Trend of misconceptions in force and motion using the Conceptual Change Model (CCM): A systematic literature review

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Abstract
Misconceptions regarding force and motion are still prevalent in science education at all levels of schooling and contribute to students' poor conceptual understanding. These misconceptions must be addressed promptly to prevent them from hindering students' conceptual understanding at subsequent educational levels. One way to reduce students' misconceptions is by using instructional models that create cognitive conflict and facilitate conceptual reconstruction, such as the Conceptual Change Model (CCM). This study is a systematic literature review (SLR) aimed at determining whether the CCM can reduce students' misconceptions. The method used followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, with articles retrieved from the ScienceDirect and Google Scholar databases for the years 2019–2025. Articles were selected based on predefined inclusion and exclusion criteria. The results of the review of 31 articles can be summarized as follows: (1) Indonesia is the country that has conducted the most research on the influence of CCM on misconceptions regarding force and motion; (2) Misconceptions appear in nearly all sub concepts of force and motion, and are dominated by Newton's Laws; (3) Various learning strategies have been used to reduce misconceptions, such as CCM, the inquiry model, the STEM approach, computer simulation media, and the POE strategy. The analysis results indicate that conceptual change-based strategies, particularly CCM, are the most dominant and effective approach, marked by a significant reduction in misconceptions and an increase in students' conceptual understanding. The conclusion of this study is that CCM can reduce misconceptions regarding force and motion.

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1. Introduction

Science are taught at all levels of education under the Merdeka Curriculum in Indonesia. The Natural Sciences subject systematically examines natural phenomena so that students master knowledge, facts, concepts, and principles, and develop a scientific mindset (Fitra, 2022). The essence of science education is not merely to emphasize the mastery of knowledge products, but also to integrate the scientific process and the development of attitudes, so that students do not merely memorize information, but are able to understand concepts, apply the scientific method, and develop scientific thinking (Mufidzah, 2024). Science plays a strategic role in improving students' science literacy. Science scores on the Programme for International Student Assessment (PISA) from 2006 to 2015, ranging from 382 to 403, saw a significant decline in 2018 to 296, and then increased again in 2022 to 403. This result placed Indonesia 62nd out of 70 participating countries, far below the international average of 493, indicating that Indonesian students' science literacy skills still require serious attention and improvement efforts.

Natural science is a body of knowledge consisting of concepts and facts about the universe (Esti Wahyuningsih, 2016; Andriyani, Wahyu, 2018). One of its essential characteristics is that science is a product comprising concepts, principles, laws, and theories (Mufidzah, 2024). Concept mastery is a key factor in student learning outcomes; low achievement reflects weak concept mastery by students (Andriyani & Wahyu, 2018). On the other hand, students enter the learning process with prior concepts formed from everyday knowledge and experiences (Van Den Berg, 1991), which often

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conflict with scientific concepts (Purwasih et al., 2020). This discrepancy in knowledge indicate a conceptual error.

A misconception, or "misconception," refers to a misunderstanding of scientific concepts (Echols & Shadily, 1996). Misconceptions occur when students explain phenomena based on erroneous beliefs, and if left unaddressed, they become increasingly entrenched and more complex (Krebs, 1999; Allen, 2014; Resbiantro et al., 2022). Misconceptions can occur at all levels of education (Surmaini et al., 2021) and pose a major obstacle to understanding new concepts (Zubac, 2018; Maliada et al., 2023). One topic in science at the junior high school level that often leads to misunderstandings is force and motion, even though this topic serves as the foundation for understanding more complex scientific concepts at higher levels (Riyadi, 2020; and Maulidina & Khusaini, 2023).

Several studies have reported high rates of student misconceptions regarding the concepts of speed, velocity, acceleration, friction, free-fall motion, and the application of Newton's laws, with misconception rates ranging from 44% to 70% (Purwasih et al., 2020; Wells et al., 2020; Arruum & Desstya, 2024; Isnaini et al., 2024). Various studies confirm that misconceptions are influenced by many factors, such as inappropriate learning strategies, the dominance of lecture-based methods, limitations in learning media, characteristics of the subject matter, and the strength of students' everyday experiences that are inconsistent with scientific concepts (Wandersee et al., 1993; Rohmah et al., 2023; Guerra et al., 2024; Samsudin et al., 2024). For this reason, science instruction should be intentionally structured to uncover and address misconceptions by engaging students in actively rebuilding their understanding. In addition, the use of diagnostic instruments such as the three-tier test is essential for identifying misconceptions at an early stage of learning (Juita et al., 2023; Rafika et al., 2023).

One of learning model widely reported to be effective in remediating misconceptions is the Conceptual Change Model (CCM). This model was developed based on conceptual change theory, which emphasizes the importance of cognitive conflict between students' initial conceptions and scientific concepts (Posner et al., 1982). Conceptual change can occur when students become dissatisfied with their initial conceptions and subsequently discover a new concept that is understandable, reasonable, and useful (Treagust & Duit, 2008; Mufit et al., 2023). Several studies indicate that the CCM is capable of significantly reducing misconceptions and enhancing students' conceptual understanding across various science topics, including force and motion (Asgari et al., 2018; Zulfikar et al., 2019; Samsudin et al., 2024).

However, the CCM requires structured learning strategies to be implemented effectively in the classroom. One strategy considered aligned with CCM principles is Predict, Observe, and Explain (POE). The POE strategy facilitates learning through three main activities: making predictions based on prior knowledge, conducting observations through experiments or demonstrations, and explaining the results of these observations based on scientific concepts (White & Gunstone, 1992; Tao & Gunstone, 1999). The integration of POE into CCM has been shown to strengthen conceptual conflicts, increase student engagement, and facilitate a shift in understanding toward correct concepts (Astiti et al., 2020; Erdem Özcan & Uyanik, 2022).

