Utari & Muadin, 2023). This is consistent with Hidayani, et al., (2025) and Prihantoro et al., (2025), which show that the implementation of the three pillars of deep learning and 6C competencies is still carried out separately. This learning model focuses on developing a deeper understanding of subject matter through comprehensive learning experiences, in which students are involved not only cognitively but also emotionally in their learning process. According to Suwandi et al., (2023), this approach seeks to transform the traditional learning paradigm, which tends to emphasize memorization and repetition of information, into learning that is more constructive and reflective. This change enables students not only to understand learning content but also to develop critical thinking skills, creativity, and problem-solving abilities.

Specifically, science content related to biological systems in biology lessons has a strategic role in equipping students with an understanding of life and their surrounding environment (Mangelep et al., 2023). Science concepts are abstract for elementary school students, making them vulnerable to surface learning. Through this approach, students do not merely memorize concepts but also understand and are able to apply them in real life (Santoso et al., 2023). To achieve deep understanding (deep learning), pedagogical interventions and learning media are needed to connect such abstractions with concrete reality (Fullan et al., 2018).

The use of science learning media plays an important role in overcoming students' learning difficulties. A study by Eka & Risma, (2023) shows that the appropriate and structured use of learning media can significantly increase students' interest in learning, mastery of the material, and achievement. Science learning aims to generate ideas and thinking so that students can think in a focused manner (Ayuni et al., 2024). Learning aids, whether digital or traditional, function as tools for delivering information in a more engaging and interactive manner. Dewi & Handayani, (2021) state that learning aids can improve the effectiveness of the learning process by simplifying abstract concepts into more concrete ones.

Although various studies have demonstrated the effectiveness of learning media in improving students' understanding of science concepts, most studies still focus on developing and testing media as learning products. For example, Soeharto, (2021) showed that concrete media in the form of the "Teleng" teaching aid can help students understand the structure of human bones and joints. Other studies have also reported that the use of learning media can improve students' motivation, engagement, and learning outcomes in science (Dewi & Handayani, (2021); Eka & Risma, (2023)). However, these studies generally emphasize the effect of media on learning outcomes, while the implementation of learning media to support the deep learning approach has not been widely explored in depth. In addition, research examining teachers' experiences in integrating learning media with deep learning principles, particularly in teaching the human movement system in elementary schools, remains very limited.

On the other hand, research on deep learning in elementary education has largely addressed conceptual aspects, learning characteristics, or its relationship with 21st-century competencies and the 6C dimensions (Utari & Muadin, 2023); Hidayani et al., (2025). These studies have not specifically revealed how teachers translate deep learning principles into science learning practices through the use of concrete media in the classroom. In fact, successful implementation of deep learning is determined not only by teachers' conceptual understanding but also by pedagogical strategies and the use of media that can connect abstract concepts with meaningful learning experiences for students.

Based on this gap, the novelty of this study lies in its effort to describe the implementation of the deep learning approach through the use of concrete learning media on the human movement system in elementary school. Unlike previous studies that focus on media effectiveness or conceptual studies of deep learning, this study explores teachers' actual experiences in designing, implementing, and utilizing learning media to realize meaningful, mindful, and joyful learning. In addition, this study identifies the obstacles faced by teachers and the adaptive strategies used to integrate learning media with deep learning principles. The urgency of this study lies in the need to obtain an empirical picture of how deep learning principles can be practically implemented through concrete media in science learning, particularly on the human movement system, which is characterized by abstract concepts and requires learning experiences that can be directly observed. This understanding is important as a basis for teachers in designing science learning that is not only oriented toward conceptual mastery but also encourages active engagement, meaning-making, and students' learning experiences. Therefore, this study aims to describe the implementation of the deep learning approach through learning media on the human movement system in elementary school, thereby providing an empirical contribution to the development of more meaningful and student-centered science learning practices.

METHOD

This study employed a descriptive qualitative method to collect information and analyze data through verbal expressions and images related to the topic under investigation (Atthahirah et al., 2024). Technically, the qualitative method describes facts and objects systematically, with interpretations presented descriptively based on direct findings in the field (Agustin & Mahardi, 2024). As a research technique, the qualitative approach uses narratives to explain each stage of the study, from events to real situations in the field (Charisma et al., 2022).

