JSER

Journal of Science Education Research
Journal homepage: https://journal.uny.ac.id/index.php/jser/index

ISSN: 2597-9701

Multiple Representations in Physics Learning Research: A Content Analysis Review of Trends, Opportunities, and Challenges

O. Ate[1], Parno[2*], N. Munfaridah[3]
[1,2,3]*Master of Physics Education Program, Universitas Negeri Malang, Indonesia*
[*]*Corresponding Author. Email: parno.fmipa@um.ac.id*

Keywords
Multirepresentation and Physics learning

Phone*: +628123827124

Abstract

The study aimed to present the trends, opportunities, and challenges of using multiple representation in physics learning from Junior High School to Higher Education. Through the Content Analysis method, this study analyzed 45 journals that examined of using multiple representation in physics learning obtained using Publish or Perish with Google Scholar and Scopus databases from 2019-2023. The results showed that the number of publications of using multiple representation has increased. The most widely used research type was quantitative. High school students and materials (waves and motion) were the target research subjects and popular materials. Learning physics using multiple representations has the opportunity to facilitate students' concept understanding, problem solving ability, and representation ability. The challenges faced in its use are teachers' difficulties in organizing representations in a structured and coherent manner, as well as students' difficulties in representing physics concepts in graphics and equations. In relation to these findings, it is suggested that future researchers adopt qualitative research and increase the diversity of physics subjects and topics. Also, the abilities measured, such as students' thinking and cognitive explore multiple representation in physics learning. Future research could explore the potential of digital technology and qualitative approaches to use multiple representation to enrich the quality of physics education.

History
Received: October 3, 2024
Revised: November 22, 2024
Accepted: January 9, 2025

How to cite:
Ate, O., Parno, & Munfaridah, N. (2025). Multiple Representations in Physics Learning Research: A Content Analysis Review of Trends, Opportunities, and Challenges. *Journal of Science Education Research*, 9(1), 32-42. doi:https://doi.org/10.21831/jser.v9i1.72954.

INTRODUCTION

Physics is a science that uses the analysis of everyday events that underlie technological progress and the implementation of science with the principle of prioritizing scientific processes to produce work and train constructive, creative, analytical, logical, systematic thinking and best understood through real experiences and effective teaching methods (Aryanti & Widodo, 2020; Munawaroh et al., 2021; Musyarrof et al., 2018) (). However, physics is a difficult subject for students in several countries such as Vietnam, Turkey, America, and including Indonesia (Ady, 2022; ÇERMİK, 2020; Jannah et al., 2022; Ngo, 2022; Redish et al., 2006). The difficulty is influenced by the daily experiences that students have had, including previous learning experiences (Barke et al., 2009) and physics learning oriented with various presentations of abstract concepts (Klein *et al*., 2019). Therefore, educators need to find effective solutions. The most prominent solution is the use of multiple representation. Multiple representation has a very important role in teaching concepts and phenomena that are considered difficult and abstract in physics learning (Fredlund et al., 2015).

Multiple representations are the use of multiple forms of representation in instructional materials simultaneously to enhance meaningful learning that includes visible external representations, such as text, graphics, or images, as well as internal representations in the form of mental models (Bollen et al., 2016; Gilbert & Treagust, 2009). Researchers discussing multiple representations in learning depart from theories and assumptions about information processing and the limitations of human working memory (Ainsworth & Th Loizou, 2003; Baddeley, 1992; Scheiter et al., 2020). The three main functions of multiple representations, as expressed by Ainsworth (1999), are. The first is the multiple representations to provide additional

representations or support cognitive processes. The second is to limit the potential for misinterpretation by utilizing one representation to confirm another. Thirdly, employing multiple representations serve as a method to stimulate students to develop a more profound comprehension of a given scenario. This representation ability also includes the process of understanding certain phenomena, assessing the thinking process, and determining the level of understanding of the information (Hung et al., 2022).