Accordingly, this research seeks to carry out a systematic literature review on efforts to address students' misconceptions in the topics of force and motion through the Conceptual Change Model (CCM) integrated with the Predict, Observe, and Explain (POE) approach. The review is organized based on publication year, country of origin, and key research outcomes. More specifically, this study aims to: (1) identify the countries where research on POE-based CCM has been conducted to reduce misconceptions; (2) analyze studies that focus on misconceptions in force and motion; and (3) examine the findings reported in the selected articles. It is expected that the results of this review will offer both theoretical insights and practical guidance for teachers, researchers, and developers in science education to design more effective instructional strategies for overcoming misconceptions and strengthening students' conceptual understanding.

2. Method

A Systematic Literature Review (SLR) is a methodological approach designed to gather, assess, and synthesize existing studies on a particular topic in a systematic and organized manner. This method is commonly applied in academic research and policy contexts to provide a thorough and current overview of available knowledge (Page et al., 2021; Wang et al., 2025). The selected articles concentrate on efforts to address misconceptions in the topics of force and motion through the implementation of the Conceptual Change Model (CCM) combined with the Predict, Observe, and Explain (POE) strategy. This review aims to identify research trends and summarize key findings that can serve as a reference for future studies. The review process using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide a systematic and transparent framework for conducting literature reviews. These guidelines involve several essential stages, including formulating research questions, performing a comprehensive literature search, screening and extracting relevant data, evaluating study quality, analyzing the results, and reporting the conclusions (Tricco et al., 2018).

2.1. Steps for a Systematic Literature Review Using the PRISMA Method:

2.1.1. Initial Stage of the Systematic Review

This systematic review was conducted collaboratively within a research team. Therefore, the researchers routinely discussed with team members and the supervising professor to avoid differences in the interpretation of terms that could arise due to differing geographical backgrounds or professions. This process was carried out to ensure consistency of understanding and methodological accuracy. In its implementation, the researchers applied several steps:

a. First, after the research topic was clearly defined, the researchers considered search limitations based on language and year of publication, while remaining mindful of the potential to overlook important literature.

b. Second, keywords were determined through an initial search across several major databases, followed by the identification of core terms, synonyms, and relevant spelling variations to form the basis of the search strategy.

c. Third, the search also utilizes thesaurus terms available in each database to obtain more specific results, given the differences in indexing systems across databases.

d. Fourth, to broaden the scope and prevent the omission of relevant literature, the researcher uses natural language search by combining various alternative keywords.

2.1.2. Creating a PRISMA Flowchart

a. Step 1 : Preparation

Create a PRISMA flowchart and identify the appropriate databases for the literature review based on the research topic. The databases used as sources for article searches are Google Scholar and ScienceDirect. These databases were chosen because they provide broad access to reputable scholarly publications. In addition, Google Scholar and ScienceDirect are well-established platforms that support searches for a wide range of relevant studies, thereby ensuring that the literature on misconceptions addressed through the POE (Predict, Observe, and Explain)-based Conceptual Change Model (CCM) is comprehensive and representative.

b. Step 2 : Doing the database search

The article search was conducted through the Google Scholar and ScienceDirect databases for the years 2019–2025 using a combination of keywords linked by the operators “AND” and “OR.” The criteria applied included articles in English, fully accessible, and relevant to the research topic. After all limitations were applied, the number of articles obtained was then accumulated and listed in the identification stage of the PRISMA flowchart. This is explained in more detail as follows:

1) Search for articles in databases (Google Scholar and Science Direct) using keywords as shown in the Table 1.

Table 1. Searching for articles in databases (Google Scholar and Science Direct) using Keywords

No	Database	Keywords
1.	*Google Scholar*	*"Remediate Misconception" AND "Conceptual Change Model" AND "POE" or "Remediate Misconception" AND "Force and Motion" or "Misconception" AND "CCM" or "Misconception" AND "Predict, Observe, and Explain" atau "Reducing Misconception using Conceptual Change Model with POE" or "Reducing Misconception" AND "Force and Motion" or "Student Misconception" AND "Force and Motion"*
2.	*Sciencedirect*	*"Conceptual Change Model" or "Remediate Misconception" or "Reducing Misconception" AND "Force and Motion"*

2) Selected Criteria

To find the desired and relevant articles, several filter features were used. There are four inclusion and exclusion criteria for articles, as shown in the Table 2.

Table 2. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication Type	Journal article	Cooks, theses, dissertations
Language	Written in English	Written in a language other than English
Content Focus	Remediation of misconceptions regarding force and motion using the Conceptual Change Model (CCM)	Research unrelated to the study topic on student misconception remediation using CCM in force and motion topics
Accessibility	Full-text articles	Not fully accessible
Publication year	Published between 2019-2025	Published before 2019 or after 2025

Based on the search results, 2.103 articles were retrieved from Google Scholar and 217 from ScienceDirect, resulting in a total of 2,320 articles in the search across the selected databases.

c. Step 3 : Additional sources

Studies identified from sources beyond the main database, such as manual searches of reference lists, were recorded separately in the flowchart. This process resulted in 15 additional articles.

d. *Step 4 : Remove all duplicates*

All retrieved records were carefully checked to identify and remove duplicate entries. A total of 160 duplicate articles were found and excluded, leaving the remaining records for further analysis.