The study was conducted in November 2025 at SD Negeri 02 Ngringo, Karanganyar Regency, Central Java. The study involved one informant, namely a sixth-grade classroom teacher who teaches science. The informant was selected purposively based on the suitability of the informant's characteristics with the research focus, rather than on considerations of numerical representation. The selection of one informant was based on the consideration that the teacher was both the designer and implementer of learning on the human movement system using Boneka Sendi media, had experience implementing the deep learning approach in science learning, and was directly involved in the planning, implementation, and evaluation of learning. Thus, the informant was considered a key informant with direct knowledge and experience relevant to the phenomenon under study. Purposive selection was conducted to obtain in-depth information in accordance with the research focus. The validity of the information was not based solely on interviews with the informant but was strengthened through participatory observation and documentation of the learning materials and media used. The object of the study was the implementation of the deep learning approach through the use of Boneka Sendi media on the human movement system.

The indicators of deep learning implementation referred to three main pillars: mindful learning, meaningful learning, and joyful learning. Mindful learning was identified through activities demonstrating learning awareness, focused attention, reflection, and active student engagement in understanding concepts. Meaningful learning was identified through students' ability to connect human movement system concepts with everyday experiences, conduct exploration, engage in discussion, and construct conceptual understanding. Meanwhile, joyful learning was identified through a pleasant learning atmosphere, student enthusiasm, positive interaction during learning, and student engagement in using Boneka Sendi media.

Data were collected through participatory observation, in-depth interviews, and documentation. Data analysis used the Miles and Huberman interactive model, consisting of data collection, data condensation, data display, and conclusion drawing. The analysis process began with transcription of interview results and recording of observation results, followed by

open coding to identify themes related to planning, implementation, evaluation, obstacles, and the implementation of mindful learning, meaningful learning, and joyful learning principles. Subsequently, related codes were grouped into broader categories and themes to obtain a comprehensive understanding of the phenomenon under study. Data credibility was maintained through technique triangulation by comparing observation, interview, and documentation results. In addition, the researcher conducted member checking by asking the informant to review the interpretation of the data to ensure consistency between the research findings and the experiences conveyed by the informant. This process was conducted to enhance the validity and trustworthiness of the findings.

RESULT AND DISCUSSION

This study describes the implementation of the deep learning approach through the use of Boneka Sendi media on the human movement system at SD Negeri 02 Ngringo. Data were obtained through an in-depth interview with one sixth-grade teacher, participatory observation during learning, and documentation of learning materials. The three data sources were compared to assess the consistency of the findings. The discussion focused on three main aspects: (1) learning planning, (2) learning implementation and evaluation, and (3) obstacles and adaptive strategies in using Boneka Sendi media.

Table 1. Interview results related to the implementation of the deep learning approach through the use of learning media on the human movement system

Aspect	Interview Results
Planning	(1) The teaching module was developed collaboratively with fellow classroom teachers and the teacher working group approximately two weeks before the semester began, starting with an analysis of learning outcomes, a search for references on joint structures, and the development of a learning media prototype. (2) The sixth-grade classroom teacher acted as an instructional designer who designed the learning sequence and integrated Boneka Sendi media into every stage of the activities rather than using it as an additional teaching aid. (3) The selection of Boneka Sendi media was based on the abstract and mechanical characteristics of the human movement system, which required concrete visualization of how hinge and ball-and-socket joints work: <i>"The human movement system is abstract and mechanical. I chose Boneka Sendi because it can concretely visualize how hinge and ball-and-socket joints work, which cannot be achieved through static images in books."</i> (4) Activities were planned according to the three principles of deep learning: mindful learning ("Pause for a Moment" session and simple physical challenges), meaningful learning (problem-based learning connecting the material with writing, playing kasti, walking, and exercising), and joyful learning (a mini-laboratory and the educational "Guess the Movement" game).
Implementation	(1) The teacher used Boneka Sendi as the main tool to demonstrate the parts of joints (hinge and ball-and-socket) and their mechanisms: <i>"I show specific parts of Boneka Sendi, such as the location of the hinge or ball-and-socket joint, so that students can see the visual facts of the joint position rather than merely imagine the text in a book."</i> (2) The implementation applied scaffolding: students were directed to focus on one type of joint before moving to another, then demonstrate the media movement using their own bodies and connect it with everyday activities. (3) Students were trained in science process skills (observation, classification, questioning, and drawing conclusions) through prompting questions: <i>"During the simulation, I prompted the question: 'Why can the hand rotate but the knee cannot?' At the end, they drew their own conclusions about the range of movement of each joint based on their findings."</i> (4) The distribution of roles in small groups (media operator, recorder, and presenter) encouraged cooperation, objectivity, and responsibility.