Multiple representations in physics learning allows students to develop a deeper understanding of physics concepts through different ways of representation. External representations such as text, graphs or images can help students visualize concepts concretely, have a positive influence on cognitive abilities, facilitate students with different abilities and provide a positive learning experience in stimulating the development of students' identity (Mardatila *et al*., 2019; Mellu & Langtang, 2023; Munfaridah & Goedhart, 2022; D. Rahmawati & Setyarsih, 2021; R. Rahmawati *et al*., 2021; Widianingtiyas *et al*., 2015; Widyawati *et al*., 2015; Yusup, 2009). Meanwhile, internal representations, such as the mental models, allow them to build a more abstract understanding (Taher et al., 2017).

Research on the use of multiple representations has been widely found, especially in the context of physics education (Munfaridah & Goedhart, 2022; Opfermann et al., 2017). Similar research has been conducted by examining the benefit of multiple representations in physics learning in high school (Nikat et al., 2021). However, the articles are still limited to the benefits of multiple representations in physics learning at the high school level. Therefore, a recent literature review of using multiple representation in physics learning from junior high school to higher education. In addition, it needs to review the current literature to gain an in-depth understanding of the trends, opportunities, and challenges related to the role of multiple representation in physics learning and the development of the research's topic.

In general, this study aimed to contribute to the growing knowledge of using multiple representations in physics learning from Junior High School to Higher Education. This research specifically aimed to answer the following questions: What are the trends, opportunities, and challenges of the research of using multiple representations in physics learning from junior high school to higher education? By presenting an overview of the current state of research and practice, the study can inform prospective physics teachers, physics teachers, and researchers regarding the trends, potential, and implications of using multiple representations, as well as identify the challenges in transforming physics learning. However, this research must be conducted to gain a deeper understanding of the trends, opportunities, and challenges associated with the role of multiple representations in physics learning and contribute to the development of more effective teaching strategies and educational materials that cater to diverse learning styles, as well as promote a deeper understanding of complex physics concepts.

RESEARCH METHOD

This research used a qualitative method with content analysis to investigate and analyze the trends, opportunities, and challenges of using multiple representations in Physics learning. The steps of content analysis referred to the method developed by Khan et al. (2003) . The steps are:

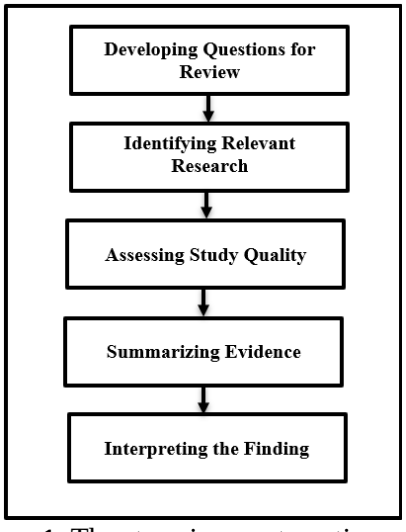

Figure 1. The steps in a systematic review

Developing Questions for Review

Developing good and structured questions when formulating a literature review is a crucial stage. The questions should be precise, clear, and relevant to the purpose of the literature research. The questions of the study are:

1. What is the research trend of using multiple representations in physics learning? a) Number of studies, b) Types of studies, c) Research subjects, d) Physics topics.
2. What are the opportunities for using multiple representations in physics learning?
3. What are the challenges that may be faced in using multiple representations in physics learning?

Identifying Relevant Research

Finding relevant research is an urgent stage in compiling a literature review. The first step is, browsing through scientific databases, journals, conferences, and other reliable sources. This study used various scientific journals related to multiple representations in physics learning. The selection of relevant research considers the scope of the topic to the current research topic. The literature search was conducted using the Publish or Perish (PoP) database search on the Scopus and Google Scholar websites. The results of the PoP search in the 2019-2024 period on the Scopus website with the keywords multiple representation and physics obtained 45 journals for review.

