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Article

Transformation of Students' Understanding of Linear Motion Sub-Materials through Assemblr Edu Learning Media at the Junior High School Level/MTs Students

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ABSTRACT
Science instruction on the topic of linear motion often leads to misconceptions because the concepts of position, velocity, and acceleration are abstract and dynamically interrelated. The prevalence of formula-based instruction causes students to tend to understand concepts procedurally without being able to relate them to physical phenomena. The use of Augmented Reality (AR)-based media, such as Assemblr Edu, has the potential to help visualize concepts in a more concrete and interactive way. This study aims to describe the transformation of students' conceptual understanding of the linear motion subtopic through the use of AR media. Unlike previous studies that mainly focus on learning outcomes, this study specifically examines the process of conceptual transformation based on the framework of Conceptual Change Theory. The research focuses on: (1) students' initial understanding, (2) the process of understanding transformation during learning, and (3) students' final understanding. This study employs a descriptive qualitative approach with subjects comprising a science teacher and six eighth-grade students in Class VIII C at MTsN 1 Lumajang. Data were collected through observation, interviews, and documentation, and analysed using thematic coding based on stages of conceptual change, with validity ensured through source and technique triangulation. The findings indicate that students' initial understanding is dominated by procedural patterns and conceptual misconceptions. During instruction, AR visualization triggered cognitive conflict that encouraged conceptual restructuring through visual exploration, social interaction, and teacher facilitation. Students' final understanding developed into a more conceptual and applied form, as evidenced by their ability to explain relationships between variables and apply them in real-life contexts. These findings suggest that the integration of AR with appropriate pedagogical support facilitates meaningful and relatively stable conceptual change. This study implies that AR-based learning should be designed not only as a visualization tool, but as a structured pedagogical strategy to support students' conceptual development.

INTRODUCTION

One of the main challenges of 21st-century education is to provide learning that is not only visually appealing, but also conceptually meaningful. In the era of Society 5.0, the integration of technology in learning is a strategic necessity to help students understand abstract concepts.(Sakiinah et al., 2022). However, various studies show that the use of educational technology has not been fully optimized due to limitations in digital competence and pedagogical design that has not been systematically integrated. In science education, especially physics, many concepts require relational thinking and mental modeling skills. One of the topics that often causes misconceptions is linear motion, especially in distinguishing between Uniform Linear Motion and Uniformly Accelerated Linear Motion. This difficulty arises because students must understand the dynamic relationship between position, time, velocity, and acceleration simultaneously (Deria & Wardani, 2022; Jaapar et al., 2020). Without adequate visual support, the concept tends to be understood procedurally through memorization of formulas, rather than as an interconnected conceptual system.

Previous research shows that misconceptions about motion are not easily overcome through verbal explanations alone (Arda & Anita, 2021). According to Potvin and colleagues, conceptual errors often persist because students maintain their initial, unstructured thinking frameworks. (Meiliyadi et al., 2025). In line with this, Ibáñez and Delgado-Kloos emphasize that visual and interactive learning experiences can help students build more accurate mental representations of physical phenomena (Nofri dkk, 2025).

One form of technological innovation that is developing is Augmented Reality (AR), which enables the interactive integration of virtual objects into the real environment. (Jannah & Atmojo, 2022). In the context of education, AR is considered capable of helping to visualize abstract concepts through dynamic three-dimensional representations (Nofri dkk., 2025). Several studies have shown that the use of AR increases student motivation and learning outcomes (Masri et al., 2023). Interactive simulations and virtual visualization are also known to support conceptual understanding and scientific literacy in science learning (Masruroh et al., 2021; Rembulan & Susanti, 2021). However, most of these studies primarily focus on quantitative outcomes, such as test scores or learning motivation, and provide limited insight into how students' conceptual understanding actually changes during the learning process (Agustin & Aqua Kusuma Wardhani, 2023).

On the other hand, experts such as Paul A. Kirschner, John Sweller, and Richard E. Clark in research by Nur Wachid et al. remind us that learning technology does not automatically improve understanding if it is not accompanied by adequate pedagogical guidance (Majid et al., 2023). A minimal guidance approach has the potential to cause cognitive overload, especially with complex scientific material. This means that the effectiveness of AR is highly dependent on the learning design and the role of the teacher as a conceptual facilitator.

Based on initial observations at MTs Negeri 1 Lumajang, it was found that some eighth-grade students still had difficulty distinguishing between GLB and GLBB even though the material had been taught previously. Teachers stated that students tended to understand the concept in terms of formulas but had difficulty explaining the relationship between changes in velocity and acceleration conceptually. These findings indicate the existence of misconceptions that have not been thoroughly resolved.