Aspect	Interview Results
Evaluation	(5) The joyful learning atmosphere was evident from students' enthusiasm: <i>"The students were very enthusiastic. The classroom atmosphere became lively because they felt as if they were playing with a doll, even though they were conducting an anatomical analysis."</i> (1) Based on the teacher's account, students were able to explain the steps of joint movement in their own words: <i>"Because they were actively involved in handling the media, they could retell the steps of joint movement in their own words."</i> (2) Students began to understand simple cause-and-effect relationships, for example by predicting problems if one of the joints became locked or damaged. (3) Students connected the material with habits for maintaining physical health, such as the importance of proper sitting posture to keep the skeleton healthy. (4) Students' enthusiasm and comfort during learning were relatively high: <i>"The enthusiasm was very high. No students were passive because the media attracted their attention visually and motorically."</i>
Obstacles	(1) The number of Boneka Sendi units was limited, so students had to take turns using them: <i>"The constraint is the limited number of doll units, so students have to take turns."</i> (2) The hinge part of the media was prone to wear if not used carefully, so the teacher needed to provide usage instructions before learning began. (3) As a follow-up, the teacher planned to develop more interactive media variations with the possibility of integrating digital technology: <i>"I plan to develop more interactive media variations, perhaps by combining them with digital AI/AR applications to strengthen the deep learning aspect."</i>

Based on Table 1, the interview results were then analyzed together with observation and documentation data. At the planning stage, attention was directed to the alignment of objectives, activities, and media. During implementation and evaluation, attention was directed to teacher actions, student activities, observable forms of understanding, and the implementation of the three deep learning principles. Meanwhile, the obstacles were analyzed based on the condition of the media and the teacher's strategies for ensuring that all students continued to have learning opportunities. In this way, the discussion does not merely state that learning was conducted systematically but explains behavioral and process evidence showing how Boneka Sendi media supported deep learning.

1. Learning Planning Through Boneka Sendi Media

The interview results showed that the teacher planned the learning collaboratively with fellow teachers and the teacher working group. Planning began approximately two weeks before the semester started by analyzing learning outcomes, searching for references on joint structures, and developing a media prototype. The teacher did not position Boneka Sendi as an additional tool but incorporated it into the sequence of activities so that students could directly observe and practice joint mechanisms.

The selection of the media was based on the abstract and mechanical characteristics of the human movement system. The informant explained, *"The human movement system is abstract and mechanical. I chose Boneka Sendi because it can concretely visualize how hinge and ball-and-socket joints work, which cannot be achieved through static images in books."* This statement indicates that the decision to use the media was based on a pedagogical need to bridge abstract concepts with students' concrete experiences.

Documentation data reinforced the interview findings. The teaching module included learning objectives translated into observation activities, movement simulations, group discussions, and reflection. Boneka Sendi is presented in Figure 1 as part of the activity sequence, while the reading materials contain the structure and mechanisms of hinge and ball-and-socket joints. The alignment among the teaching module, media, and planned activities shows that planning was directed toward achieving learning objectives rather than merely providing teaching aids.

Figure 1. *Boneka Sendi* Learning Media



Source: Researcher's Documentation, 2025

At the planning stage, activities were designed according to the three principles of deep learning. The mindful learning aspect was designed through the "Pause for a Moment" session and simple physical challenges, such as asking students to pick up an object without bending their elbows, so that students became aware of joint functions before entering the theoretical discussion. This is consistent with Salong & Ansiska, (2025), which shows that structured integration of mindful learning can increase meaningful student engagement. The meaningful learning aspect was designed through problem-based learning that connected the material with activities such as writing, playing kasti, walking, and exercising. Mudlofir, (2021) states that one application of meaningful learning is actively involving students so that they can directly experience the meaning of learning activities. Meanwhile, the joyful learning aspect was designed through a mini-laboratory atmosphere and the educational game "Guess the Movement," which aimed to create a learning experience that was not monotonous, activity-rich, and interactive (Affandi et al., 2024).

