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A bibliographic review of the difficulties related to the topics of mechanics

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Abstract
This paper presents a literature review on the difficulties faced by students in Mechanics, carried out by consulting articles in journals, dissertations, and theses that address the subject. The research method used is a Systematic Literature Review (SLR) and the research focuses on publications in physics education, covering the first records on the subject, at the end of the 1970s, with a main emphasis on studies carried out in the last ten years and excluding the rarely cited older articles. The works found were selected because they were: highly cited articles, review articles, and recent articles in the main journals in the area (last ten years) and organized into four categories: i) spontaneous conceptions, ii) conceptual resources used by students, iii) constructivist methods and iv) engagement methods. In the works identified, it was found, for example, that there is a significant amount of publications that explore the subject, but a consolidated solution has not yet been observed. Furthermore, it is clear that the traditional methods of teaching physics contribute little to the understanding of basic concepts and that there is a shortage of studies that propose practical solutions to the problems experienced by physics teachers working in high schools. The research concentration is with higher education students, without a progressive development to address this problem from high school onwards.

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1. Introduction

Students' difficulties with Newtonian physics have been widely explored for decades (Arons, 1977; Halloun & Hestenes, 1985; Arons, 1990; HESTENES et al., 1992; Hake, 1992; Arons, 1997; Hake, 1998; Hake, 2012; McDermott, 2014; Daud et al., 2015; Quibao et al, 2019; Uibson & Frei, 2023; Prarokijjak et al., 2024), however, continuing to explore the topic is necessary since the problems associated with it are far from having a solution. That is, even though there are many works in this area, the conceptual difficulties remain to this day. After an extensive bibliographic survey (McDermott, 1991 and 1996; Hake, 1992; Arons, 1997; Hake, 1998; Redish & Smith, 2008; Hake, 2012; Docktor & Mestre, 2014; Duit, et.al., 2014; Gaspar, 2014; McDermott, 2014; Mendes & Souza Filho, 2020; Odden, 2021; Dominguez et al., 2023; Krajcik & Shin, 2023; Robertson et al., 2023; Potvin et al., 2024; Sengul, 2024; Sagatbek et al., 2024) we realized that many authors have focused on these themes. Arnold Arons and Robert Karplus are recognized as fundamental figures in physics education research in the United States and are considered pioneers in the field (Hake, 2004). Arons' teaching approaches were deeply influenced by the thinking of philosophers such as Socrates, Plato, Montaigne, Rousseau, Dewey, Whitehead, and Piaget. However, his methodology was primarily shaped by his tireless efforts over decades to improve introductory science teaching. He achieved this by listening carefully to students' responses and drawing inspiration from Socratic questions to explore physics concepts.

Reviewing students' difficulties in physics is essential for several reasons: i) Improving understanding – Identifying common struggles helps educators adjust their teaching methods to make concepts clearer and more accessible. ii) Enhancing problem-solving skills – Physics involves critical thinking and mathematical reasoning. Addressing difficulties allows students to develop stronger problem-solving strategies. iii) Boosting confidence and interest – Struggling with physics can discourage students. By reviewing difficulties and providing support, educators can help build students' confidence and keep them engaged in the subject. Iv) Adapting teaching methods – Understanding where students struggle allows teachers to refine their instructional approaches, using better explanations, demonstrations, or interactive learning tools. v) Improving performance – By tackling difficulties early, students can perform better in exams and practical applications, ensuring a stronger grasp of fundamental physics concepts. vi) Bridging knowledge gaps – Physics builds upon previous knowledge. Identifying and addressing difficulties prevents gaps that could hinder learning in advanced topics. vii)

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Encouraging scientific thinking – Reviewing and overcoming challenges fosters a mindset of curiosity and persistence, essential for scientific inquiry and innovation.

An interesting account presented in (Hake, 2004) reveals that in the 1980s, after an unsuccessful attempt to explain Newtonian mechanics to prospective physics teachers, Hake sought guidance on effective pedagogical methods by making telephone calls to educators nationwide. However, he had little success until Robert Karplus of the University of California at Berkeley advised him to contact Arnold Arons of the University of Washington. During a thirty-minute telephone conversation, Arons shared crucial insights based on his twelve years of experience in elementary education (Arons, 1977). Arons recommended abandoning the traditional approach of passive lectures and lectures and explained in detail his method of teaching physics: emphasizing hands-on laboratory experience with concrete physical systems, promoting interactive engagement at increasing levels of complexity, and emphasizing operational definitions and Socratic dialogue. This conversation was a significant turning point in Hake's journey, directing him toward a more effective and interactive approach to teaching physics.

Students arrive in the classroom with preconceptions based on everyday experiences, which are incompatible with the scientific vision and resistant to change. This makes it difficult for them to learn details such as force, movement, speed, acceleration, gravity, and work energy (Daud et al., 2015).

In their literature review (Tomara & Gouscos, 2017) they present instructional strategies to promote conceptual changes about force and motion, highlighting the difficulties faced by students. The study explores practical approaches, such as computer simulations, kinesthetic activities, and deductive explanations. In the review, they emphasize the crucial role of the teacher and the importance of collaborative student participation in practical and planned activities to improve conceptual understanding. The use of computer simulations is particularly highlighted as a tool to challenge and confront students' pre-existing conceptions about the concepts of force and motion. The study emphasizes the importance of the teacher's role and the need to involve students in practical and collaborative activities to improve conceptual understanding. (Kirya et al., 2021) highlights the presence of alternative conceptions and two frameworks are discussed in the article: the misconceptions framework and the resource framework. The first suggests that students have rational conceptions based on their previous experiences, which may not be compatible with the understanding of experts. The resource framework emphasizes that students possess knowledge elements that can be activated and organized to form a more sophisticated understanding of physics concepts. Both frameworks offer valuable insights for developing more effective teaching strategies.