e. *Step 5 : Screening articles*

At this stage, the remaining articles were screened according to predefined selection criteria, mainly focusing on their relevance to the research topic. A total of 71 articles met the initial screening requirements.

f. *Step 6 : Screening – Excluded articles*

The titles and abstracts were then examined in greater depth to assess their relevance. Articles discussing efforts to address misconceptions about force and motion, the application of the Conceptual Change Model (CCM), the use of the POE (Predict, Observe, Explain) strategy, or a POE-based combination of the CCM were considered to meet the relevance criteria. Following this process, 20 articles were excluded.

g. *Step 7 : Eligibility*

The number of excluded articles from the previous step was deducted from the screened articles, resulting in 51 studies categorized as eligible for full-text review. These articles were examined thoroughly to ensure alignment with the research objectives and inclusion criteria.

h. *Step 8 : Eligibility – Record Excluded*

All articles that passed the seventh stage were read in full and in detail. Articles deemed not to meet the requirements and not to align with the established inclusion criteria were subsequently excluded from the review process and classified into the "Excluded Articles" group, as their content was not relevant to the focus of this study.

i. *Step 9 : Included*

The final number of included studies was obtained by subtracting the excluded full-text articles from the total eligible records. As a result, 31 articles were considered relevant to the research focus. These selected studies were then analyzed and synthesized by examining their findings and key information. The final stage involved writing the review and presenting the results of the SLR in a detailed manner consistent with the research objectives.

3. Results and Discussion

Using the Systematic Literature Review method and the PRISMA flowchart, the article search was conducted through the ScienceDirect and Google Scholar databases using a combination of keywords related to misconceptions, the Conceptual Change Model (CCM), reduction misconceptions, and force and motion. PRISMA flowchart can be seen in Figure 1.

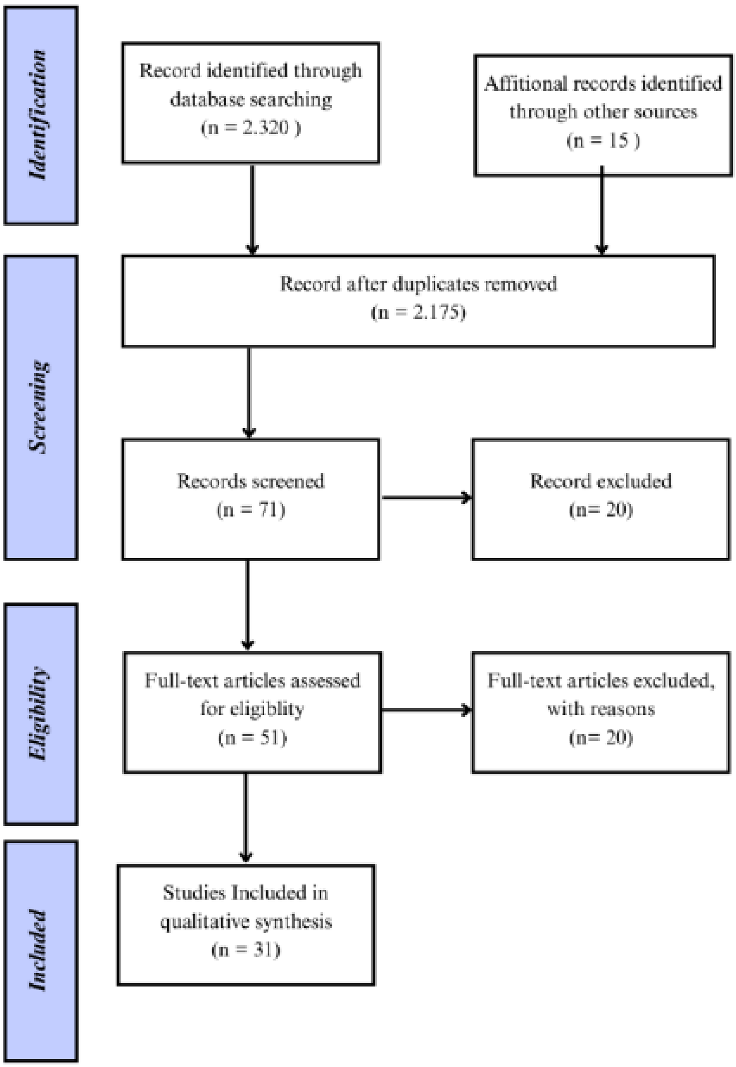

Figure 1. PRISMA Flowchart
Source: Personal documents

The initial search yielded 51 articles. Subsequently, the articles were selected based on inclusion and exclusion criteria, which included publication type, topic relevance, content focus, accessibility, and year of publication. After undergoing the identification, screening, and eligibility stages, 31 articles that met the criteria were selected for use in this study, while the remaining articles were excluded. This selection process is presented in the PRISMA flow diagram in Figure 1.

Based on the analysis of the 31 selected articles, the results are presented as follows:

a. Distribution of countries

Studies examining misconceptions and the application of the Conceptual Change Model (CCM) and various learning strategies to reduce them have been conducted in various countries. A detailed breakdown of the countries of origin of the studies is shown in Figure 2.

