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Mapping and Analyzing High School Physics Misconceptions: Novel Insights from a 20-Year Bibliometric Study (2002-2022)

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Abstract

The primary objective of this study is to comprehensively explore, identify, and visually represent the research landscape related to physics misconceptions over the past two decades. This encompasses research trends, authorship patterns, the most prolific institutions, countries of origin, profiles of top-cited articles, and key themes through favorable keywords. It can be known which physics materials are often studied in terms of misconceptions and efforts to identify them. To fulfill this objective, a meticulous bibliometric analysis was conducted on a dataset comprising 61 meticulously selected documents, screened using specific search queries. Data were extracted from the Scopus database and analyzed using VOSviewer software. The analysis results show that the research trend of physics misconceptions has increased in recent years. Information on authors, institutions, subject areas, countries, and most influential documents was also analyzed in the study, along with the number of citations and article production. Of paramount significance (17 clusters and 297 items) is the revelation that research in the realm of physics misconceptions gravitates towards understanding the role of technology-mediated learning, brain processes, individual student characteristics, and assessment techniques can all contribute to a better understanding of misconceptions and how they can be effectively addressed in educational settings. In essence, the implications of this research extend beyond the realm of physics education, touching on teaching methodologies, curriculum design, educational policies, and the broader advancement of scientific literacy in Indonesia.

Keywords: Bibliometric; Misconception; Physics; Research trend

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INTRODUCTION

Physics is a scientific discipline that endeavors to describe and elucidate natural laws and phenomena through conceptual frameworks shaped by human cognition (Uher, 2021). Students engage in physics learning by discerning physical events occurring in their environment to grasp fundamental concepts. Physics encapsulates the comprehension of the

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physical world, achieved through the abstraction of environmental complexities (Krenn et al., 2022). This substantiates the interrelation between physics education and the apprehension of natural concepts. Tanggira et al. (2022) underscores the pivotal role of conceptual understanding in the pedagogy of physics, signifying its significance as a cornerstone of effective learning.

In contemporary times, an array of studies has honed its focus on misconceptions, which inherently harbor adverse effects on the learning process (Entino et al., 2021; Kurtuluş & Tatar, 2021). Misconceptions, as consistent erroneous cognitive patterns, can manifest across various educational tiers, including physics subjects (Resbiantoro et al., 2022). They stem from flawed reasoning despite pertinacious adherence to a certain perspective. Students with limited analytical capacities tend to be more susceptible to misconceptions (Siler & Klahr, 2012). These misinterpretations can convolute comprehension and yield a disparity between conceptual grasp and empirical findings.

Numerous recent articles have discovered misconceptions over successive decades (Suprapto, 2020; Volfson et al., 2020; Zajkov et al., 2017). However, a comprehensive review and thorough investigation of the latest contributions are warranted to glean contemporary insights. To accomplish this, bibliometrics emerges as a quantitative approach to dissecting bibliographic data gleaned from scholarly articles and journals (Ellegaard & Wallin, 2015; Zupic & Čater, 2014). This strategic approach aligns with the contemporary trend of amalgamating diverse research strands into clusters, thereby illuminating progressive areas of inquiry.

The publication of research related to misconceptions in physics education has increased markedly. However, there is still a lack of comprehensive bibliometric examination in this domain as relevant studies and authors are predominantly used as sources of literature review. The exam is conducted to provide a broader understanding of the discipline and look at the distribution of publication mapping trends visualized in physics misconceptions (Ghani et al., 2022; Su et al., 2021; Zhang et al., 2022).

Bibliometrics is an evaluation of research from various literature that has been widely produced (Ellegaard & Wallin, 2015). There are four benefits obtained by using bibliometric analysis methods, namely (1) analyzing trends in individual research or fields of study, (2) providing evidence of the impact of individual research or fields of study, (3) finding new emerging research fields, (4) identifying potential research collaborators and suitable sources for publication. In addition, bibliometric analysis can be used to view articles' contributions to developing physics misconception literature using a statistical approach (Gatto et al., 2023; Maretti et al., 2019). However, the difference between this bibliometric research and previous ones is that it focuses on physics education, uses the Scopus database, and utilizes the VOSviewer application.