To understand the dynamics of this change, this study uses Posner's Conceptual Change Theory framework, which explains that conceptual change occurs when students experience dissatisfaction with their initial conceptions and then construct new concepts that are more intelligible, plausible, and fruitful (Kyriakopoulou, 2025). This perspective is in line with Jean Piaget's constructivism, which emphasizes the importance of the accommodation process in cognitive restructuring (Ulya, 2024).

Despite the growing body of research on AR in education, there is still a lack of studies that examine the mechanism of conceptual change in depth, particularly through qualitative approaches and within the context of junior high school (MTs) physics learning. Previous studies rarely explore how students reconstruct their initial misconceptions into scientifically accepted concepts through stages of conceptual change (Jaapar et al., 2020; Rembulan & Susanti, 2021).Therefore, this study addresses this gap by focusing on the process of conceptual transformation rather than merely measuring learning outcomes.

Unlike previous studies, which generally focused on the effectiveness of AR media on learning outcomes, this study specifically focuses on the process of transformation in students' conceptual understanding during learning using Assemblr Edu. This transformation is not merely assessed based on final outcomes but is analyzed in depth through changes in how students explain concepts, identify relationships between variables, and apply the concept of linear motion in various contexts. The analysis was conducted sequentially at the stages before, during, and after learning, thereby providing a more comprehensive picture of the dynamics of conceptual change experienced by students in a gradual and meaningful manner.

Therefore, this study aims to: (1) identify students' initial misconceptions and procedural understanding of linear motion; (2) analyze the process of conceptual change during AR-based learning, including the emergence of cognitive conflict and conceptual restructuring; and (3) describe the development of students' final conceptual understanding as reflected in their ability to explain and apply linear motion concepts**.** The novelty of this study lies in its in-depth analysis of the mechanisms of conceptual change in the context of AR integration in junior high school/MTs physics learning, thereby contributing theoretically and pedagogically to the development of meaningful technology-based learning.

METHODS

This study employed a qualitative approach with a descriptive design to explore the process of students' conceptual change in learning linear motion through the use of Augmented Reality media based on the Assemblr Edu application. A qualitative approach was selected because the study focuses on understanding the dynamics of students' thinking processes, learning experiences, and meaning construction in a natural classroom setting rather than measuring learning outcomes quantitatively (Fadli, 2021). Qualitative research allows researchers to understand the dynamics of thinking, learning experiences, and the meanings constructed by students during the learning process (Daruhadi & Sopiati, 2024). The analysis of conceptual change in this study refers to Posner et al.'s Conceptual Change Theory, which emphasizes dissatisfaction with initial conceptions and the development of new concepts that are intelligible, plausible, and fruitful (Kyriakopoulou, 2025).

The study was conducted in the odd semester of the 2025/2026 academic year at MTsN 1 Lumajang, East Java. The participants consisted of one science teacher and six eighth-grade students from Class VIII C selected through purposive sampling (Andrade, 2021). The selection criteria included students who actively participated in AR-based learning and were able to articulate their understanding during interviews. Although the number of participants was relatively small, it was considered sufficient in qualitative research because the focus is on depth rather than generalization. Data saturation was achieved when no new themes or significant variations in students' responses were found during repeated observations and interviews, indicating that the data were sufficiently rich to represent the phenomenon under study.

The research procedure was carried out in three stages: preparation, implementation, and analysis. In the preparation stage, the researcher conducted preliminary observations, reviewed relevant literature, and developed research instruments such as interview guidelines and observation sheets based on indicators of conceptual change. The implementation stage was conducted during a learning session on linear motion using Assemblr Edu. During this stage, the researcher identified students' initial understanding, observed the emergence of cognitive conflict during interaction with three-dimensional visualizations, and documented classroom interactions and student responses. The analysis stage was conducted continuously alongside data collection to ensure the consistency and depth of interpretation.

Data were collected through participatory observation, semi-structured interviews, and documentation (Rifa'i, 2023). Participatory observation was used to capture classroom dynamics and students' responses to AR-based learning (Rofiah, 2022). Semi-structured interviews were conducted to explore students' initial understanding, experiences during learning, and changes in their conceptual understanding (Hansen, 2020). Documentation, including learning materials, photos of activities, and students' work, was used as supporting data to strengthen the findings (Sari et al., 2025).