Assessing the Quality of Study

It is a crucial step in preparing a literature review, which aims to verify the validity, reliability and strength of the evidence, generated by the studies in the review. To ensure the quality of the studies, inclusion and exclusion criteria were used to determine the relevant and appropriate literature. Inclusion criteria refer to the parameters to select studies for the literature review. The inclusion criteria of the study were: 1) Research articles published from 2019-2024; 2) Research articles discuss multiple representations in the form of journals; 3) Research in formal education in junior high schools to higher education in physics learning. The exclusion criteria were: 1) Research articles published before 2019; 2) Research in the form of books or other forms of journals; 3) Research does not discuss multiple representations in physics learning.

The process of selecting literature -by adopting to these criteria - will allow the literature review to focus on studies to relevant research question, verify the quality and reliability of the studies, and narrow the scope of the review to achieve more focused and reliable results.

Summarizing Evidence

Furthermore, summarizing the evidence in the research results is an important step in preparing an informative and structured literature review. This stage involves preparing a clear and comprehensive summary of the main findings of each study that has been identified based on Sinta/Scopus-indexed journals, considering the research questions and inclusion requirements.

Interpreting the Finding

Discovery in content analysis refers to identifying, analyzing, and synthesizing of key findings from previous research and scholarly publications. The synthesis of findings is a crucial stage in this research, where the results from various literature will be combined and integrated. In this process, various views and approaches related to the use of multiple representations in physics learning will be organized into a coherent and structured conceptual framework. This conceptual framework uses as the basis and foundation for the proposed recommendations to improve the quality of physics learning.

RESULT AND DISCUSSION

The discussion in this systematic literature review article of using multiple representations in physics learning addresses three aspects. First, the research trend of using multiple representations, which includes the number of studies, types of studies, research subjects, and physics topics. Second, the opportunities arise from using multiple representations in physics learning research. And, the challenges that may arise of using multiple representations in physics learning. The three aspects are described as follows.

Research trends of using multiple representations in physics learning

The number of articles published reflects how common the research is within a certain period. Based on the data in Figure 2, articles that review of using multiple representations is found from 2019-2023. The highest number of publications was seen in 2022, with 13 publications. The more research that examines multiple representations, the greater the positive impact on the development of education in Indonesia, especially in physics learning. This statement i refers to the idea that the ultimate goal of research is to improve learning practices, identify effective learning strategies, and provide recommendations for further research (Flor et al., 2021; Hake, 1998). Therefore, it is imperative to conduct research that examines the use of multiple representations in physics learning.

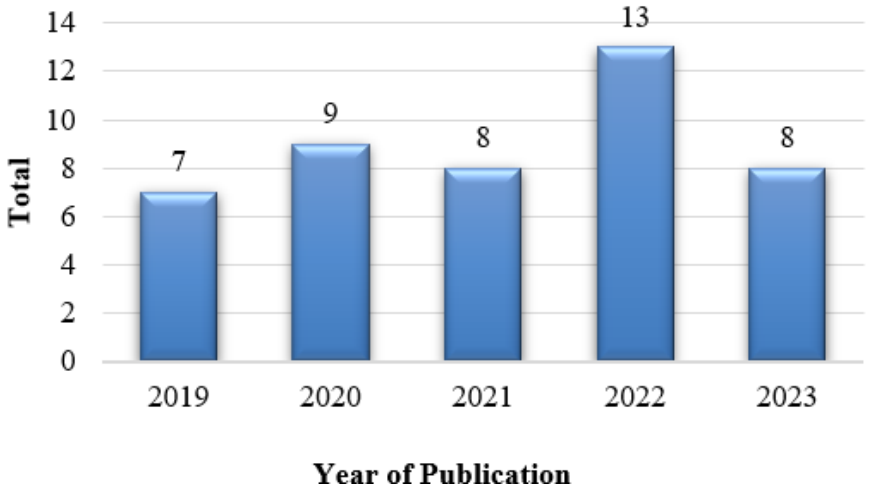

Figure 2. The Trend of Increasing Research of Using Multiple Representations in Physics Learning Over 5 Years

Type of the Research

Based on Figure 3, quantitative is the most widely used of research design in exploring of using the multiple representations. The greater number of quantitative research than other types of research has the reason of usefulness in producing data that calculated and analyzed statistically. This data are in line with numerous prior investigations that researchers tend to use quantitative research methodologies in field studies of education, as opposed to qualitative approaches (Johnston, 2014; Lincoln et al., 2004).