Therefore, this study aims to explore research trends and contributions, author profiles, institutions, countries, sources, and subject areas regarding physics misconception research. This study also describes the direction of physics misconception research, the most favorable keywords, and visualization. This research can inform future researchers to identify research gaps in physics misconceptions. In addition, for policymakers, this research can inform the physics education curriculum by providing insights into the current research on physics misconceptions.

METHOD

In this study, a bibliometric analysis model was carried out using quantitative

methods by integrating a qualitative descriptive approach. The bibliometric analysis in this study focuses on journal publications on an international scale. This study uses the Scopus database as an alternative step in finding various indexed literature appropriate to research topics with a wide range of coverage from various countries. Data was searched through the Scopus database with the search query "Physics and Misconception 2001-2023," and 61 articles that were the data source in this study were found. The results were obtained by searching Scopus data with the *.ris* format. Then, it is processed using VOSviewer software to obtain data mapping through the visualization process and Ms. Excel to process data in graphical form. Data mining was conducted using detailed metadata sources on August 17, 2023. This kind of bibliometric analysis provides new knowledge and skills in processing metadata. It provides updates or trends in the research world to provide convenience for researchers and educators in identifying knowledge gaps that need to be corrected in the future.

Figure 1 Research phase flow (Dawana et al., 2022; Suprapto et al., 2021)

Figure 1 shows the process of data analysis using the bibliometric analysis method. This method is used to map research trends using the VOSviewer software. VOSviewer is used to show the Co-Occurrence of the relationship between authors, documents, and keywords that are relevant to the research topic (Bornmann et al., 2018; Guleria & Kaur, 2021; Oladinrin et al., 2023). The data analysis process is carried out by determining keywords first (Physics and Misconceptions 2001-2003) and then entering these keywords on the Scopus page until the results are found. When the desired data has been obtained, the next step is to enter the data obtained in *.ris* format. Into VOSviewer to see the mapping results. In-depth analysis was carried out by looking at network visualizations and overlays, which were then analyzed to see the relationship between physics and misconceptions. The results of the data mapping analysis from VOSviewer are then described by reinforcing the form of literature studies from sources in the form of journals with high credibility.

RESULT AND DISCUSSION

Publication Trend

Figure 2 shows trends in physics misconception research over the last two decades. This research tends to be stable in the first decade and has no extreme decline, with the highest publication peak in 2003. From 2004 to 2006, research was needed on physics misconceptions. In the second decade, the research trend experienced extreme ups and downs. From 2014 to 2016, it experienced an increase and then stabilized from 2016 to 2017. However, from 2018 to 2019, this research experienced a decline and again increased to an extreme in 2020. In 2020, the world experienced the Covid-19 pandemic, and there was a change in the learning system. Even online learning is not a perfect way to determine which students require the most significant assistance for learning recovery (Lin et al., 2020). This situation causes students to experience many difficulties in learning, so they develop misconceptions about mathematics, science, and reading (Dewi & Wulandari, 2021). Then, the research trend continues to decline until the half of 2023. It represents half of 2023; research on misconception has not

yet been published. It is important to explore topic misconception in physics learning, the factor -age and gender- of misconception, and measure teacher competence (Sejati & Sayekti, 2022; Soeharto & Csapó, 2022)