Data analysis was conducted using the interactive model of Miles, Huberman, and Saldaña, which includes data reduction, data display, and conclusion drawing (Qomaruddin & Sa'diyah, 2024). In addition, thematic coding was applied to identify patterns in the data. The coding process involved open coding to identify initial categories, followed by thematic categorization based on key indicators of conceptual change, such as misconceptions, cognitive conflict, conceptual reconstruction, and conceptual stabilization. These categories were then interpreted using the stages of conceptual change proposed by Posner, namely dissatisfaction, intelligibility, plausibility, and fruitfulness. The validity of the data was ensured through source triangulation and technique triangulation to enhance the credibility and consistency of the finding (Intifada dkk., 2025). The research procedure was simplified into a single flow to improve clarity and readability, consisting of three main stages: preparation, implementation, and data analysis. Each stage is interconnected and represents the sequential process of the study.

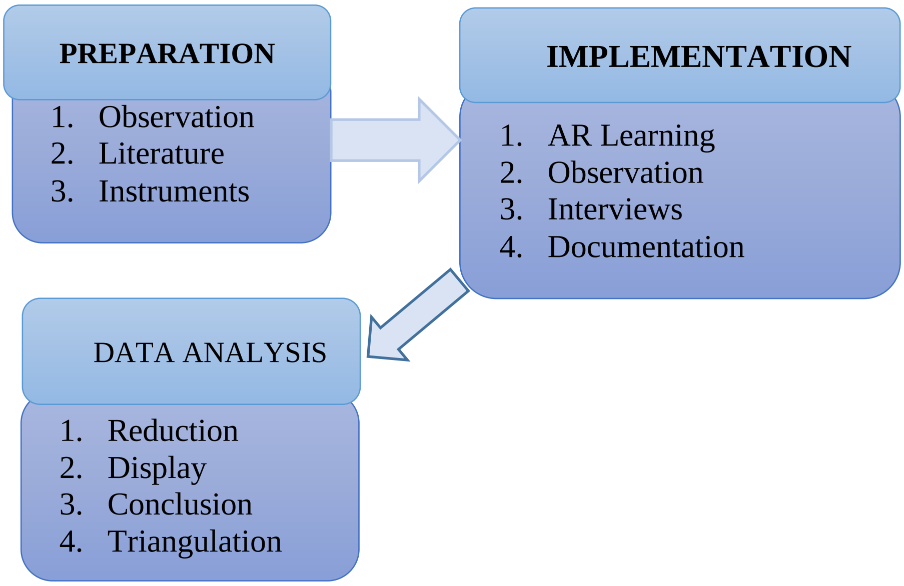

Figure 1. Research Flow Diagram

RESULTS AND DISCUSSION

Students' initial understanding of the concept of linear motion before using Assemblr Edu media

The primary focus of this study was to identify students' prior understanding before using Assemblr Edu. Results from observations, interviews, and documentation indicate that students' understanding remains procedural and focused on memorizing formulas. Students tend to define acceleration as faster motion and distinguish between uniform linear motion and uniformly accelerated linear motion solely based on mathematical equations, rather than their physical characteristics. For example, five out of six students initially defined acceleration only as "moving faster" without recognizing it as a change in velocity over time. One student stated, *"acceleration means the object moves faster,"* indicating a misconception. Although most students were able to solve numerical problems correctly, four out of six students still struggled to explain the conceptual relationship between position, velocity, and acceleration. Furthermore, their ability to physically interpret velocity–time graphs had not yet developed, as students tended to focus only on numerical values rather than their physical meaning, indicating the presence of misconceptions that hindered a comprehensive understanding of the concepts

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Figure 2. Classroom Atmosphere Before Using Assemblr Edu Media

These findings indicate the presence of significant misconceptions and the absence of an integrated conceptual model among students. Observation indicators showed that students rarely connected mathematical formulas with real-life motion phenomena and tended to rely on symbolic manipulation without conceptual explanation. The concept of linear motion tends to be understood as a disconnect between mathematical symbols and real-world phenomena, so that students are able to perform calculations but struggle to explain their physical meaning. This situation leads to errors in interpreting the relationship between position, velocity, and acceleration (Febriana & Nada, 2020). Furthermore, a fragmented understanding makes it easy for concepts to be misinterpreted when applied to different contexts. This finding is consistent with various previous studies indicating that linear motion is one of the topics with a high rate of misconceptions at the junior high school level. Difficulties in understanding abstract scientific concepts and connecting them to physical phenomena are also frequently reported in technology-based science learning research (Jaapar et al., 2020).