This topic is widely studied and due to the large number of articles it is very difficult to carry out a review, therefore the adopted criterion of not including old articles that are rarely cited and the preference for including highly cited and recent articles, in the main journals in the area, from the last ten years, is necessary.

2. Method

The research method used is a Systematic Literature Review (SLR) (Azarian et al, 2023). SLR is a systematic method for collecting secondary data and answering formulated questions as shown schematically in Figure 1. SLR refers to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) framework in this study. (Xiao & Watson, 2019) is a set of evidence-based minimum reporting items for systematic reviews and meta-analyses. In general, PRISMA includes four PRISMA steps: identification, screening, eligibility, and inclusion (Xiao & Watson, 2019; Page et al, 2021).

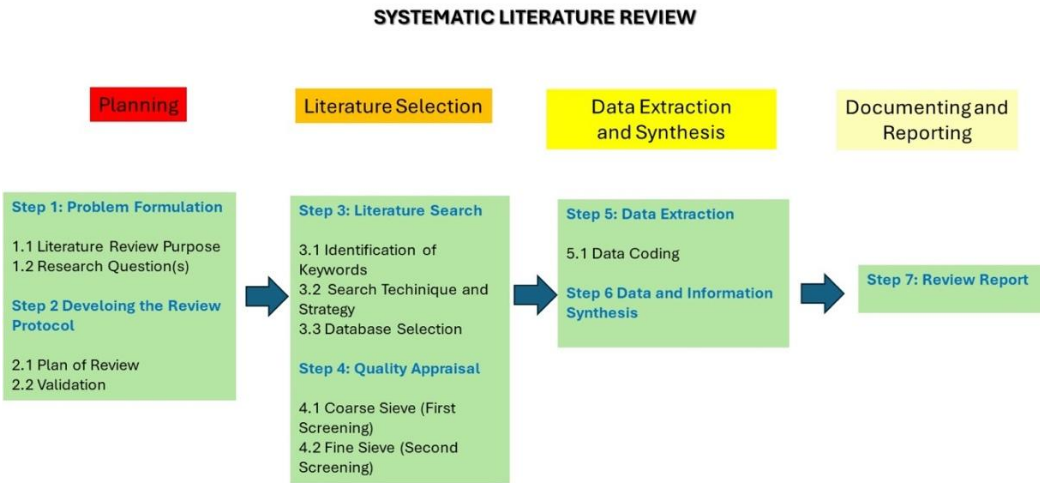

Figure 1. The Systematic Literature Review steps. (Azarian et al, 2023)

Steps for PRISMA

a. Identification; keywords, search criteria, databases, extracted records

b. Screening: inclusion/exclusion criteria

c. Eligibility: quality assessment

d. Included: The final number of articles included

For this work; identification stage: a survey of the universe of works through the keywords: “spontaneous conceptions”, “conceptual resources’ and ‘conceptual errors of students” in the teaching of physics about Mechanics, in addition to some related themes such as: “Force Concept Inventory” (FCI), “Peer Instruction”, “peer learning”, “non-Newtonian conceptions”, “conceptual change”. The records were extracted from the platforms: ERIC (2024) (n= 131 works), and *IOPScience* (2024) (n= 47 works), Google Scholar (2024) (around 19,900 works), Physical Review Journals (2024) (around 40 works), and AIP Publishing (2024) (around 89 works). Screening stage: the inclusion criteria were peer-reviewed papers, literature review in the form of journal articles, articles relevant to the research topic, open access (free), platforms where Brazilian universities have access; and articles published in English, Spanish, or Portuguese. The exclusion criteria were journal articles unrelated to the topic, non-open access or requiring payment, and articles not published in English, Spanish, or Portuguese. Eligibility stage: selection of works that help to understand the current scenario regarding students' errors and conceptual resources in teaching physics about Mechanics, selection based on the number of citations, on December 27, 2024. The oldest ones were used to define the categories and those from the last 10 years for a more up-to-date discussion. Inclusion stage: The outcome yielded (n = 41) research article data used in the systematic literature review. The data collection process leading to the final data is clearly illustrated in Figure 2 and Table 1.