The finding that the teaching module was developed collaboratively confirms that the teacher is not merely an implementer but also part of a learning community. This is consistent with Sofwan & Sari, (2025), who explain that successful IPAS learning based on deep learning cannot be separated from the teacher's roles as learning designer, facilitator, motivator, and reflector. The development of a module that includes analysis of learning outcomes, reference searching, and media prototyping is also in line with Fullan et al., (2018), who emphasize that deep learning requires pedagogical design that connects conceptual abstractions with concrete reality. The selection of concrete media for abstract material reinforces Soeharto, (2021) regarding the use of concrete media to support understanding of bones and joints. The design of the three deep learning principles from the teaching-module stage is also consistent with Andyanie et al., (2025), who emphasize the integration of mindful, meaningful, and joyful learning in learning planning. Based on these findings, the planning of Boneka Sendi use was not merely oriented toward providing teaching aids but was directed toward building learning experiences appropriate to the characteristics of the human movement system. Integrating the media into the teaching module made each activity connected to the learning objectives, from observation and movement practice to discussion and reflection. This shows that concrete media become effective when positioned as part of pedagogical design rather than used separately from the learning process. In this context, Boneka Sendi functions as a mediator that helps teachers translate abstract human movement system concepts into experiences that students can observe and manipulate. Thus, systematic planning is an important factor enabling mindful, meaningful, and joyful learning principles to be implemented in science learning

2. Learning Implementation and Evaluation through the Use of Boneka Sendi Media

The interview results showed that during implementation, Boneka Sendi was used as the main medium for demonstrating the parts and mechanisms of joint movement. The teacher applied scaffolding by directing students to focus on one type of joint before moving to another. Students then demonstrated the media movements using their own bodies and connected them with everyday activities. Prompting questions such as "*Why can the hand rotate but the knee cannot?*" were used to encourage students to use their observations to explain the range of movement of each joint.

Observation results showed that students actively observed the direction of joint movement, discussed, tried to match the media movements with body movements, asked questions, and participated in the "Guess the Movement" game.

Assigning roles as media operator, recorder, and presenter also provided opportunities for students to participate in the learning process. This condition shows that Boneka Sendi functioned as an exploration medium that guided students to acquire concepts through activities rather than merely receiving explanations from the teacher.

At the same time, implementation encountered two main obstacles. First, the number of media units was limited, so students had to take turns using them: *"The constraint is the limited number of doll units, so students have to take turns."* Second, the hinge part of the media was prone to wear when not used carefully, requiring the teacher to provide usage instructions before learning began. Observation results showed the teacher's adaptive strategies, namely dividing students into small groups, arranging turns to use the media, and assigning roles within groups so that all students could still gain direct experience. As a follow-up, the teacher stated plans to develop more interactive media variations: *"I plan to develop more interactive media variations, perhaps by combining them with digital AI/AR applications to strengthen the deep learning aspect."*

Overall, during implementation, Boneka Sendi functioned as a student exploration tool guided by teacher scaffolding, allowing the three principles of deep learning (mindful, meaningful, and joyful learning) to be evident in classroom practice. At the evaluation stage, the three data sources showed a positive tendency in conceptual understanding and student engagement, with the note that this study did not use quantitative learning outcome tests. The obstacles related to the limited number and durability of the media were mitigated through group management and role distribution, while digital technology integration remained a follow-up plan.

The use of Boneka Sendi during implementation functioned as a bridge between abstract scientific concepts and students' concrete experiences. When students could see the direction of joint movement, manipulate the media, and compare it with their own body movements, learning no longer stopped at memorization. This finding is consistent with Donovan, (2019), who states that deep learning occurs when students understand the meaning of material, seek relationships among concepts, connect the material with prior experiences, and apply it to new situations. This explanation is reinforced by Nasution et al., (2024), who state that the deep learning approach encourages students to connect new information with prior knowledge, develop conceptual understanding, engage in critical reflection, and apply knowledge in real contexts. These findings show that the contribution of Boneka Sendi to deep learning occurs through the integration of concrete experiences and students' thinking activities. When students observe the direction of joint movement, manipulate the media, and then compare it with their own body movements, they have opportunities to build relationships between observed objects and the scientific concepts being learned. The prompting questions provided by the teacher further strengthened this process because students did not merely perform movements but were also guided to explain why movement differs across joint types. Thus, Boneka Sendi functions not only as a visualization medium but also as a tool that facilitates observation, classification, reasoning, and conclusion drawing. This is why the media can support the implementation of deep learning in learning the human movement system.