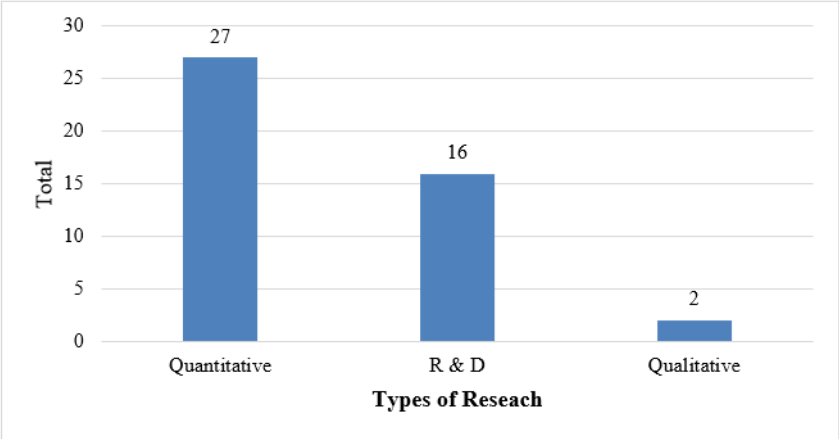

Figure 3. The Distribution of Research on the Use of Multiple Representation in Physics Learning Based on Types of the Research

R & D research has also begun to be widely used to explore the use of multiple representations in physics learning with the aim of producing educational products based on their research findings. These products include books (Annisa et al., 2022), teaching materials (Harti, 2022), assessment sheets (Ellianawati et al., 2020; Silaen et al., 2019), teaching aids (Rahayu et al., 2021), virtual practicum tools (Widodo et al., 2022) and worksheets (Rukhmana, 2021). These products not only present diverse learning resources but also provide assistance in the learning process for students, thus improving the quality of physics learning. In the context of further development, future researchers can explore the potential use of digital technology, such as interactive learning software or online learning platforms that integrate multiple representations in physics learning. It can enrich the variety of educational products produced.

Qualitative research is rarely used in studying of using multiple representations. However, this type of research is starting to be widely used in other cases because it can describe in detail and complete of a phenomenon, not only social issues but also some educational issues (Indah et al., 2022; Punch, 2013). Thus, the lack of qualitative research in examining of using multiple representations open up good opportunities for future researchers. This article suggests adopting a qualitative approach and focus of using multiple representations in physics learning.

Subject of Research

In the research stage, researchers require research subjects to test their hypotheses. Data presented in Figure 4 showed that high school students are the top number as research subjects, followed by physics teachers' candidates, and junior high school students. It implies that students are the most commonly used research subjects in educational research, especially in exploring multiple representations in physics learning. Supported by Susetyarini & Fauzi (2020) , high school students are often used as subjects in educational research. However, data on education levels shows how rarely students of junior high school students are used as the subject of research of using multiple representations. This provides an opportunity for future researchers to study of using multiple representations at the junior high school level.

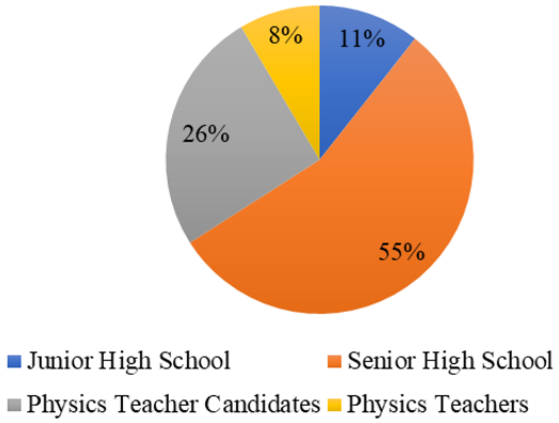

Figure 4. The Distribution of Research of Using Multiple Representations in Physics Learning Based on Research Subjects