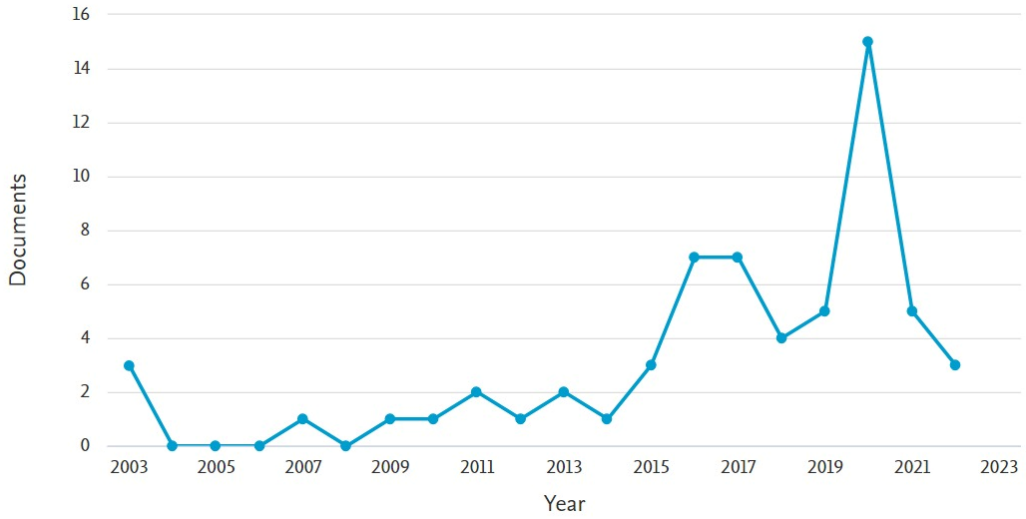

Figure 2 The year-wise distribution of physics misconception research

The Top Productive of Authors, Affiliations, and Regions

According to Table 1, five researchers from AIR-US have contributed to physics misconception research. For example, Arora, A. and Erberber, E. have experience in study analysis and comparative studies of large-scale international and national assessment data. Their achievement in physics misconception makes AIR to be the most productive affiliation. It has focus and capabilities in research and program evaluation about education, which worked with educators, students, and policymakers to study and implement programs and policies that improve outcomes. Additionally, researchers from Turkey, Indonesia, and Malaysia are the top researchers who contributed to physics misconceptions.

Table 1 The top productive authors

Author	Affiliation	Region	Total Docs
Arora, A. Erberber, E. Mai, T. Neidorf, T. Tsokodayi, Y.	American Institutes for Research (AIR)	United States	4
Diani, R.	UIN Raden Intan Lampung	Indonesia	3
Eryilmaz, A	Middle East Technical University (METU)	Turkey	2
Halim, A.	Universitas Syiah Kuala	Indonesia	2
Halim, L.	Universitas Kebangsaan Malaysia	Malaysia	2
Kaltakci-Gurel, D.	Kocaeli University	Turkey	2

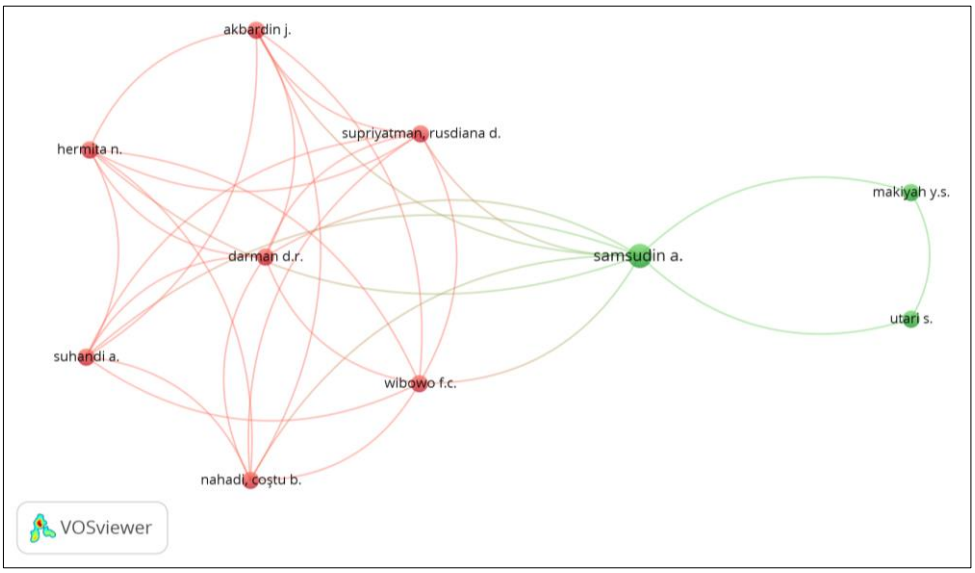

Figure 3 Visualization of co-authorship analysis

In Figure 3, there are two interconnected research collaboration clusters, where Samsudin, A. is central to all visualized nodes, with seven total link strengths. One of their articles, entitled "Contribution of Virtual Microscopic Simulation (VMS) to Unveil Students' Conceptual Development and Misconceptions of Physics Concepts of Heat Transfer", finds that VMS is a learning medium that can help students improve their understanding of concepts and remediate misconceptions in physics lessons (Wibowo et al., 2017).

Regarding the most productive affiliations (Table 2), The American Institutes for Research leads the number of publications with 4 documents. One of their documents with the most citations is titled "Results for Student Misconceptions, Errors, and Misunderstandings in Physics and Mathematics" (Neidorf et al., 2020). METU-Turkey and two Indonesian public universities are second in the most productive affiliations. METU has Eryilmaz, A., and Indonesia has Diani, R. and Halim, A., who have experience in critiques and analysis of research in measurement and evaluation of science and math education. Other six public universities in Indonesia participated in physics misconception research.