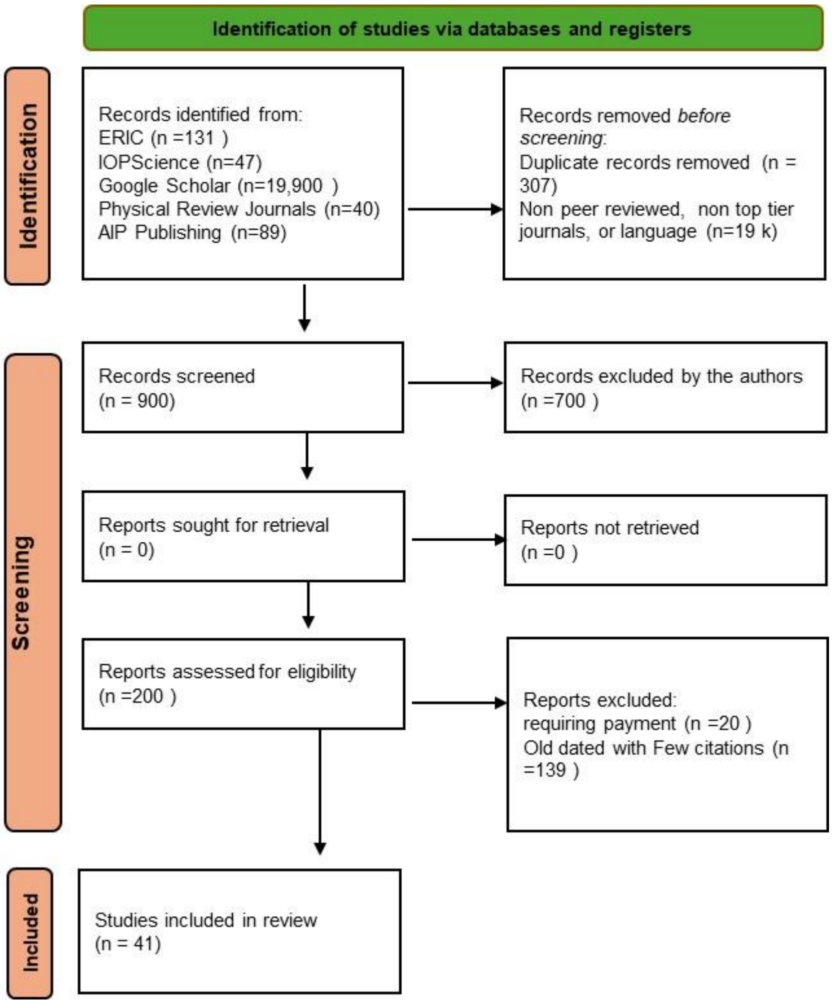

Figure 2. PRISMA steps adapted from (Page et al, 2021)

Table 1. Category and References Used in the Present Review

Category/number of sources	References
Misconceptions 11 sources	Abou & Hestenes, 1985; Arons, 1973; Arons, A. B., 1985; Arons & Holbrow, 1990; Arons, 1997; Daud et al., 2015; Krajcik e Shin, 2023; Odden, 2021; Prarokijjak et al., 2024, Redish e Smith, 2008; Van Heuvelen, 1991.
Conceptual resources 9 sources	Bauman et.al, 2024; McDermott, 2014; Docktor & Mestre, 2014; Dominguez et al., 2023; Halloun, I. A., & Hestenes, D., 1985; Hestenes & Swackhamer, 1992; Rinaldi, 2017; Robertson et al., 2023; Sengul, 2024.
Constructivist methods 13 sources	Hake, 1987, 1992, 1998, 2004, 2012, 2014; Kirya et al., 2021 Kovarik et.al, 2022; Moreira, 2021; Quibao et.al., 2019; Uibson & Frei, 2023; Resbiantoro & Setiani, 2022; Sagatbek et al., 2024.
Engagement methods 8 sources	Mazur, 1997, 2014; McDermott, 1991, 1996, 1999; Müller et al., 2017; Potvin et al., 2024; Tomara & Gouscos, 2017.

3. Results and Discussion

We will present below the articles that were selected in this review according to the categories in which they were classified.

3.1. Misconceptions

Students' spontaneous conceptions are ideas, beliefs, and interpretations that they form about a phenomenon (Krajcik & Shin, 2023). These conceptions are formed based on personal experience, observation of the world around them, intuition, and intuitive reasoning. These conceptions are inconsistent with established scientific concepts and, therefore, can influence the understanding and learning of these concepts (Abou & Hestenes, 1985). For example, a student may have a spontaneous conception that the Earth is flat because that is how it appears from ground level, before learning about the scientific evidence that proves otherwise.

In his works (Arons, 1990, p. 49; Arons, 1997, p. 56), Arons argues that most of our students come to us already possessing intuitive rules or conceptions that are often pejoratively labeled as "misconceptions." However, he points out that these intuitive notions are not necessarily malevolent or peculiar; on the contrary, they are grounded in everyday experience and were initially held by our predecessors. Arons suggests that our pedagogical approach becomes sounder and more reasonable when we characterize these notions as understandable "preconceptions" subject to change through concrete experience, rather than treating them as ignorant concepts that must be immediately corrected through verbal instruction and passive demonstrations in which the student does not participate. The challenge lies in offering students adequate Socratic guidance to stimulate critical thinking and the formation of insights, without, however, overloading them to the point of demotivating them and compromising the intellectual experience in question. The idea that a significant improvement in physics teaching could be achieved if teachers began to listen more attentively to their students is firmly established (Arons, 1973). For him, by listening to students' responses to carefully formulated and targeted questions, educators could better understand students' mental processes, identify the difficulties they face, and anticipate obstacles that could prevent them from mastering a concept. This type of active listening, according to Arons, allows the teacher to provide the type of help needed for the student to advance in their reasoning, without simply giving a ready-made answer, criticizing the common attitude of some teachers who believe that simply by explaining a concept in their way, the student will have no difficulty in understanding it. Considering this arrogant and ineffective stance, since it underestimates the importance of interaction and understanding the student's difficulties, and proposes that, instead of adopting an authoritarian and unidirectional stance, teachers should be willing to rediscover physics through dialogue with students, listening to their doubts, answers, and reasoning. By adopting this process of listening and interaction, there would be a profound and positive transformation in the quality of physics teaching, resulting in a visible and continuous improvement. The change lies in the willingness to adopt a more dialogic approach and less focus on transmitting immediate answers.