Within the framework of Conceptual Change Theory, this stable but erroneous initial understanding reflects the dominance of assimilation without accommodation (Kyriakopoulou, 2025). Students tend to incorporate new information into their existing frameworks without making fundamental adjustments to their conceptual structures. As a result, misconceptions persist because they are still considered sufficient for solving routine problems. Students also have not yet experienced dissatisfaction with their initial concepts because they have not been confronted with situations that require a deeper explanation. Therefore, this condition becomes a crucial starting point for conceptual transformation, especially when students begin to gain more representative learning experiences that can trigger a gradual restructuring of their understanding.

The process of transforming students' understanding of linear motion learning by utilizing Assemblr Edu media

The second focus analyzes the process of conceptual change during AR-based learning at MTsN 1 Lumajang using Assemblr Edu. Results from observations and interviews indicate that the transformation of understanding occurs gradually through the mechanisms of cognitive conflict and meaning reconstruction. Data were analyzed using thematic coding based on stages of conceptual change, namely misconception, cognitive conflict (dissatisfaction), conceptual reconstruction, and stable understanding. Students' interactions with three-dimensional motion simulations revealed a mismatch between their initial concepts and the observed phenomena, particularly in interpreting acceleration. For example, four out of six students showed confusion when observing motion simulations, as indicated by hesitation, repeated questioning, and revision of initial answers. One student stated, *"I thought acceleration always means faster speed, but here the speed changes gradually,"* indicating the emergence of cognitive conflict. The resulting confusion signaled the emergence of dissatisfaction as a prerequisite for conceptual change (Kyriakopoulou, 2025). This conflict then prompted the students to revise their understanding through visual exploration, group discussions, and the teacher's explanations. This process demonstrates that conceptual change does not occur instantly, but rather through the integration of visual experiences and ongoing cognitive reflection.

Figure 3. Classroom Atmosphere During Learning Using Assemblr Edu Media

AR visualization via Assemblr Edu serves as a catalyst for cognitive conflict by presenting dynamic representations of motion that cannot be explained by students' procedural understanding. Similar findings were reported in previous studies showing that interactive simulations and virtual laboratories can facilitate conceptual exploration and strengthen students' scientific understanding (Masruroh et al., 2021; Rembulan & Susanti, 2021). As students observe the simulation, they begin to recognize the discrepancy between their initial concepts and the phenomena displayed. Observation indicators showed that students actively compared simulation results with their prior understanding and began to question inconsistencies. Through independent exploration and group discussions, students gradually reconstruct the concept of acceleration as a change in velocity over time (Nafi'an, 2021). For instance, several students revised their explanations from "acceleration is faster motion" to "acceleration is a change in velocity," indicating conceptual reconstruction. This process demonstrates that concrete visual experiences help students understand the relationships between variables more comprehensively. Representational and visual-based learning approaches are known to support students in reconstructing abstract scientific concepts into more meaningful understanding. New concepts become more intelligible because they are not only understood abstractly but are also reinforced by the integration of interactive visualizations and the teacher's verbal explanations throughout the learning process.

The process of conceptual change is influenced not only by the use of technology, but also by social interaction and the active role of teachers as learning facilitators. Teachers help direct students' attention, provide conceptual explanations, and connect visual representations with relevant theoretical frameworks (Purnamira Tania et al., 2023). Discussions among students also reinforce the process of reflection and conceptual clarification, as students exchange ideas and evaluate different explanations. Triangulation of observation, interview, and documentation data confirmed that these interactions supported the consistency of conceptual change findings. Although there were technical challenges, such as limited devices and network connectivity, these did not significantly hinder the restructuring of students' understanding. Overall, these findings indicate that conceptual change occurs through the integration of cognitive conflict, visual exploration, and reflective dialogue, which aligns with the mechanisms of Conceptual Change Theory in fostering a more scientific understanding (Kyriakopoulou, 2025).

Students' final understanding after participating in linear motion learning using Assemblr Edu media

The third finding indicates that students' final understanding following instruction using Assemblr Edu showed more stable and conceptual development. Based on observations, interviews, and documentation, students no longer distinguished between uniform linear motion and uniformly accelerated linear motion solely based on formulas, but were able to explain the characteristics of these motions conceptually. All six students were able to explain acceleration as the rate of change of velocity over time, although with varying levels of depth. For example, one student stated, *"acceleration is not just faster motion, but how velocity changes over time,"* indicating a shift from procedural to conceptual understanding. Students also began to interpret motion graphs in a more coherent and logical manner. Additionally, students could relate the concepts to real-world phenomena, such as vehicle braking or bicycle acceleration. Documentation data showed that five out of six students were able to provide relevant real-life examples, demonstrating the ability to transfer concepts to new contexts. These findings confirm that students' understanding has evolved from procedural to conceptual and applied.