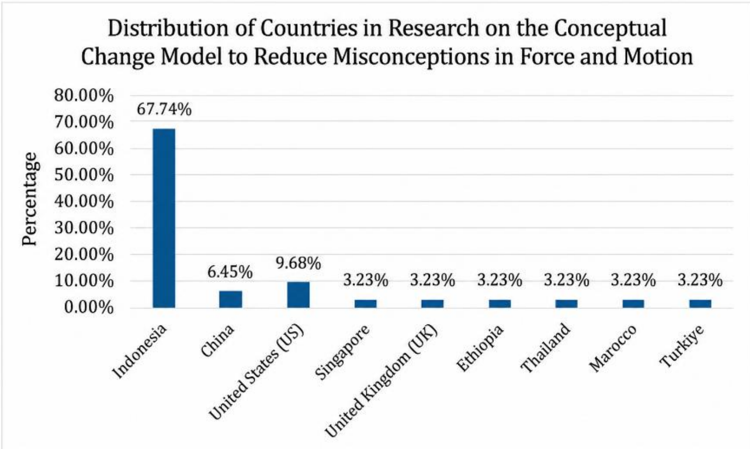

Figure 2. Distribution of Countries in Research on the Conceptual Change Model to Reduce Misconceptions in Force and Motion

Based on the analysis of the 31 reviewed articles, the research was dominated by Indonesia, accounting for a very large proportion approximately 67.74% of the total articles. This indicates that attention to the issue of misconceptions in science education, particularly regarding force and motion, is growing rapidly in Indonesia. Meanwhile, other studies are distributed across various countries such as China (Li et al., 2023; Yang et al., 2024), the United States (Vosniadou, 2019; Addido et al., 2022; Athanasopoulos, 2023), Singapore (Sommeillier et al., 2021), the United Kingdom (Wells, et al., 2020), Ethiopia (Getu et al., 2024), Thailand (Prarokijjak et al., 2024), Morocco (Bouzid et al., 2022), and Turkey (Pacaci et al., 2024). This indicates that research on misconceptions is not only developing at the national level but has also become a global concern.

b. A Study of Misconceptions in Force and Motion

Based on the analysis of the 30 articles reviewed, it was found that junior high school students' misconceptions regarding force and motion are relatively high in number and diverse, and exhibit relatively consistent patterns across various countries. The results of the categorization of misconceptions regarding force and motion based on the analyzed articles are presented in the Figure 3.

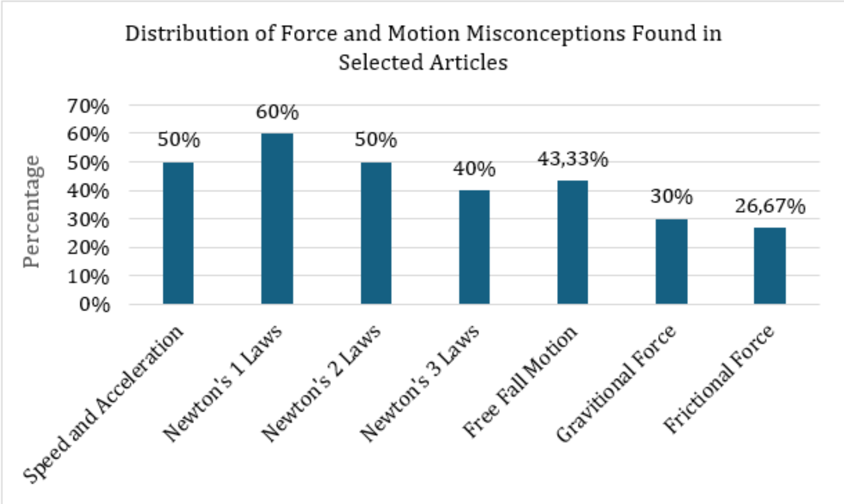

Figure 3. Distribution of Force and Motion Misconceptions Found in Selected Articles

Based on the figures, misconceptions related to Newton's First and Second Laws were the most prevalent, each appearing in more than half of the articles. One of the main misconceptions is the assumption that a force is always required to maintain motion, so that an object will stop when the force is removed, which contradicts the concept of inertia (Astiti et al., 202; Athanasopoulos, 2023; ; Samsudin et al., 2024). This way of thinking also reflects the pre-Aristotelian view that motion always requires a force (Bouzid et al., 2022) and was found in approximately 60% of the articles. A further misconception concerns how force, velocity, and acceleration are related. Many students assume that force is directly linked to velocity rather than acceleration, and they often struggle to differentiate between velocity and acceleration (Wells et al., 2020; Samsudin et al., 2024). Students also often assume that motion with constant velocity still has acceleration, a misconception exacerbated by poor graph-reading skills (Taufiq et al., 2020; Wells et al., 2020). This misconception was found in approximately 50% of the articles.

Regarding Newton's Third Law, students also exhibit significant misconceptions, particularly concerning the action–reaction pair. A common misconception is that objects with greater mass produce larger forces than smaller ones, even though, according to scientific principles, action–reaction pairs are equal in magnitude and opposite in direction (Wells et al., 2020; Samsudin et al., 2024). A similar misconception was also found regarding the concept of collisions, where students assume that a larger or more active object exerts a more dominant force (Yang et al., 2024). Misconceptions regarding the concepts of gravity and free-fall motion were also key findings in this study. Some students assume that objects with large masses will fall faster than objects with small masses, without realizing that all objects experience the same gravitational acceleration (Anggoro et al., 2019; Zulfikar et al., 2019; Khoirunnisa & Afifa, 2024). In addition, students also have misconceptions about gravitational force, such as the belief that gravitational force only acts on objects falling downward or does not act in outer space (Juita et al., 2023).