> "Most of our students come to us imbued with intuitive rules or notions that we are strongly tempted to call, pejoratively, "misconceptions." These intuitive notions are, however, neither perverse nor idiosyncratic; they are rooted in everyday experience, and they were initially held by all our predecessors. Our pedagogical orientation becomes sounder and more reasonable if we characterize these notions as understandable "preconceptions" to be altered through concrete experience, rather than as ignorant "misconceptions" to be removed instantaneously through verbal inculcation and a few demonstrations in which the student does not actively participate." (Arons, 1997, p. 56).

Providing appropriate Socratic guidance is more of an artistic skill than an exact science, and it depends critically on several factors specific to the situation in which it is to be applied: the context established by the teacher; the vocabulary used in the textbook and the teacher; the sequence in which the concepts are developed and presented; the nature of the assessments and questions to which students are exposed; and the level of sophistication of the intended student group (Arons, 1997 - Miscellaneous topics - 11.9). Each student begins his or her study of physics bringing with him or her an ingrained set of commonsense beliefs about how the physical world works, developed over years of personal experience. Studies of physics teaching suggest that conventional teaching methods fail to achieve the desired outcomes for students (Van Heuvelen, 1991).

Although the traditional method allows students to develop some knowledge about the topic, they often need support to achieve deeper conceptual understanding and apply learning in new contexts using scientific practices (Redish & Smith, 2008). Students' preconceptions in physics profoundly influence how they assimilate, interpret, and integrate new information with prior knowledge during the learning process (Odden, 2021).

Daud et al. (2015) analyze how students present a prioritization of visible observations over abstract interpretations of physical concepts, often confusing scientific ideas with everyday notions. Examples include associating force with an “internal impulse” or confusing velocity with position. Difficulties also arise in the interpretation of graphs and their connection with physical concepts. The article proposes diagnostics and conceptual change strategies, such as analogies and cognitive conflicts, to help students restructure their ideas, emphasizing the need for teaching that prioritizes deep understanding, promoting critical thinking, scientific literacy, and deep and active understanding instead of superficial memorization.

Prarokijjak et al. (2024) analyzed common misconceptions of high school students about force and motion, focusing on Newton's Laws of Motion. The methodology involved administering the Force Concept Inventory (FCI) test to 40 students from Thammasat Secondary School, combined with semi-structured interviews to deepen the understanding of the concepts presented by the students. The results indicated that the main errors were related to kinematics (42.50%) and active forces (21.04%). The study also showed that the occurrence of these misconceptions varies according to school level and career interests. Students in the 2nd year of high school (Mathayom Suksa 5) had fewer misconceptions compared to those in the 1st year (Mathayom Suksa 4). In addition, students specific to science careers obtained a median of 8.00 in the results, while those directed to careers in social sciences registered a median of 4.00. The authors recommend specific educational strategies to correct these misconceptions, such as the use of diagnostic tests and teaching methods that promote a deeper understanding of concepts.

3.2. Conceptual Resources Used by Students

Students' conceptual resources for understanding physics are the knowledge, ideas, and strategies they use to understand and solve problems related to physical concepts (Robertson et al., 2023). These resources include mental models and representations, which are the ways students visualize or interpret physical characteristics; prior concepts, which are ideas acquired through everyday experiences or previous learning, influencing the interpretation of new topics; informal intuitions, based on personal opinions that are not always aligned with scientific models; problem-solving strategies, which involve methods or approaches that students employ to deal with physical questions; and causal relationships, which are the conditional arrangements between different characteristics and their causes. These resources are fundamental to learning, but they can also represent obstacles if they are not specifically defined or refined throughout the educational process, requiring teachers to help students improve their scientific understanding of physics.

Understanding why students form their ideas and how their initial conceptions quickly develop from their everyday experiences is essential in physics education. However, intuitive understandings of the world often differ from scientific explanations. However, students’ conceptual structures vary significantly. (Docktor & Mestre, 2014) provide a comprehensive overview of research on physics education in higher education, based on a paper originally commissioned by the National Academies, identifying common misconceptions and developing strategies to correct students’ misconceptions in physics, synthesizing physics education research (PER). The material provides promising suggestions for advancing PER.