Figure 4. Students Answering Questions in Front of the Class

This change indicates the formation of a more integrated conceptual model that combines mathematical, visual, and phenomenological representations. Observation indicators showed that students were able to connect equations with graphical representations and explain their physical meanings during classroom discussions (Jaapar et al., 2020; Masruroh et al., 2021). Through the use of Assemblr Edu, three-dimensional visualizations help make previously abstract concepts more concrete, particularly in understanding the dynamic relationship between position, velocity, and acceleration. Students no longer rely solely on mathematical symbols but begin to connect them with visual representations and observed real-world phenomena. This strengthens students' understanding while boosting their confidence in explaining concepts independently and logically (Subhan & Pratama, 2023). Within the framework of Conceptual Change Theory, this situation reflects the attainment of the fruitful stage, where the new concept not only replaces the old, erroneous one but is also used productively to explain various phenomena consistently and scientifically (Kyriakopoulou, 2025).

Thus, the transformation that occurs is not temporary but indicates a relatively stable conceptual restructuring within students' cognitive structures. This change is evident in students' consistent use of understood concepts to explain various different situations. For instance, students were able to apply the concept of acceleration in different contexts without returning to their initial misconceptions. Students' understanding evolves from procedural patterns oriented toward rote memorization toward a deeper conceptual and applied understanding (Majid et al., 2023). Students are not only able to solve problems but can also logically explain the meaning behind the calculations. This indicates that the learning process has resulted in a meaningful conceptual change, where new concepts have been internalized and can be applied flexibly (Kyriakopoulou, 2025).

Overall, this study demonstrates that Augmented Reality-based learning is capable of facilitating a shift in students' understanding from procedural memorization toward a more structured and in-depth conceptual understanding. This transformation process occurs through systematic stages, beginning with limited initial understanding, the emergence of cognitive conflict due to the mismatch between concepts and phenomena, followed by conceptual reconstruction through visual exploration, and culminating in the application of concepts in broader contexts (Fauziyah & Munahefi, 2024). Each stage is interrelated and contributes to the formation of a more scientific understanding. However, these findings should be interpreted within the context of a limited number of participants. These findings confirm that meaningful and interactive learning experiences play a crucial role in fostering conceptual change in students. Interactive digital learning environments have also been reported to improve students' engagement, conceptual reasoning, and scientific literacy in science learning contexts (Rembulan & Susanti, 2021).

The effectiveness of AR media remains highly dependent on the instructional design implemented and the teacher's role as the primary facilitator in the learning process. Technology does not automatically bring about conceptual changes; rather, it serves as a tool that reinforces students' knowledge-construction process. Without guidance, explanation, and reinforcement from the teacher, the visualizations displayed risk becoming merely visual experiences devoid of deep conceptual meaning. Therefore, the integration of AR technology with appropriate pedagogical strategies is essential to support systematic and sustainable transformations in students' conceptual understanding (Sweller, 2024).

CONCLUSION

The use of Assemblr Edu-based Augmented Reality media in teaching linear motion to eighth-grade students at MTsN 1 Lumajang indicates its potential to facilitate gradual conceptual change. The transformation of understanding occurred through three main stages, namely the identification of initial procedural limitations in understanding, the emergence of cognitive conflict through three-dimensional visual exploration, and the formation of a more conceptual and applicable final understanding. Students no longer understood linear motion as merely memorizing formulas, but were able to explain the relationship between position, velocity, and acceleration and apply it in everyday contexts. This process reflects the stages of conceptual change, from dissatisfaction with the initial concept to the construction of more meaningful and productive new concepts. However, these findings should be interpreted within the context of a limited number of participants and a specific learning setting. The effectiveness of AR-based learning is influenced by the readiness of infrastructure and the role of teachers in managing cognitive conflicts and facilitating reflective discussions in the classroom. Thus, AR media does not function solely as a visual aid, but as an integrated pedagogical tool when supported by appropriate instructional design. This study implies that the integration of AR in science learning should be oriented not only toward enhancing visualization, but also toward supporting structured conceptual change processes. Furthermore, this study contributes to the literature by providing empirical evidence on how AR-based learning facilitates the process of conceptual transformation, particularly within the framework of Conceptual Change Theory at the junior high school level.

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