Regarding friction, some students believe that friction can accelerate an object's motion or is always greater than the applied force (Sari et al., 2019; Kusumaningtyas et al., 2025). In addition to these qualitative findings, several studies also present quantitative data that confirm the high prevalence of misconceptions among students. Kusumaningtyas et al. (2025) found that 45.8% of students experienced misconceptions in understanding the concepts of force and motion. Saputra and Rusyati (2025) reported that only 27.92% of students demonstrated correct scientific understanding, while the majority showed conceptual errors. Similarly, Prarokijjak et al. (2024) found that although overall understanding appeared fairly good, misconceptions were still evident, as reflected in a Force Concept Inventory score of 70.51% with errors in several subtopics.

c. Research Findings

One of the main aims of this study was to examine how effective different instructional strategies are in reducing students' misconceptions, especially in the topics of force and motion. Based on the analysis of 31 selected articles, a summary of the key findings is presented in Table 3.

Table 3. Research Findings on the 31 articles selected

No	Author	Countries	Research Findings
1.	Zulfikar et al. (2019)	Indonesia	The use of CCM was able to reduce misconceptions on the concept of gravitational force by up to 40.91% (from 56.82% to 15.91%), which is the highest reduction. This means that PDEODE*E-based CCM is effective in reducing student misconceptions. PDEODEE-based CCM is a combination of the Conceptual Change Model (CCM) with the PDEODEE strategy, which includes the Prediction–Discussion–Explanation–Observation–Discussion–Exploration stages that facilitate students in reconstructing student understanding towards scientific understanding.
2.	Samsudin et al. (2024)	Indonesia	CCM provides a framework that encourages students to think critically by creating a clash between scientific knowledge and their existing beliefs. This clash occurs when students' ideas or ways of thinking do not align with scientific facts, leading them to realize that their understanding is incorrect. This realization serves as the foundation for correcting and reconstructing accurate concepts through the conceptual change process. The improvement in the conceptual understanding of 11th-grade Senior High School students after using the task-based CCM PDEODE*E is demonstrated by the experimental class's N-Gain score of 0.73 (high category), which is higher than the control class's score of 0.42 (low category).
3.	Samsudin et al. (2020)	Indonesia	The use of CCM with computer simulation as a medium showed that 86% of 27 high school students in Bangka Belitung achieved conceptual change in the "Satisfactory" category, thereby altering students' conceptions regarding the theory of kinetic gas
4.	Taufiq et al. (2020)	Indonesia	Motion misconceptions were reduced using a guided inquiry model assisted by STEM Student Worksheets, which showed that students' conceptual understanding fell into the "conceptual understanding" category at 58.58%, with misunderstandings at 25.49%, guesses at 3.19%, and "don't understand" at 12.75%. Activities using experimental methods helped students correct misunderstandings about linear motion, which initially stood at 47.30% and decreased by 25.49%.
5.	Soeharto & Csapó (2022)	Indonesia	Misconceptions are strongly associated with science learning and have a direct impact on students' achievement in science. When students fail to properly understand certain scientific concepts, they tend to struggle with more advanced related topics, which ultimately leads to unsatisfactory learning outcomes. Nevertheless, misconceptions are rarely examined in classroom assessments or school-level tests, and they are also not adequately addressed in national examinations in Indonesia. In practice, teachers often prioritize the attainment of curriculum-based learning objectives without recognizing that students may still hold incorrect conceptions about scientific ideas.
6.	Juita et al. (2023)	Indonesia	Identified various misconceptions related to Newton's law of gravity. These include the belief that gravitational forces only occur between planets, that the size of an object determines its distance from the center of mass, and that gravity does not exist in outer space. Other misconceptions involve the assumption that gravitational force follows the direction of the resultant force or an object's motion, that interacting objects exert unequal gravitational forces, and that gravitational field strength depends on the mass of the test object. Students also tend to misunderstand the concept of distance, confuse gravitational potential energy with gravitational potential, assume that all planets revolve around each other, consider planetary orbits perfectly circular, perceive Earth as a perfectly spherical body, and believe that a satellite's speed is determined by its distance from Earth's surface. Among these, the most prominent misconception (23%) appears in the subtopic concerning the relationship between gravitational field strength, gravitational potential energy, and gravitational potential.
7.	Suprapto (2020).	Indonesia	Misconceptions in science learning can arise from four main factors: Students: Misconceptions are often triggered by incorrect prior knowledge, flawed everyday intuition, limited cognitive abilities, and low interest in learning. Teacher factors also play a role when teachers lack a deep understanding of the material or unconsciously pass on misconceptions to students. Additionally, the instructional materials or literature used—whether textbooks or other learning media—may contain incorrect, ambiguous, or incomplete information, thereby reinforcing misconceptions. Finally, inappropriate teaching contexts and methods—such as instruction that emphasizes rote memorization of concepts without