The difficulty that students face regarding concepts of Mechanics has been going on since High School since the mid-1980s (Halloun & Hestenes, 1985) demonstrated that even students with good performance in Physics subjects tend to maintain misconceptions that are inconsistent with the basic concepts of Mechanics. According to (Rinaldi, 2017, p. 64 to 67) after analyzing the questions from the 2013 National High School Exam, an exam that is the gateway for students to Higher Education at Public Universities in Brazil, when checking the errors and correct answers to a basic question about the action of the friction force, in which the text explains that the friction force is essential for a person to be able to move, especially when climbing a ramp because the friction between the feet and the ground prevents a person from slipping and provides the necessary grip for them to apply force against the ground and be able to walk. This test considered a question that addressed a difficult topic, and a very intriguing fact is that the higher the student's score, in the total test, the higher the percentage of students who choose the alternative that states that friction is the opposite force to movement, that is, these same students who got this question wrong, got more complex questions right, this report indicates that the problem has persisted for more than 30 decades. (Sengul, 2024) reports that when teachers prioritize mechanical learning based on repetition, many students end up acquiring knowledge superficially, with little long-term retention, since traditional physics courses generally emphasize the passive transfer of knowledge, memorization of formulas, and solving standardized problems. Thus, we have observed throughout the research that students who perform better in traditional questions have difficulties in conceptual questions, so understanding students' conceptual knowledge is essential to improving physics teaching (Sengul, 2024). Since the creation of the Force Concept Inventory test (Hestenes et al., 1992), the FCI has been applied at two main moments in introductory Physics courses: at the beginning, through a pre-test that assesses students' prior knowledge, and at the end, through a post-test that measures the conceptual progress obtained during the course (Uibson & Frei, 2023).

In the study by (McDermott, 2014, p. 734), when addressing mechanics, with an initial focus on kinematics, it was observed that students had difficulty understanding the concepts of speed and acceleration. In one of the activities, two identical steel balls rolled along adjacent tracks, and students were asked if, at any point, the two balls had the same speed. In the example, two identical steel balls roll along adjacent tracks: one horizontal and the other inclined. Ball A moves at a constant speed on a horizontal track, while ball B descends a ramp with a higher initial speed and overtakes ball A. As it goes up, ball B reduces its speed and is overtaken by ball A, generating two crossing points. McDermott seeks to assess the student's ability to distinguish kinematic concepts from each other when comparing the observed movements of two balls, presenting the speed comparison task, with the ball A moving in a straight line and asking the question: "Do balls always have the same speed?" And ball B moving on an inclined plane.

A strong tendency was observed among students to associate the moments in which the balls occupied the same position with the moments in which the velocities were equal. When asked to compare the accelerations of the balls, their performance was even more unsatisfactory, indicating greater difficulty in this concept.

By the time they complete introductory courses, students often demonstrate an inability to reason qualitatively about physical phenomena. Instead, they tend to resort to simplistic problem-solving approaches that rely exclusively on formulas. To understand the reasoning of students, who have traditionally accumulated conceptual errors, the application of theoretical resources has shifted to exploring how they understand specific concepts, now considered productive resources that can enrich learning (Robertson et al., 2023). This approach is in line with the theory of cognitive resources in science education, promoting a more constructive and contextualized view of students' conceptual development. (Bauman et al., 2024) Emphasize a resource-oriented approach, focusing on students' generative ideas rather than their misconceptions.

Robertson et al. (2023) indicate that students may form misconceptions about physics concepts before they even begin to learn about the content, and it is up to teachers to identify these prior ideas to transform them into scientific knowledge. This study presents a method to identify common conceptual resources that students use to understand specific physics topics, using students' written responses, drawing on physics education research (PER) that has historically focused on identifying students' difficulties and alternative conceptions, proposing an approach focused on students' conceptual resources. Resources are activated in a context-dependent manner and can vary in different situations. These resources are ideas expressed by a student that can be continuously related to physics, so students' ideas, even if incorrect, should not be discarded and can be productive for learning. The study offers a practical guide for researchers seeking to identify common conceptual resources in physics, emphasizing the importance of adopting an approach that values students' initial ideas and their connection to formal physics.

When students begin studying physics, they bring with them some ideational resources that may vary in the way they interpret and assimilate new knowledge. These misconceptions represent a great challenge, and thus the importance of addressing them through learning strategies that help them review and correct their mistaken ideas. The results (Sengul, 2024) indicate that teaching strategies should transcend memorization, encouraging students to engage in scientific practices, such as planning experiments, formulating questions, and analyzing data. This approach will favor the development of critical thinking and allow students to apply their knowledge in different contexts, highlighting the challenges in implementing innovative teaching strategies in the university context, such as resistance on the part of teachers and the need for professional development. Sengul investigates the impact of different teaching methods on students' approaches to problem-solving in physics in higher education, aiming to analyze how students face kinematics problems, in order to compare traditional teaching with innovative methods, highlighting the importance of active learning and reviewing misconceptions. In (Sengul, 2024) they aimed to explore students' conceptions about kinematics through two questions extracted from the book. The first question focused on the analysis of position versus time graphs to determine the speed and velocity of two objects at different times and the second question describes an experiment involving three balls and three tracks, seeking to understand the movement and speed of the balls, using the data provided.

> “This study showed that college students tended to solve familiar problems and had difficulty with context-based problems. For example, question 1 was a typical graphical problem, and students had consistent knowledge and logical progression levels. However, question 2 required students to think

> about the context of a ramp. Students tended to use mathematical skills without any explanation of the question. Therefore, we need to focus on teaching physics in a context that guides students in understanding how a phenomenon occurs in everyday life. In these two problems, we assumed that students would approach them differently. We found different knowledge levels, skill types, and logical progression levels." (Sengul, 2024, p. 15).