Table 2 The most productive affiliation

Affiliation	Region	Total Docs
American Institutes for Research (AIR)	United States	4
Middle East Technical University (METU)	Turkey	3
Universitas Syiah Kuala	Indonesia	3
Universitas Islam Negeri Raden Intan Lampung		
Universiti Kebangsaan Malaysia	Malaysia	2
University of Washington	United States	2
Kocaeli Universitesi	Turkey	2
Universitas Sebelas Maret	Indonesia	2
Universitas Negeri Yogyakarta		
Universitas Pendidikan Indonesia		
Universitas Negeri Padang		

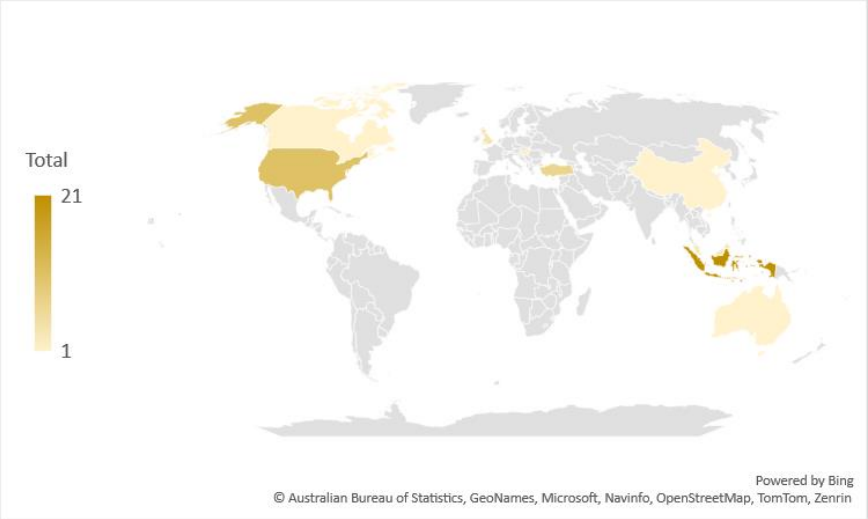

Figure 4 The map of the most productive country

Based on Figure 4, Indonesia has dark yellow, which means Indonesia is the most productive region and has published 21 international-indexed Scopus articles. Perhaps the most prolific reason Indonesia has published physics misconceptions is because Indonesia's science performance was reported to be the lowest among 41 countries in the 2018 PISA report (Soeharto & Csapó, 2022). This suggests that Indonesian students have difficulties understanding and applying scientific concepts, leading to misconceptions about physics. On the other hand, two universities in the United States and Turkey give the United States second place and Turkey third place in top productive affiliation. Australia, Belgium, Canada, and China have the last rank in each document.

Type of Documents and Source Publishing

According to Figure 5, half of the document types in physics misconception research are conference papers. Many international conferences have been held over the last decades. There is only 1 article proceeding that discusses misconceptions about physics at the 6th International Conference of the Balkan Physical Union in Istanbul, Turkey, carried out in the first decade (2006). However, in the second decade, many proceedings articles followed the conference, with a peak year in 2019 with six articles proceeding. The proceedings article was published through 3 different sources. Half of the types of proceeding articles are published in JPCS, 17% in AIP, and the rest in other journals not included in the top five journals attached in Table 3. The article takes second place in the research document on misconceptions of physics. The article was published in three different journals, including RSTE, JOTSE, and JBSE (percentage of 0.3%), and the rest are published in several journals that are not included in the top five sources.