No	Author	Countries	Research Findings
			providing opportunities for exploration and clarification—can make it difficult for students to distinguish between scientific concepts and pre-existing misconceptions.
8.	Athanasopoulos (2023).	Amerika Serikat	Teachers must not only be aware of potential misconceptions but also actively address them to help students develop a deeper conceptual understanding. The post-test results for 8th grade showed that the cognitive dissonance approach was more effective than the p-prims approach, with an average of 65% (cognitive dissonance) versus 48% (p-prims). Meanwhile, in 9th grade, both methods improved scores, but the improvement for students using the cognitive dissonance approach was greater (a "moderate–large" effect size). This indicates that strategies that induce cognitive conflict are more effective at fostering conceptual change compared to those that merely build on students' prior knowledge step by step.
9.	Surmaini et al. (2021)	Indonesia	Misconceptions can be found at all levels of education, from elementary school through college, and tend to be more common among students with low analytical skills. In many cases, misconceptions arise when students are required to connect several basic concepts that require a deeper understanding. The results of misconception identification among 27 tenth-grade students using the Certainty of Response Index (CRI) instrument showed that 11 students had a good understanding of the concept, with an average score of 40.74%, which falls into the moderate category. Meanwhile, 8 students were categorized as not yet understanding the concepts, with an average score of 29.62%, which falls into the low category, and 8 other students were identified as having misconceptions with the same average score of 29.62% in the low category.
10.	Sommeillier et al. (2021)	Singapura	According to Sommeillier, R., et al. (2020), the definition of preconceptions encompasses four aspects: (1) knowledge that influences how students understand natural phenomena and scientific explanations, (2) knowledge that is stably structured, (3) knowledge derived from everyday experiences and prior learning, and (4) knowledge that can act as a barrier to the process of learning new concepts.
11.	Vosniadou (2019)	Amerika Serikat	Preconceptions are intuitive ideas about natural phenomena that a person holds, but they are often inconsistent with scientific concepts and tend to resist instructional intervention, thereby hindering the acquisition of scientific concepts. Science education should not only convey scientific content but also develop students' critical and cognitive thinking skills so that they are able to understand abstract and counterintuitive scientific concepts.
12.	Astiti et al. (2020)	Indonesia	The results of a study involving 47 fifth-grade elementary school students showed that (1) the pre-instruction conceptual profile using the POE strategy revealed that, on average, 67% of all study participants held misconceptions regarding each concept item. (2) The post-instruction conceptual profile using the POE strategy revealed that, on average, 7.4% of all study participants held misconceptions regarding each concept item. (3) POE strategy is effective in reducing misconceptions in science topics, including force and motion, characteristics of living organisms, and properties of materials.
13.	Wells et al. (2020)	Inggris	Students' misconceptions in motion concepts are relatively high, reaching approximately 44%, particularly regarding the concepts of velocity and acceleration. Many students are unable to distinguish between position, velocity, and acceleration, and mistakenly believe that acceleration decreases as velocity decreases—as in the case of a coin thrown upward—even though gravitational acceleration remains constant downward. Students often believe that force is directly related to velocity rather than acceleration, reflecting a misunderstanding of Newton's Second Law. In the context of Newton's Third Law, some students think that objects with larger mass produce greater forces, even though action–reaction pairs are equal in magnitude and opposite in direction. Taken together, these findings suggest that many students still have difficulty grasping the relationships among key concepts in kinematics and dynamics from a scientific standpoint.
14.	Resbiantoro & Setiani (2022)	Indonesia	Based on the findings of the study, there are several diagnostic tools for identifying misconceptions, namely interviews, open-ended tests, multiple-choice tests, two-tier tests until four-tier tests. The main contributing factors that cause of misconception include incorrect intuitive experiences, flawed analogies, inadequate instruction, and scientific language that is difficult for students to understand. Several effective remediation strategies involve simulation-based learning, the

No	Author	Countries	Research Findings
			conceptual change model, inquiry-based learning, multimedia instruction, model-based teaching, laboratory experiments, and concept maps. These approaches emphasize the importance of students' active engagement in exploring and scientifically reconstructing science concepts.
15.	Li et al. (2023)	China	Conceptual change does not simply involve adding new information or completing missing knowledge; instead, it focuses on restructuring existing ideas by replacing misconceptions with scientifically accurate concepts. In addition, collaborative learning through argumentative discussion has been shown to be effective in supporting this process, as it encourages students to actively defend, reconsider, and improve their understanding.
16.	Anggoro et al (2019)	Indonesia	Research findings involving 120 first-year students in the Primary School Teacher Education (PGSD) program, using a visual multimedia-assisted conceptual change model, demonstrated that the model effectively helped participants engage in conceptual change and provided them with better explanations than before. Participants were able to correctly explain the concepts of force and motion after undergoing conceptual change instruction.
17.	Getu et al. (2024)	Ethiopia	This study examined the effect of the Predict–Explain–Enact–Observe–Reflect (PEEOR) strategy on students' understanding and motivation in learning force and motion. Using a quasi-experimental pre-test–post-test design, the research involved 107 second-year general science students at Woldia College of Teacher Education. Data were gathered through a 15-item conceptual test and a post-instruction motivation questionnaire, with reliability coefficients of 0.75 (KR-20) and 0.84 (Cronbach's Alpha), respectively. The results from descriptive analysis and ANCOVA showed that the PEEOR group (adjusted mean = 6.787) achieved significantly higher scores than the conventional group (adjusted mean = 5.134). The POE group (adjusted mean = 6.472) did not differ significantly from the other groups. Additionally, students' motivation scores differed significantly across the three groups ($p < 0.05$).
18.	Samya et al (2021)	Indonesia	The POE strategy was applied to reduce misconceptions among eleventh-grade students at SMAN 3 Banda Aceh. The experimental group taught with POE achieved a higher average score (86.02) and N-gain (79.55, high category) compared to the control group (79.38; N-gain 71.18, high category). These findings indicate that POE was more effective and better received, as shown by the improved learning outcomes. The POE strategy also provides several advantages in the learning process. It encourages students to express their ideas, promotes active participation in discussions, and supports motivation in learning concepts. In addition, it allows teachers to better understand students' reasoning processes, strengthens students' analytical and evaluative abilities, fosters curiosity during investigative activities, improves conceptual understanding, and increases student involvement while giving them opportunities to apply what they have learned. However, the approach also has certain limitations. One of the main challenges arises when students work on test questions, as they may be less accustomed to receiving direct and detailed explanations compared to more traditional, teacher-centered methods.
19.	Mustofa et al. (2024)	Indonesia	Based on the results of the assessment of students' conceptual understanding, the majority of students demonstrated a low initial understanding of Newton's laws, with 40% of students identified as having misconceptions and 53.33% falling into the category of insufficient knowledge. One of the most common misconceptions found was the belief that force is always required to maintain motion. After implementing the POE (Predict–Observe–Explain) strategy, there was a significant increase in the number of students who successfully shifted from misconceptions to a more scientific understanding. The most conceptual changes occurred in the material on Newton's Third Law and were dominated by the revision stage, indicating the development of students' understanding from initial concepts toward concepts more in line with scientific principles.
20.	Yatmanto et al. (2025)	Indonesia	The research results indicate that differentiated instruction using the POE (Predict–Observe–Explain) strategy is effective in enhancing students' understanding of scientific concepts and their scientific thinking skills. This model has also proven capable of reducing misconceptions through the processes of prediction, observation, and explanation, which encourage the reconstruction of students' understanding. However, its implementation requires careful planning