The work carried out in (Sengul, 2024) entitled "Linking Traditional Teaching to Innovative Approaches: Student Conceptions in Kinematics" analyzes how different teaching methods influence problem-solving in university physics education. The research compares traditional practices, such as rote memorization and passive learning, with innovative approaches, which promote active learning and scientific inquiry, and explores students' prior conceptions about physics, including the misconceptions they bring to the classroom. These misconceptions can hinder the assimilation of new knowledge and, therefore, need to be addressed effectively so that students acquire a more accurate understanding of the concepts. The study also focuses on the relevance of active learning strategies, such as group learning, collaborative problem-solving, and experimentation, which help students identify and reformulate their incorrect ideas. The conceptual change approach helps students recognize their prior conceptions and revise misconceptions through discussions, collaborative problem-solving activities, and experiments (Sengul, 2024).

Aiming to analyze the models developed by first-year engineering students, and evaluating the effectiveness of the pedagogical approach in an integrated physics and mathematics course in STEM education, (Dominguez et al., 2023) highlight the importance of integrating physics and mathematics in STEM education through modeling activities. The study shows how this approach can improve students' theoretical understanding and practical application of concepts, promoting deeper and more collaborative learning. The research emphasizes the need for real-world problem scenarios to motivate students and develop their problem-solving and critical thinking skills. Choosing a classic Mechanics problem to study a ball descending an inclined plane and then performing a horizontal throw, the students needed to determine in which positions they should place the ball so that when descending the ramp, it would fall into the cup, so they used mathematical and physical models to predict the ball's movement. Most students were able to construct appropriate theoretical models for the problem, but many mixed up units of measurement (centimeters and meters), resulting in incorrect answers; others neglected the fact that the initial velocity of the ball begins at a specific angle; and one group made a mistake when applying the equation. The work was divided into 18 groups; five groups were able to make the ball fall into the cup; three groups applied complete and correct models but were unable to make the ball fall into the cup due to errors in units and equations; and the other groups had difficulty applying the models consistently due to misinterpretations of the problem or failures in applying the units. The conclusions were that group work helped in the construction of more complete models, facilitating peer learning, since the practical application of the theoretical models proved to be complex.

3.3. Constructivist Methods

In (Hake, 1998) pedagogical approaches that emphasize the active construction of knowledge by the student, rather than a passive transmission of information, constructivist methods, are explored. In these approaches, learning occurs when students are engaged in the learning process, interacting with the content, with their peers, and with the teacher. In this study, Hake compares traditional teaching methods with "interactive engagement" approaches, showing that students involved in active learning methods perform better. He highlights that learning is more effective when students are engaged in the learning process, interacting with the content and with others, which is a fundamental principle of constructivist approaches. Active learning and problem-solving are important strategies, as they allow students to explore, test, and reformulate their ideas, promoting deeper understanding and long-term retention. In addition, these methods highlight the importance of the zone of proximal development, where learning occurs in interaction with the teacher or peers, who offer support and challenges that lead the student to reach higher levels of understanding. The focus is on active student participation, inquiry-based teaching, collaboration, and problem-solving, promoting more meaningful and lasting learning.

Aiming to improve introductory physics instruction at the local, state, and national levels, (Hake, 1998) engaged in a program of development, dissemination, and research, creating Socratic Dialogue Induction (SDI). In (Hake, 1992) a presentation was made of the Socratic Dialogue Induction laboratory in the Physics Department of Indiana University, Bloomington, with students of the initial undergraduate courses, which reports the use of Socratic pedagogy in university laboratories of introductory physics and shows its effectiveness in promoting the student's transition to the Newtonian world, as measured by pre-and post-course tests with the conceptual understanding of mechanics exam (Halloun & Hestenes, 1985). These Socratic Dialogue Induction (SDI) Labs were developed based on Arnold Arons' half-century of ethnographic research, which involved listening carefully to students' responses to explore Socratic questions related to physics, science, and thought processes (Hake, 2012). This program consisted of "guided construction" labs in which hands-on experiments in introductory mechanics were conducted using the principles of the Socratic method. The method relied on listening carefully to students' responses and asking Socratic questions about physics, science, and reasoning concepts, culminating in a more effective approach to teaching introductory physics.

This research culminated in a milestone in introductory physics education. Following Arons' principles, SDI Labs were designed to help students think like physicists by encouraging them, for example, to: (1) recognize the importance of operational definitions; (2) use and interpret visual, graphical, vectorial, mathematical, and textual representations; and (3) consider thought experiments and experimental limitations. According to (Hake, 1992), engaging students in simple experiments of a Newtonian nature creates conflicts with their common-sense understanding. This, in turn, promotes collaborative discussions among students and opens the space for Socratic dialogue with the instructor. In his work (Arons, 1985), the process of Socratic dialogue is outlined as follows: it is crucial to learn to formulate simple and sequential questions, guiding students in an intentionally Socratic manner. After each question, it is imperative to be silent and listen carefully to the answer. Most inexperienced questioners tend to provide their own answer or modify the question if they do not get an immediate response. It is important to wait at least four or five seconds, so that students have time to reflect and will respond articulately, truly explaining their lines of reasoning. As students respond to these thoughtful prompts, it becomes possible to identify the underlying errors, misunderstandings, and flaws in logic. There is no benefit in simply providing students with "correct answers" or "clear explanations." Students do not benefit from these answers or explanations; they simply memorize them. The real benefit to students comes when they are prompted to confront contradictions and inconsistencies in their arguments and, as a result, spontaneously alter their statements.