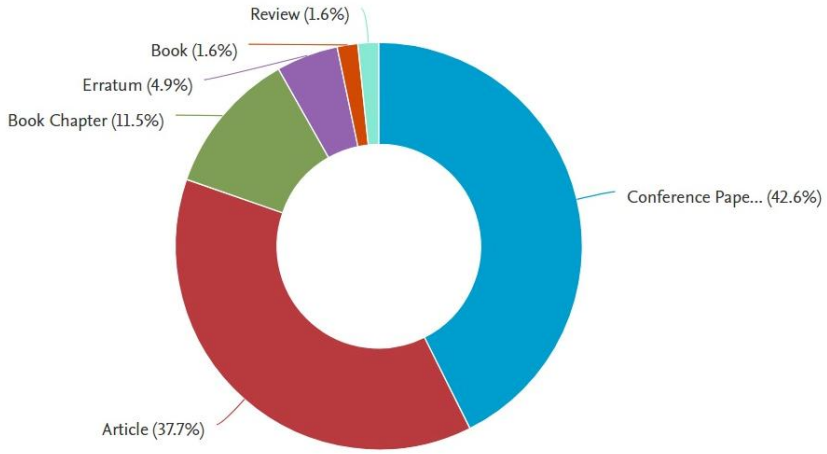

Figure 5 Types of documents

Table 3 Top sources

Source Title	Publisher	Type	Top Subject	Total Docs
Journal of Physics: Conference Series (JPCS)	IOP Publishing Ltd Institute of Physics Publishing	Conference Proceeding	Physics and Astronomy	14
AIP Conference Proceedings	American Institute of Physics Inc.			5
IEA Research for Education	Springer Nature	Book Series		4
Research in Science and Technological Education (RSTE)	Taylor & Francis	Journal		
Overcoming Students' Misconceptions in Science Strategies and Perspectives from Malaysia	Springer Singapore	Book	Social Sciences	2
Journal of Turkish Science Education (JOTSE)	EKIP Buro Makineleri A.			
Journal of Baltic Science Education (JBSE)	Scientific Methodical Center	Journal		

Looking into more detail in JPCS, the articles with the most citations are "Diagnostic Test with Four-Tier in Physics Learning: Case of Misconception in Newton's Law Material" (n=10), developing a valid and reliable diagnostic test with 84% feasibility in very decent criteria (Maharani et al., 2019). Other articles from JPCS have also identified misconceptions through four-tier diagnostic tests on heat and temperature (Fenditasari et al., 2020) and mechanical waves (Tumanggor et al., 2020).

Top-Cited Documents

By analyzing the most cited documents in a particular field, researchers can identify the most influential research and

researchers (Fei et al., 2022). This can help guide future research and collaborations. Table 4 illustrates the top-cited articles. Research by McRorie & McKeown (2017) is leading on the topic of misconceptions in physics, where this article provides an evidence-based approach to understanding the physics of functional fibers in the gastrointestinal tract and resolving enduring misconceptions about insoluble and soluble fiber. In the second place, Tanner et al. (2018) discuss the common misconceptions in electronic energy transfer (ET) and aim to bridge the gap between chemistry and physics, highlighting the clichés and simple formulae to be avoided in ET studies and providing alternative treatments.

Table 4 Top five-cited documents

Author	Title	Source	Citation
McRorie & McKeown (2017)	Understanding the Physics of Functional Fibers in the Gastrointestinal Tract: An Evidence-Based Approach to Resolving Enduring Misconceptions about Insoluble and Soluble Fiber	Journal of the Academy of Nutrition and Dietetics	258
Tanner et al. (2018)	Misconceptions in electronic energy transfer: bridging the gap between chemistry and physics	Chemical Society Reviews	114
Alwan (2011)	Misconception of heat and temperature among physics students	Procedia - Social and Behavioral Sciences	64
Brault Foisy et al. (2015)	Is inhibition involved in overcoming a common physics misconception in mechanics?	Trends in Neuroscience and Education	62
Kaltakci-Gurel et al. (2017)	Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics	Research in Science and Technological Education	60

Ranked third, Alwan (2011) delves into prevalent misconceptions concerning heat and temperature among physics students. These misconceptions encompass notions such as equating temperature to the "intensity" of heat, relying on skin or touch for temperature determination, and disconnecting perceptions of hotness and coldness from energy transfer. The belief that boiling temperature remains constant and the misinterpretation of boiling point as the upper limit of temperature is also addressed. Additionally, the misconception that a cold object lacks heat is elucidated.

Subsequently, Brault Foisy et al. (2015) elucidate the role of inhibition in rectifying a prevalent physics misconception in mechanics. The study posits that experts in mechanics do not necessarily eliminate or transform their misconceptions during learning; instead, these misconceptions may persist within their cognitive frameworks but are restrained when providing accurate responses.