Figure 2. Use of Boneka Sendi Learning Media



In the mindful learning aspect, the "Pause for a Moment" session and activities involving awareness of body movements positioned students' bodily experiences as the starting point of learning. This is consistent with Winarno, (2024), who explains that one technique for implementing mindful learning is self-reflection, which provides students with

opportunities to reflect on something based on their experiences. The use of scaffolding to focus students' attention on one type of joint first is also consistent with Salong & Ansiska, (2025), which shows that structured integration of mindful learning can increase meaningful engagement. The implication is that science learning can begin with phenomena directly experienced by students rather than with textual definitions. This is in line with the principle of mindful learning, which emphasizes students' awareness of learning objectives (Taqiyya et al., 2025).

In the meaningful learning aspect, connecting the human movement system material with activities such as writing, playing kasti, walking, and kicking a ball shows that concepts were bridged through experiences close to students' lives. This is consistent with Mudlofir, (2021), who states that one application of meaningful learning is actively involving students so that they can directly experience the meaning of learning activities, as well as with Jeet & Pant, (2023), who emphasize the importance of meaningful experiences for developing 21st-century skills. It is also consistent with Santoso, (2023) regarding the effectiveness of contextual phenomenon-based learning in improving science literacy. These findings indicate that Boneka Sendi is effective as a cognitive bridge between the human movement system material and the real-life contexts of elementary school students.

In the joyful learning aspect, the "Guess the Movement" game and the mini-laboratory atmosphere are consistent with Affandi et al., (2024), who state that joyful learning aims to create learning experiences that are not monotonous, activity-rich, and interactive. This finding also supports Hasfiana, (2025) and Putri, (2024), who show that joyful learning and deep learning approaches contribute positively to student activity and engagement in learning. This study shows that a pleasant learning atmosphere does not merely create a lively classroom or make students feel happy but functions as a condition that encourages students' engagement in thinking processes. The "Guess the Movement" game engaged students emotionally and socially, while the activity remained directed toward academic goals through matching the position of Boneka Sendi with the demonstrated movement. Thus, joyful learning becomes meaningful because students' enjoyment occurs alongside activities of observing, analyzing, discussing, and drawing conclusions. This shows that Boneka Sendi supports joyful learning not merely because its form is attractive to students. Furthermore, this finding is consistent with Cahya et al., (2023), who state that learning media can train concentration, increase students' focus on learning materials, and encourage active engagement. This study adds that concrete media such as Boneka Sendi not only attract attention but can also serve as tools for developing thinking processes. Prompting questions encourage students to use their observations to understand the range of joint movement, allowing the media to function as a thinking tool rather than merely a display tool.

Learning evaluation showed conceptual understanding, as indicated by students' ability to explain the mechanism of joint movement in their own words and connect joint types with everyday activities. The informant stated, *"Because they were actively involved in handling the media, they could retell the steps of joint movement in their own words."* Observation showed students listening, handling the media, discussing, answering reflection questions, and practicing movements. Documentation of activity sheets also showed answers connecting joint types with particular movements in daily activities. Students began to explain simple cause-and-effect relationships, such as possible problems when a joint becomes locked or damaged. These findings indicate that the media helped students move from recognizing terms toward understanding that could be explained and applied in familiar contexts. This finding is consistent with Luthfiyah et al., (2025), who found that the implementation of deep learning in IPAS can support the effectiveness and quality of learning in elementary schools, particularly in connecting concepts with contexts. The ability to predict consequences when a joint becomes locked or damaged is also consistent with Hasim et al., (2025), who showed that metacognitive learning strategies can strengthen elementary students' cause-and-effect reasoning in science learning. These findings are more appropriately understood as indications of conceptual understanding and student engagement observed during the learning process. Thus, the reason Boneka Sendi can support the implementation of deep learning is not merely because the media is visually attractive, but because it is used together with scaffolding, prompting questions, contextual activities, discussion, and reflection. This integration enables students to observe concepts concretely, connect them with experiences, and use their observations to construct understanding.