Following Arons' ideas, SDIs were designed to help students think like physicists by encouraging them to appreciate the need for operational definitions, interpret graphical, vectorial, mathematical, and written representations, and consider thought experiments and the limiting conditions of each situation. After years of dedicating himself to SDIs, Hake concluded that attempts to teach students to think like physicists were successful. This was evidenced by the high normalized learning gains (~0.6) based on pre-test and post-test results using the Force Concept Inventory (FCI) and tests developed by Halloun and Hestenes with SDI students (Hake, 2012).

In (Hake, 1998) it is observed that students who participated in activities based on the Socratic method showed substantial gains in learning fundamental concepts, because of a greater understanding and application of scientific ideas. Dialogue not only helps students internalize the content but also prepares them to face complex challenges, providing a solid foundation for critical thinking and problem-solving. (Moreira, 2021) criticizes traditional methods in teaching physics, which prioritize memorization and mathematical formalism, to the detriment of conceptual and contextualized understanding. He defends meaningful learning, connecting new knowledge to the context and reality of students, using scientific modeling, experimentation, and virtual laboratories as essential tools. Moreira emphasizes the importance of prior knowledge, the predisposition to learn and the dialogical relationship between teacher and student. In addition, he suggests teaching physics as a human construction, subject to revisions, to stimulate critical thinking. He proposes profound reformulations in teaching to make it more relevant and accessible to students.

The study by (Sagatbek et al., 2024) investigates the impact of problem-based learning (PBL) on high school students' performance and attitudes toward physics. Using a sample of 63 10th-grade students divided into experimental (PBL) and control (traditional learning) groups, the research measured students' physics knowledge and attitudes before and after the intervention. The results showed that students in the PBL group showed a significant increase in physics knowledge compared to the control group. However, there were no significant changes in students' attitudes and beliefs toward learning physics. This suggests that although PBL can improve academic performance, it may not be enough to change deeply ingrained perceptions and attitudes. The study highlights the need for more research to understand how different pedagogical approaches can influence not only students' knowledge but also their attitudes toward physics. Implementation of PBL by experienced teachers can be an effective strategy for improving learning, but it must be complemented by other techniques to impact students' beliefs and attitudes.

Kirya et al. (2021) critically address the challenges and problems in physics education in Uganda, highlighting the urgent need for pedagogical and assessment reforms. The analysis reveals that the low pass rate of students in physics is a direct reflection of the problematic learning approaches, such as rote memorization, that are prevalent in the Ugandan education system. The teacher-centered, lecture-based teaching model limits student interaction and active participation, which are essential for constructing knowledge according to the principles of constructivism. The constructivist approach suggests that students construct their understanding through interaction with the environment and by integrating new information with their prior experiences. In conclusion, the paper argues that addressing students' alternative conceptions and implementing more effective teaching and assessment methods are crucial steps toward improving physics education.

3.4. Engagement Methods

According to (McDermott, 1996), engagement methods refer to pedagogical practices that encourage students' active participation in the learning process. These methods seek to involve students in a meaningful way, challenging them to reflect, discuss, and interact with the content in a dynamic way, arousing their interest and curiosity. The importance of evidence-based teaching methods that actively involve students in the learning process is highlighted, using activities that promote problem-solving, exploration of concepts, and practical application of knowledge. Instead of being passive recipients of information, students are encouraged to become active participants, engaging deeply with the concepts and with their peers. McDermott emphasizes that these practices are essential to promote more effective learning, which goes beyond simple memorization and leads to long-term understanding and retention of the concepts learned.

Inquiry-based and problem-based scientific practices encourage students' active participation, encouraging them to question their own and others' conceptions, make comparisons, and reconstruct their understanding based on evidence from the discoveries made (Potvin et al., 2024).

At the University of Washington (McDermott et al, 1996), a comprehensive instructional material called "Physics by Inquiry" was created with the goal of supporting active and deep learning, as well as promoting investigative processes in which students can revise their preconceived ideas and reach more authentic concepts. The book consists of two volumes, covering mechanics, electricity, optics, and thermodynamics. The proposed questions encourage students to question, make predictions, and communicate their ideas. The focus of the book is on developing conceptual understanding, guiding students to apply their knowledge in new situations, rather than simply memorizing it.

Studies conducted (Quibao et.al., 2019) analyzed the conceptual learning in physics of students entering exact science courses, evaluating the impact of traditional and active teaching methodologies. Using the Force Concept Inventory (FCI), pre-and post-tests were applied to 599 students at USP São Carlos. The results show that students in classes with active methodologies had, on average, conceptual gains twice as high as those in traditional classes.

These studies have consistently shown that, in courses where traditional approaches are exclusively employed, students' conceptual learning generally shows very low gains. These results suggest that in traditional courses, students tend to preserve their understanding of physical phenomena essentially unchanged even if this understanding contradicts the Newtonian principles and mathematical formalism that they apply in problem-solving and that this is independent of the educational institution or the teacher, as also pointed out by (Mazur, 1997).

> In other words, students learn algorithms and formulas, but they do not learn the fundamental principles and ideas behind those phenomena, nor do they change their way of thinking. These FCI results, together with other similar studies carried out throughout the 80s and 90s, began an intense debate and questioning about the effectiveness of teaching methodologies traditionally adopted in these disciplines, with important implications for the development and consolidation of the area of research that is now internationally recognized as Physics Education Research (PER), which has an active community of researchers and specialized publications (McDermott e Redish, 1999, p.755)." (Quibao et al., 2019, p.2. Free translation from Portuguese).