Lastly, Kaltakci-Gurel et al. (2017) contribute by designing and validating a four-tier misconception test to gauge the misconceptions harbored by pre-service physics teachers (PSPTs) regarding geometrical optics. The study identifies six misconceptions held by over 10% of the PSPTs, signifying their significance in shaping misconceptions related to geometrical optics.

Keywords Trend and Visualization

Researchers can identify research themes and topics frequently discussed by analyzing keyword co-occurrence. This

can help researchers better understand the research landscape in a particular field. Table 5 shows the most frequently used keywords in physics misconception research.

Table 5 Most favorable keywords

Keyword	Occurrences	Total Link Strength
Students	15	57
Physics	13	82
Misconceptions	12	69
Student Misconceptions	6	27
Science	6	64
Misconception	6	21
Diagnostic Tests	6	22
Physics Education	5	18
Gravity	5	57

The keywords "Students," "Physics," and "Misconceptions" are the most prominent in terms of occurrences and link strengths, indicating their central role in the research. These keywords indicate that the research focuses on students' role in physics misconceptions. The relatively high total link strength suggests that there is a significant amount of research linking students to the concept of misconceptions in physics education. "Diagnostic Tests" suggests a practical approach to identifying and addressing misconceptions, potentially highlighting the importance of assessment tools in physics education. The keywords "Science" and "Physics Education" show that the analysis might extend beyond physics alone, touching on broader educational and interdisciplinary aspects. The keyword "Gravity" is interesting, as it suggests a topic within physics where misconceptions could be prevalent. The moderate link strength indicates much research connecting gravity-related misconceptions and physics education.

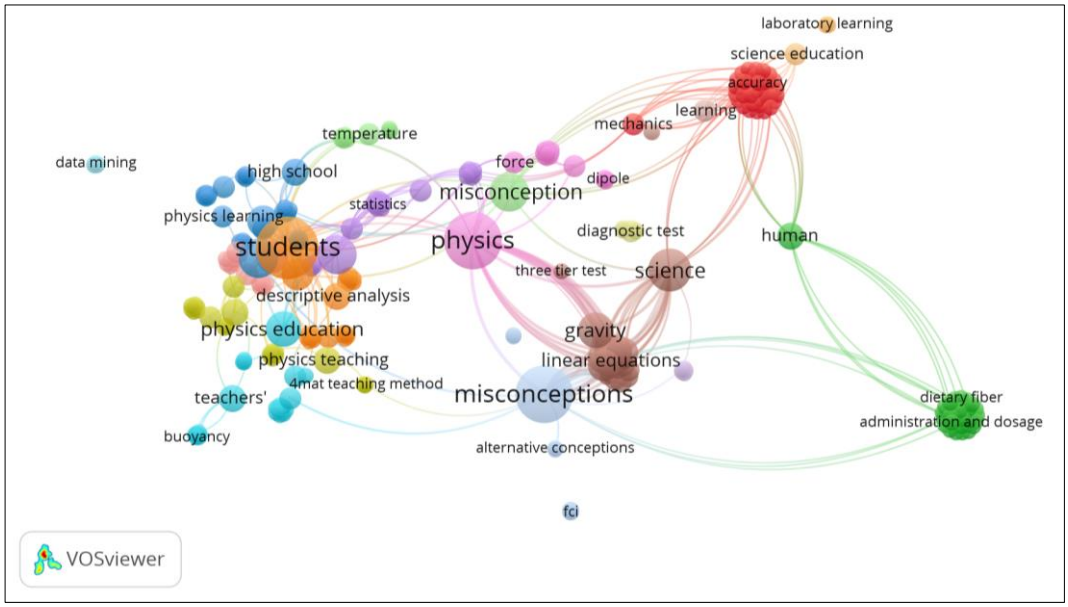

Figure 6 Visualization of keyword co-occurrence analysis

Keyword co-occurrence visualization can be depicted in Figure 6. There are 17 clusters formed with a total of 297 items. Some emerging materials include buoyancy, geometrical optics, modern physics, astronomy, heat, mechanics, viscosity, and atomic models. In the misconception and misconceptions nodes, the research directions are blended learning, learning systems, concept understanding, students, anterior prefrontal cortex, anterior cingulate,

science, physics, diagnostic tests, and alternative conceptions. The following explains the direction of research on misconceptions of physics.