3. Obstacles in the Implementation of Boneka Sendi Media

In implementing Boneka Sendi media in science learning, several obstacles were related to the availability and condition of the learning media. The findings showed that the limited number of Boneka Sendi units and the durability of the learning media materials, which were prone to damage, were among the challenges in implementing the learning process. The

limited number of media units meant that not all students could use the media simultaneously, while repeated use of the media materials created a risk of damage. This finding is consistent with Wahyuni & Baniati, (2025), who state that the implementation of deep learning-based science learning faces challenges in designing deep and meaningful learning. In addition, Fadila & Fitriyeni, (2024) and Yasin et al., (2024) explain that limited infrastructure and learning media can become obstacles to implementing science learning under the Merdeka Curriculum.

To overcome these limitations, the teacher implemented several strategies in using Boneka Sendi media. These strategies included dividing students into small groups, arranging turns to use the media, and assigning roles within each group. These strategies enabled all students to continue having opportunities to interact with the media despite the limited number of Boneka Sendi units. Thus, the limited number of media did not directly stop the implementation of deep learning but encouraged the teacher to manage learning adaptively. This is consistent with Yolanda et al., (2024), who emphasize the importance of contextual learning strategies for improving conceptual understanding even when available facilities are limited. In addition, Sofwan & Sari, (2025) position the teacher as a designer, facilitator, motivator, and reflector in deep learning-based instruction.

In addition to the limited number of media units, the physical condition of Boneka Sendi was also a concern for its continued use. The materials of Boneka Sendi may wear out when used repeatedly, requiring maintenance and repair so that the media can continue to function optimally. This condition shows that the use of concrete media requires not only the availability of tools but also regular maintenance. Therefore, the sustainable use of Boneka Sendi needs to be supported by appropriate management, maintenance, and media development according to learning needs. The teacher's plan to develop more interactive media variations through possible integration of digital AI/AR technology may serve as an alternative for media development, but it remains a follow-up plan and was not part of the implementation observed in this study.

Based on the research findings, it can be concluded that the main obstacles in implementing Boneka Sendi media lie in the limited number of media units and the condition of materials that are prone to wear due to repeated use. These obstacles did not hinder the overall implementation of learning because the teacher applied adaptive strategies, including dividing students into small groups, arranging turns to use the media, assigning roles within groups, and providing instructions on media use before learning began. Nevertheless, the limited number and condition of the media remain aspects that need attention so that Boneka Sendi can be used optimally and sustainably. Therefore, regular media maintenance and the development of stronger and more interactive media are needed to support the implementation of the deep learning approach in science learning.

CONCLUSION

This study shows that the implementation of the deep learning approach in elementary school science learning on the human movement system can be effectively realized through the use of concrete Boneka Sendi media systematically integrated into the learning process. The findings confirm that concrete media function not only as tools for visualizing abstract concepts but also as means of supporting mindful, meaningful, and joyful learning. Practically, these findings show that teachers can use concrete media as part of learning design to help students understand abstract concepts through activities of observing, practicing, discussing, and reflecting on learning experiences. Through concrete, contextual, and participatory learning experiences, students have opportunities to develop deeper conceptual understanding through observation, exploration, discussion, reflection, and problem-solving activities. Scientifically, this study contributes to the development of deep learning-based science education in elementary schools by showing that successful implementation of deep learning depends not only on the use of learning media but also on teachers' ability to design meaningful learning experiences, manage learning interactions, and apply adaptive strategies according to students' needs. These findings reinforce the view that integrating concrete media with appropriate pedagogical strategies can bridge abstract science concepts and students' real-life experiences, thereby supporting deeper conceptual understanding. Based on the findings, teachers are advised to integrate concrete media systematically into science learning and develop learning activities that encourage active engagement, reflection, and connections between learning materials and everyday life. Schools should support the procurement, maintenance, and development of innovative learning media so that the implementation of deep learning can be sustained. In

addition, developing media that integrates digital technologies, such as augmented reality (AR) or artificial intelligence (AI), may be an alternative for enriching students' learning experiences. Future research is recommended to examine the effectiveness of Boneka Sendi media using quantitative or mixed-methods approaches so that its impact on improving students' learning outcomes, science literacy, and 21st-century competencies can be measured more comprehensively.

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