In (McDermott, 1991), it was reported that students' spontaneous conceptions persisted after the course with traditional methods. Traditional teaching methods, often focused on the reproduction and memorization of formulas, generally result in a superficial understanding of concepts. Although students can solve problems mechanically, they face difficulties when trying to apply knowledge in new contexts. In contrast, innovative approaches, such as problem-based learning and scientific inquiry, stimulate a deeper engagement with the content. These methodologies encourage students to question their previous conceptions and correct misconceptions, promoting more meaningful and rigorous learning. In the search for the non-use of the traditional method, (Marques, et al., 2021) address the application of active methodologies in teaching, highlighting their potential to transform education by promoting greater engagement, collaboration, and the development of critical skills. Based on a systematic review of the literature from 2011 to 2021, using the Thomson Reuters ISI Web of Science® database, they identify advantages such as the creation of dynamic environments and the improvement of academic performance, while at the same time addressing the regularity of challenges, such as the greater effort required from teachers and the need for structural changes in teaching.

The most common active methodologies include problem-based learning, project-based learning, flipped classroom, and educational games. Although these practices are widely discussed today, studies on them emerged as early as the 1990s (Mazur, 2014), which was first published in 1997, entitled Peer Instruction: A User's Manual, which developed the active methodology known as peer learning, which incorporates interactive pedagogy into the classroom. Active methodologies are processes in which students construct meaning through interaction with peers and instructors, engaging in carefully designed and structured exercises. Active learning involves active students in the learning process, whether through activities or classroom discussion, as opposed to simply passively listening to an expert (Kovarik, 2022).

A literature review on the implementation of the interactive teaching methodology Peer Instruction (PI) is carried out by (Müller et al., 2017) since its creation by Eric Mazur in 1991 until 2015, addressing the application of this interactive teaching strategy in different educational contexts and its effectiveness in learning. The review highlighted that most studies on PI are based on quantitative analyses, involving experimental and control groups. However, few studies present robust theoretical frameworks to support the investigations. This gap represents an opportunity for future studies that seek to deepen the conceptual understanding of the effectiveness of PI in different contexts. The review answers four main questions: teaching contexts where PI was implemented, impacts on student learning, results in terms of teacher attitudes and adaptations, in addition to the theoretical and methodological approaches used in studies on the subject. PI was mostly trained in universities in North America, especially in the United States, being applied mainly in STEM (Science, Technology, Engineering, and Mathematics) disciplines, with emphasis on Physics. This concentration reflects both the origin of the method, and the focus of the research groups involved. Peer Instruction has brought benefits to academic performance, conceptual learning, and problem-solving skills. Studies have often compared classes that used Peer Instruction with traditional classes, using standardized tests such as the Force Concept Inventory (FCI). The article highlights that Peer Instruction not only improved students' conceptual learning and academic performance, but also encouraged more dynamic and interactive teaching. By prioritizing active student participation and peer interaction, Peer Instruction redefines the role of the teacher as a mediator and guide in the learning process. With its flexibility and proven effectiveness, the method presents itself as a promising alternative to address educational challenges in different contexts and levels of education. One of the main challenges is the lack of a solid theoretical framework in many studies, which limits a more in-depth analysis of the factors that influence the method's results.

Resbiantoro & Setiani (2022) address students' misconceptions in physics, highlighting the importance of identifying and correcting them to improve learning. Diagnostic tools such as interviews, open-ended tests, multiple-choice tests, and multilevel tests are essential to detect these misconceptions. The work highlights that the causes of misconceptions are varied and complex, including daily experiences, language, teaching methods, and inadequate teaching materials. To remedy them, strategies such as simulation-based experiments, which, for example, use technology to create virtual learning environments where students can visualize and manipulate scientific phenomena, help to make scientific concepts more intelligible and plausible, in addition to conceptual change texts and inquiry-based learning being effective. Future teachers must be prepared to identify and correct these conceptions, preventing them from being transmitted to future generations of students. Correcting these conceptions is crucial to developing critical thinking skills, encouraging them to confront their previous ideas, build a more accurate scientific understanding and problem-solving, essential in the 21st century.

4. Conclusion

It is concluded that the difficulties and challenges faced in teaching Physics, particularly in the concepts of Mechanics, are not recent. As reported, these problems have been identified for decades, motivating scholars and researchers to investigate their causes and implications, carrying out tests and seeking new ways to understand the current scenario. Despite advances in discussions and diagnoses about the difficulties in teaching Physics, the problem remains far from being resolved. Over the years, several approaches and strategies have been proposed, but the results presented in this work show that the challenges persist, reflecting the complexity of the teaching-learning process in teaching Physics. Resistance to new methodologies, the lack of continuous training for teachers, and the structural limitations of educational institutions are just some of the factors that perpetuate this situation. In addition, gaps in students' prior knowledge and the difficulty in connecting theory and practice are issues that still need to be better understood and addressed. The evolution of physics teaching, therefore, requires a collective and continuous effort to overcome these obstacles, adapting to new educational demands and emerging pedagogical discoveries. Thus, the solution to this problem requires an integrated approach and the implementation of sustainable changes in the educational system, focusing on the development of both teachers and students. In this way, the challenges faced in physics teaching remain open, demanding constant efforts to overcome them.

Finally, given the large number of works in which the selection of articles, even though it is a cut of the total contingent, helped us to understand and present in this work, a general overview of research in physics teaching, according to the categories we listed.

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