No	Author	Countries	Research Findings
			because it can impose a high cognitive load and demands that teachers be prepared to manage the learning process effectively.
21.	Khoirunnisa & Afifa (2024)	Indonesia	The majority of students still have misconceptions about the concepts of force and motion. This is evident from the distribution of answers: 42.59% of students were only able to answer 2–4 questions correctly, 37.96% answered 5–7 questions, and only 19.44% were able to answer 8–11 questions correctly. Some of the dominant and relevant misconceptions experienced by junior high school students are: Objects with large masses fall faster than lighter objects. The mass of an object affects the distance it falls. The velocity of an object in uniform linear motion changes automatically (the misconception that velocity increases automatically). When two objects collide, the larger object exerts a greater force on the smaller object. The direction of an object's motion always follows the direction of the last force acting on it
22.	Kusumaningtyas et al. (2025)	Indonesia	The findings revealed that 45.8% of students demonstrated misconceptions, reflecting a relatively high prevalence. In other words, nearly half of the students were identified as holding incorrect understandings of the concepts. indicating that the level of misconceptions remains relatively high. Some concepts frequently misunderstood by students include the belief that friction can accelerate an object's motion, that spring force only acts when the spring is stretched, and that heavier objects fall faster because they possess greater force. This study involved elementary school students (SD), suggesting that misconceptions emerge as early as the primary education level. These misconceptions are influenced by everyday understanding (experience-based knowledge), the use of overly conceptual textbooks, and a lack of laboratory practical activities. Therefore, systematic learning strategies such as conceptual change, peer instruction, and inquiry-based learning are needed to help students build understanding that aligns with scientific concepts.
23.	Sari et al. (2019)	Indonesia	The findings indicate that elementary school students still demonstrate a considerable level of misconceptions in force and motion. The three concepts most commonly misunderstood are: (1) Free fall: many students think that heavier objects will fall more quickly, instead of recognizing that all objects experience the same gravitational acceleration; (2) Force on a stationary object: most students believe that no force is present when an object is at rest; (3) Friction: students assume that friction is always greater than the force applied to move an object.
24.	Saputra & Rusyati, (2025)	Indonesia	The research results indicate that students' conceptions of force and motion remains relatively low. This is evident from the fact that only 27.92% of responses fell into the "scientific knowledge" category (correct scientific concepts). Meanwhile, the remainder consisted of 27.92% false positives (correct answers with incorrect reasoning), 18.59% misconceptions, 23.9% lack of knowledge, and 6.76% false negatives. The dominant misconceptions were found in the concepts of displacement, vector quantities, and Newton's laws, whereas the level of misconceptions regarding the concept of friction was relatively lower. These findings indicate that students do not yet possess a strong conceptual understanding and still experience confusion in scientifically relating the basic concepts of force and motion.
25.	Prarokijjak et al. (2024)	Thailand	The results of the misconception identification study at Thammasat Secondary School showed an average FCI score of 70.51% among students, indicating that most students understand the basic concepts of force and motion, yet a significant number of misconceptions still persist. In relation to Newton's laws, the greatest proportion of misconceptions was observed in the concept of kinetic energy (42.50%), whereas the lowest occurred in the concept of active force (21.04%). Several misconceptions identified include: (1) Students assume that a continuous force is needed to maintain motion; (2) students have not yet fully understood the relationship between force and acceleration; (3) students misinterpret how forces interact on an object, particularly in relation to Newton's Second and Third Laws.
26.	Bouzid et al (2022)	Maroko	The results of the misconception identification at Moroccan High School indicate that the majority of high school students in Morocco do not yet have an adequate understanding of the concepts of force and motion based on the Newtonian framework. Instead, they tend to hold pre-Aristotelian understandings of force and motion (e.g., the idea that