Physics Topics

Physics is a subject with various topics. However, many topics are still difficult for students to understand (Ady, 2022; Janah et al., 2020). Based on Figure 5, Wave and Motion materials are the most frequently chosen material. However, there are also studies that do not explicitly disclose the materials used. Therefore, it is expected that future researchers exploring the use of multiple representations in physics learning can convey the chosen physics topics. The selection of appropriate topics can affect physics learning using multiple representations.

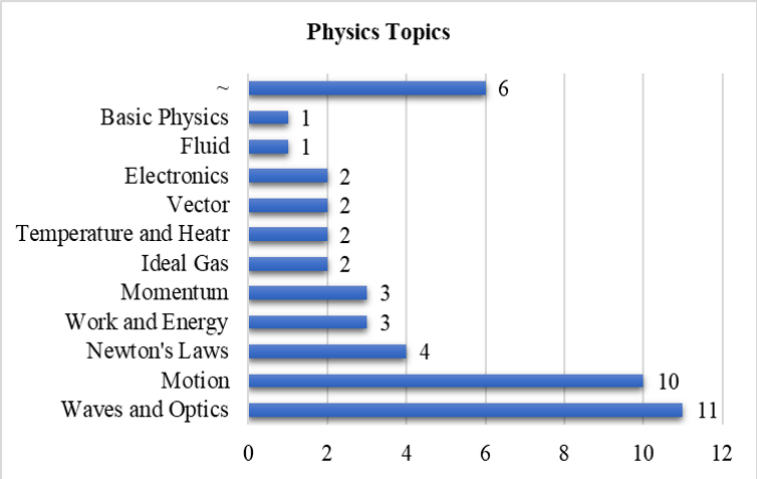

Figure 5. The Distribution of Research of Using Multiple Representations in Physics Learning Based on Physics Topics

Opportunities of Using Multiple Representations in Physics Learning

Using multiple representations in physics learning provides various interesting and potential opportunities to enhance the quality of learning. Based on the analysis of journal articles, several opportunities can be outlined as follows:

Using multiple representations is capable of building a deeper understanding and mastery of physics concepts. From the reviewed articles, there are six studies that using multiple representations help in improving students' understanding and mastery. Research findings indicate that the multiple representations approach enhances students' conceptual understanding with significant

n-gain values (Putri et al., 2020). Additionally, a study conducted by Rukhmana (2021) confirms that developing student worksheets with a multiple representations approach effectively enhances the conceptual understanding of physics teacher's candidate. Similarly, Busyairi et al. (2021) demonstrate e-modules aided by multiple representations can improve the conceptual understanding of physics teacher's candidate in the topics of rectilinear motion, vertical motion, and projectile motion. Then, the research using internal representation can improve students' understanding of the concept of physics (Batlolona et al., 2020) and research using interactive media has been shown to significantly facilitate students' conceptual mastery (Nisa & Tyas, 2022). Thus, the role of multiple representations is crucial as it allows students to access information in various forms of representation, such as visual, mathematical, and verbal, thereby facilitating deeper and holistic understanding.

Using multiple representations can facilitate students in enhancing their problem-solving abilities. Consistently, various studies reviewed of using multiple representations in physics learning is effective in improving students' problem-solving skills (Aha et al., 2020; Annisa et al., 2022; Citra et al., 2020; Krisnaningsih & Hariyono, 2022; Mardatila et al., 2019; Retno Safitri et al., 2020). The reason is that multiple representations allow students to see concepts from various perspectives, helping them develop more flexible and creative problem-solving skills. Consistent with research findings that physics experts tend to be more flexible in using multiple representations in solving physics problems, as it opens up opportunities for the development of more effective problem-solving skills (Kohl & Finkelstein, 2008). By having access to various representations, students can broaden their thinking approaches to solving complex physics problems. Therefore, multiple representations are an effective tool for enhancing students' problem-solving abilities in physics learning.