1. ***Blended Learning and Learning Systems*:** This direction likely pertains to exploring how blended learning approaches, which combine traditional classroom methods with online or digital resources, can influence the understanding and correction of misconceptions. Researchers might investigate how incorporating technology into education impacts students' ability to address and overcome misconceptions.
2. ***Concept Understanding*:** This research angle likely focuses on delving into the depth of students' understanding of fundamental concepts in science and physics. The aim could be to identify specific areas where misconceptions commonly arise and to develop strategies for improving conceptual understanding among learners.
3. ***Students*:** The keyword "students" suggests that researchers are interested in understanding how learners' characteristics, behaviors, and prior knowledge contribute to the development and persistence of misconceptions. This might involve investigating how individual student differences influence how misconceptions are addressed.
4. ***Anterior Prefrontal Cortex and Anterior Cingulate*:** These terms are related to brain regions associated with cognitive control, decision-making, and error detection. Including these terms suggests that the research might explore the neurological aspects of misconceptions—how they relate to brain processes, cognitive biases, and the brain's ability to recognize and correct misconceptions.
5. ***Science and Physics*:** These keywords indicate that the research likely centers on science and physics education domains. The goal might be understanding how misconceptions manifest in these subjects and how they can be effectively addressed within their educational contexts.
6. ***Diagnostic Tests*:** Researchers could investigate methods and tools for diagnosing misconceptions among students. This might involve the development of assessment tools and techniques to identify the specific misconceptions that learners hold, which could then inform targeted instructional strategies.
7. ***Alternative Conceptions*:** This keyword suggests a focus on understanding alternative ways of thinking that students may develop in place of the correct scientific concepts. Investigating alternative conceptions can shed light on the sources and reasons behind misconceptions, helping educators tailor their teaching methods accordingly.

What's more, some common misconceptions in physics include that everything that moves will eventually stop; a continuous force is needed for continuous motion. An object is hard to push because it is heavy (Resbiantoro et al., 2022). Some students also believe that gravitational force only acts on heavy objects or that gravity does not affect objects in water (Khandagale & Chavan, 2017). These misconceptions relate to the fundamental understanding of gravity's workings (Neidorf et al., 2020). Additionally, they believe that inertia is the force that keeps objects in motion (Khandagale & Chavan, 2017). This misconception is a misunderstanding of inertia, an object's resistance to changes in its state of motion. As a result, to address those misconceptions, effective remediation strategies through the

conceptual change approach include Simulation-Based Experiments and Conceptual Change (Resbiantoro et al., 2022). Overall, research direction in physics misconceptions can inform educators about prevalent misconceptions and effective strategies to address them. This can lead to improved teaching methodologies that foster a deeper and more accurate understanding of physics concepts among students. Some of the aforementioned diagnostic tests that previous researchers have developed can be used by educators in diagnosing the causes of misconceptions (Fatonah et al., 2022; Salmadhia et al., 2021; Tanggira et al., 2022). Consequently, it improves student learning outcomes by helping students overcome misconceptions, leading to improved performance and a more solid foundation in physics. Addressing misconceptions enhances scientific literacy among students and the general public (Halim et al., 2018). A scientifically literate society is better equipped to make informed decisions on scientific matters. This is necessary to improve Indonesia's PISA score, which is still lagging among other countries (Jones & Pratomo, 2016; Sumule et al., 2018).

CONCLUSION

To conclude, the trend in misconception research has shown a notable increase, reaching its peak in 2020. Among researchers focusing on physics misconceptions, Arora, A., Erberber, E., Mai, T., Neidorf, T., and Tsokodayi, Y. stand out as the most prolific authors, collectively contributing to a total of 4 documents. Notably, Indonesia emerges as the most productive region, having published 21 Scopus-indexed articles of international recognition. Among institutions, the American Institutes for Research takes the lead with the highest publication count, totaling 4. Concerning scholarly sources, the Journal of Physics: Conference Series (JPCS) holds a prominent position with a cumulative publication count of 14 documents. It is worth mentioning that the study by McRorie & McKeown (2017) is a pioneering work in the domain of misconceptions in physics, garnering significant attention and serving as a cornerstone for related research.

Keywords, trends, and research direction indicate a multidimensional approach to studying misconceptions in science and physics education. Researchers seem to be exploring various aspects, including how technology-mediated learning, brain processes, individual student characteristics, and assessment techniques can collectively contribute to a deeper understanding of misconceptions and how they can be effectively addressed within educational settings.

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