No	Author	Countries	Research Findings
			motion always requires a force). This study also found that the level of misconceptions did not change significantly even as students advanced to higher grade levels. Furthermore, there was no significant relationship between the level of misconceptions and factors such as age, grade level, or gender. This indicates that misconceptions are quite stable and difficult to change without appropriate instructional intervention.
27.	Alfiyanti & Jatmiko (2020)	Indonesia	The findings show that applying the POE model supported by PhET simulations leads to a significant enhancement in students' critical thinking abilities compared to traditional instructional approaches. The increase in test performance can be explained by Vygotsky's perspective, which suggests that cognitive development occurs when existing knowledge is challenged and reorganized through a state of imbalance as students acquire new understanding.
28.	Yang et al. (2024)	China	Research shows that although prospective physics teachers possess high content knowledge, with an average score of 90.5%, their ability to understand students' conceptual errors (SCE) is significantly lower, with an average score of 47.8%. The correlation between content knowledge and CEM is not significant ($r = 0.143$; $p = 0.188$), indicating that mastery of physics concepts alone does not automatically improve the ability to understand students' misconceptions, thus requiring specialized CEM training. There are three categories of misconceptions regarding force and motion in this study, including: (1) the assumption that motion must always be caused by a continuous force, that the absence of motion implies the absence of force, that velocity is directly related to the applied force, that acceleration reflects an increasing force, that only active agents can exert force, that active force gradually weakens over time, and that force continues to produce acceleration until an object reaches terminal velocity; (2) impulse is caused by a collision, initial impulse is lost or can return, impulse diminishes over time, and impulse is generated gradually or with a delay; (3) Third, misconceptions related to combined or multiple forces include the belief that motion is governed by the largest force, that it results from a balance or compromise among forces, and that the most recent force applied determines the motion.
29.	Resta et al. (2020)	Indonesia	Many students initially held misconceptions about force and Newton's laws (for example, that force is always required to maintain motion). After learning through POE, there was a significant increase in the number of students who moved from misconceptions to scientific understanding. Conceptual change profiles indicate that the POE strategy is effective for (1) uncovering students' prior knowledge; (2) eliciting cognitive conflict when predictions differ from observational results; and (3) helping students revise and construct new understandings consistent with scientific concepts.
30	Addido et al. (2022)	Amerika Serikat	CCM are effectively reduce misconceptions among pre-service teachers while improving their understanding of concepts. Through its stages, which highlight the role of cognitive conflict, learners are guided to identify discrepancies between their initial ideas and scientifically accepted explanations. As a result, a shift in understanding occurs from misconceptions toward more scientific and structured concepts. Additionally, this model helps pre-service teachers develop the ability to reflect on their own thinking, so that they not only understand concepts better but are also better prepared to identify and address misconceptions.
31	Pacaci et al. (2024)	Turki	This study is a meta-analysis examining the effectiveness of various conceptual change strategies in science education. The results indicate that, overall, these strategies have a significant impact on improving students' conceptual understanding while reducing their misconceptions. Approaches involving cognitive conflict, such as CCM, have proven to be more effective than conventional teaching methods because they reveal the discrepancies between students' prior knowledge and actual scientific concepts. Additionally, active learning approaches that include discussion, experimentation, and scientific argumentation tend to produce stronger and more enduring conceptual changes.

Based on the review of 29 articles, it can be concluded that misconceptions about force and motion remain common across all levels of education, from elementary school to university, and occur in various countries with similar patterns. These include the belief that motion requires a continuous force, confusion between velocity and acceleration, and incorrect understanding of how forces interact in Newton's laws (Wells et al., 2020; Bouzid et al., 2022; Khoirunnisa & Afifa, 2024). Misconceptions are typically identified using various diagnostic tools such as the four-tier test, CRI, and interviews, which have proven effective in revealing a deeper profile of students' conceptions (Surmaini et al., 2021; Resbiantoro & Setiani, 2022). In an effort to reduce misconceptions, various learning strategies have been implemented; however, research findings indicate that the Conceptual Change Model, when combined with the POE or PDEODE*E strategies, is one of the most effective (Zulfikar et al., 2019; Astiti et al., 2020; Mustofa et al., 2024; Samsudin et al., 2024). This approach facilitates cognitive conflict, uncovers students' prior knowledge, and encourages the reconstruction of understanding toward correct scientific concepts, as evidenced by a significant reduction in misconceptions and an improvement in student learning outcomes (Resta et al., 2020; Athanasopoulos, 2023; Yatmanto et al., 2025). Therefore, the implementation of POE-based CCM can be recommended as an effective learning strategy for addressing students' misconceptions regarding force and motion.

4. Conclusion

Based on a review of 29 selected articles from 2019 to 2025, it can be concluded that (1) Indonesia is the country that has conducted the most research on students' misconceptions regarding force and motion and efforts to reduce them, accounting for 66.67% of the 29 selected articles. Nevertheless, studies on misconceptions are also growing globally in countries such as China, the United States, the United Kingdom, Thailand, Ethiopia, and Morocco. This indicates that the issue of misconceptions in science learning, particularly regarding force and motion, is a universal problem that has garnered widespread attention in science education; (2) the study's findings show that misconceptions regarding force and motion remain relatively high and exhibit a consistent pattern across various educational levels. The most prevalent misconceptions include the belief that force is always required to maintain motion, errors in understanding the relationship between force, velocity, and acceleration, and misunderstandings regarding the action–reaction concept in Newton's laws. These findings are supported by various studies indicating that misconceptions stem not only from students' prior knowledge but are also influenced by daily experiences, teaching methods, and limitations in students' conceptual understanding; (3) The research findings from the reviewed articles indicate that various learning strategies and models have been used to reduce students' misconceptions, such as inquiry-based learning, the POE (Predict–Observe–Explain) strategy, the STEM approach, the use of computer simulations, and the conceptual change model. These diverse approaches have proven effective in helping students improve their conceptual understanding through active engagement, experimentation, and the scientific thinking process. However, among the various strategies implemented, the Conceptual Change Model (CCM), particularly when combined with the POE strategy or its extensions such as PDEODE*E, has emerged as the most dominant and effective approach. This model consistently succeeds in revealing students' prior knowledge, creating cognitive conflict, and fostering the reconstruction of understanding toward accurate scientific concepts, as evidenced by a reduction in misconceptions and an improvement in student learning outcomes.

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