Using multiple representations in physics learning provides significant opportunities to enhance students' representation skills. Referred to research (Aina et al., 2020; AM & Istiyono, 2022; Kurniasari & Wasis, 2021; Muzdalifah et al., 2019; Silaen et al., 2019; Siswanto, 2019), it found that using multiple representations play a significant role in addressing the challenges faced by students in understanding and representing physics concepts through various modes, including graphics and images. Learning models that adopt a multiple representations approach, such as Investigation Based Multiple Representation (IBMR), have proven successful in enhancing students' representation skills. The integration of multiple representations in the physics learning process can be considered an effective strategy to improve students' overall understanding of concepts and representation abilities.

Using multiple representations in learning not only impacts the understanding of physics concepts, problem-solving skills, and representation abilities but also can enhance students' critical thinking skills and overall cognitive abilities. However, there found a limited research specifically examining these abilities through the implementation of multiple representations in physics learning. Therefore, we recommend further researchers to be more extensively measure and evaluate the impact of integrating multiple representations in physics learning on students' critical thinking and cognitive abilities, as done by Abdurrahman et al. (2019) ; Nurussofi et al. (2022) ; Sapto & Sinaga (2022) . It provides a more comprehensive understanding of the benefits of using multiple representations to improve students' skills in understanding and applying physics concepts, and assisting in the development of more effective and holistic learning strategies.

The Challenge of Using Multiple Representations in Physics Learning

Based on the reviewed article, there found two main challenges commonly encountered when using various representations in physics learning. The primary challenge is the difficulty from researchers or physics educators in organizing representations in a structured and coherent manner. So, students can connect information from various sources and build cohesive understanding (Abdurrahman et al., 2019). Also, it needs to ensure that each representation supports student understanding without causing confusion or contradictions. Supported with research conducted by Davis (2006), new teachers in the field of science, including physics, face various challenges in teaching, such as difficulties in managing multiple representations and facilitating understanding of complex concepts for students.

The second challenge comes from students, namely the difficulty caused by their low ability to represent physics concepts, especially in numerical, graphical, and equation representations. Difficulty in understanding numerical, graphical, and equation representations of physics concepts can reduce students' interest and motivation in physics learning (Retno Safitri et al., 2020; Taqwa et al., 2020). This statement supports the findings stated by Bollen et al. (2017), which highlight students' difficulties in understanding symbolic and graphical representations of vector fields. These difficulties arise due to students used to use a specific

representation that is comfortable, without considers the advantages of using other representations that may be more appropriate for solving particular problems Kohl & Finkelstein (2008) (. This indicates that students have difficulty transferring information between various types of representations, such as from mathematical representations to other representations, which can negatively affect their learning interests. To address this challenge, there is a need for structured and consistent learning strategy development and training focused on the use of various physics representations by researchers, teachers, and students.

CONCLUSION

This study reviewed articles of using multiple representations in physics education from 2019 to 2023. Quantitative research dominated, with high school students as the main subjects and the topic of Waves as the focus. Multiple representations have the potential to improve students' understanding and skills, but also face challenges such as the construction of coherent representations. Understanding these trends and challenges is crucial to designing effective physics education with multiple representations from high school to university level. Limitations of current research include the focus on quantitative studies and the predominance of high school students as research subjects, which may limit the generalizability of findings across different educational levels. The lack of qualitative research of using multiple representations in physics learning suggests the need for future research to adopt a qualitative approach to gain deeper insights into the effectiveness of multiple representations in enhancing students' learning experience. In addition, future research could focus on addressing the challenges faced by educators and students in effectively using multiple representations in physics teaching, thus contributing to the development of more robust and inclusive educational practices.

ACKNOWLEDGMENTS

The author sincerely expresses gratitude to Lembaga Pengelola Dana Pendidikan (LPDP) Indonesia for funding the master's scholarship program under the Indonesian Domestic Education Scholarship.

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