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Multiple Representations in Physics Learning: A Bibliometric Analysis

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ABSTRACT
The application of multiple representation approach in physics learning has been adopted by several researchers, especially to improve the ability and achieve effective learning. The use of multiple representation approach in physics learning over the past few years has provided good results on student learning outcomes, including being able to improve and develop abstract physics concepts, scientific complex skills, metacognition skills, and problem solving. This research is the result of a review based on bibliometric analysis of multiple representations in physics learning. Data was obtained based on Scopus sources from 2013 to 2023, then obtained data as many as 121 articles which then the data was processed using RStudio and VOSViewer. Based on the results of the analysis using Rstudio and VOSViewer, it also displays other information such as year, country, author, institution, journal, co-word analysis, co-occurrence network, and visual density on occurrence. The results of this study provide a framework of the current trends of multiple representations in physics learning both in the present and some indicators that can be used as opportunities for future research.

INTRODUCTION

Physics is one of the many systematic fields of natural science that describes natural phenomena and scientists use complex mathematics to explain phenomena and use their theories with abstract symbols that are difficult to understand [1] [2]. There are also many problems that occur in the physics learning process, one of which is that some concepts are still abstract in physics and even complicated, which in solving them must involve complicated mathematics [1] [3]. In addition, everyone's ability to understand physics learning differs from one individual to another [4]. Problems that exist in the physics learning process, must be addressed immediately by using an approach or strategy that is in accordance with the existing problems, because if allowed to continue the abstract concepts will cause misconceptions in students. One that can be used to overcome these problems is to use multiple representations. In the physics learning process, students must be trained to have multiple representation skills [5]. Multiple representation is a process of approach in learning where in explaining the same concept using several representations such as (verbal, graphs, diagrams, images, numerical, and others) [1] [2] [5] [6] [7] [8] [9]. Multiple representations are an effective approach to develop abstract, complex scientific skills [1] [9] and also able to improve students' understanding of physics concepts [9] [10] [11], problem solving [12] and metacognition [13].

Several studies have shown that students' representation skills are one of the keys to success in improving problem solving skills [14]. As research has been conducted by Tri Isti Hartini, where she developed analytical mechanics courses based on multiple representations, with the help of the Geogebra application, the results of the research obtained that the course program that has been developed with the help of Geogebra and based on multiple representations is in the category of good enough. It's just that the research that has been done by Isti has limited shortcomings in analytical mechanics courses. Another study conducted by Prahani, where he examined the profile of students' multiple representation abilities in heat material, obtained the results of research that students' multiple representation abilities in heat material are still fairly low, so that the use of multiple representation-based learning is able to stimulate and train students' multiple representation abilities in learning, especially physics lessons, but in this study it has shortcomings, namely in this study only measuring three indicators, namely multiple representation abilities including verbal, mathematical, and visual. Another research conducted by Rettob where he conducted research related to student learning difficulties in understanding the concept of Lorentz force, the researcher used the MR-SR-based PIMCA learning model (Multiple representations - semiotic reasoning), however, there are weaknesses in this study where this article does not explain in detail about the PIMCA learning model based on MR-SR, then also does not present the data completely, and does not discuss the theoretical and practical implications of the research results.

In accordance with the problems that have been presented as well as the uses and benefits that have been done by many previous researchers on multiple representations, therefore the approach of using multiple representations in physics learning can be a bridge or solution in appropriate problems such as concept understanding, students' critical thinking, problem solving, and students' metacognition skills which are still a real problem in the physics learning process. With the use of multiple representations, students can do deeper learning, by going from one representation to another, which is able to develop the ability to translate observations, estimates, concepts and descriptions of a phenomenon that is still abstract [15]. In the approach of using multiple representations, there are three main functions including, first, to obtain additional information or assist existing and complementary cognitive processes, limit possible interpretations, and encourage students to better understand [1] [14].

Based on the discussion and description above, this research will focus on producing a Multiple Representation profile in physics learning based on bibliometric analysis using StudioR and VOSViewer. Research using bibliometrics was chosen because it has been proven effective to see the picture and profile of current and future research trends. This allows this article to summarize published information related to article distribution by year, country, author, institution, journal, co-word analysis. The main implication of this research is to contribute to physics learning, particularly the multiple representations approach to physics learning.

METHOD

The main method in this research uses the bibliometric analysis method [16] [17] [18] [19] [20] [21] [22] [23] [24]. In this study, the data collected was sourced from Scopus. In this article collection process focused on the time span from 2013 to 2023. Data collection for this article was collected on September 24, 2023, and the results obtained were 121 documents. The 121 documents obtained are the results using keywords (Multiple Representations and Physics Learning). In this study, Rstudio and VOSViewer applications were used. Rstudio [25] [26] [27] [28] [29] [30] and VOSViewer [31] [32] [33] [34] [35] [36] are used to analyze research trends on multiple representations in physics learning. The following is a flow of data collection and processing methods that have been carried out:

Fig 1*. Flow of Data Collection and Processing*

RESULTS AND DISCUSSIONS

Based on the results of a search conducted on Scopus which focuses on 2013 to 2023, using the keywords "Multiple Representation" and "Physics Learning", 121 documents were obtained, which were then processed using Rstudio and VosViewer. The results that have been processed using Rstudio show the results of one of them about publications on multiple representations in physics learning carried out throughout the last ten years, the following data obtained and processed using Rstudio as follows:

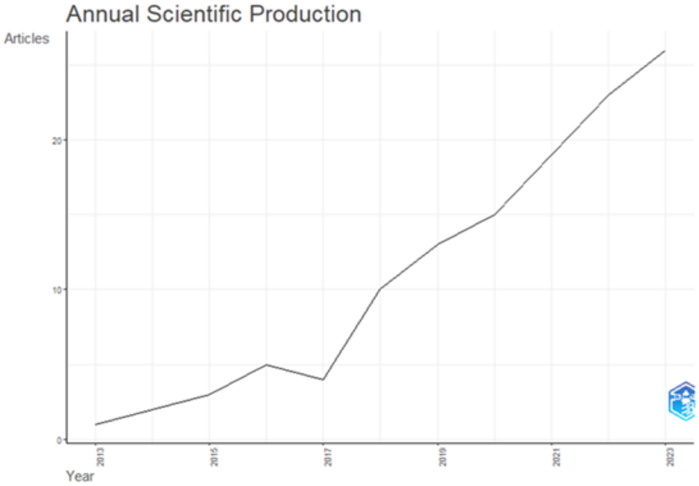

Fig 2*. Last Ten Years Publication Chart*

In Fig 2. A graph of the results of publications on multiple representations carried out over the past ten years shows that publications per year were 2013 (1), 2014 (2), 2015 (3), 2016 (5), 2017 (4), 2018 (10), 2019 (13), 2020 (15), 2021 (19), 2022 (23), and 2023 (26). So it can be seen together that there is an increase in publications every year, it just decreased in 2017, and again increased rapidly in 2023 resulting in 26 publications.

In Fig 3. is the result of data processing carried out by Rstudio, the image above is a map of the distribution of the most relevant publications related to multiple representations in physics learning, on the map the solid blue is a country that often publishes, and the light blue has publications but not as much as the dark blue. Here are the top ten countries that often make publications including the USA (141), Germany (75), China (55), Switzerland (20), Australia (18), Indonesia (14), France (11), South Korea (10), and the UK (9). So for now the country that has the most publications related to multiple representations in physics learning is the USA with 141 articles published.

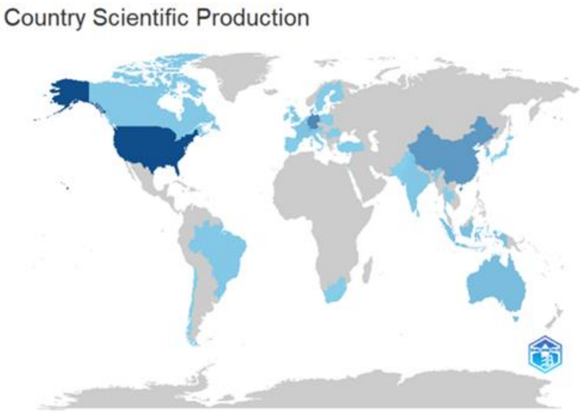

Fig 3*. Distribution Map of Most Relevant Country Publications*

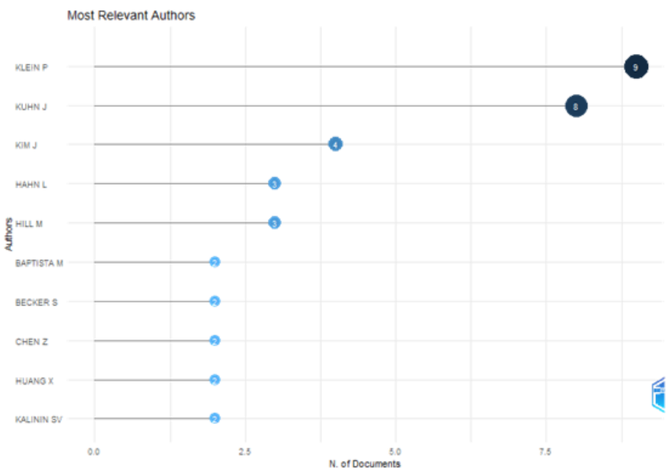

Fig 4*. Top 10 Relevant Authors Chart*

Based on Fig. 4 shows the top ten relevant authors, who often publish with the theme of multiple representations in physics learning, including Klein (9), Kuhn (8), Kim (4), Hanh (3), Hill (3), Baptista (2), Becker (2), Chen (2), Huang x (2), Kalinin (2). So we can see that for the last ten years the author who often conducts research related to multiple representations in physics learning is Klein with a total of 9 publications.

Fig 5*. Top 10 Relevant Affiliates Chart*

In Fig. 5 shows the most relevant affiliation chart, of course, affiliation is one of the contributors to publications in research on multiple representations in physics learning, in the figure above shows the top ten affiliations that have published, including Stanford University (17), Technische Universität Kaiserslautern (10), University of Göttingen (7), Nanjing University (6), Purdue University (6), University of Hong Kong (6), Curtin University (5), Florida Atlantic University (5), Fludan University (5), Korean Institute of Ocean Science you Technology (5). The above data is data obtained within the last ten years, so the relevant affiliation in publications related to multiple representations is occupied by Stanford University.

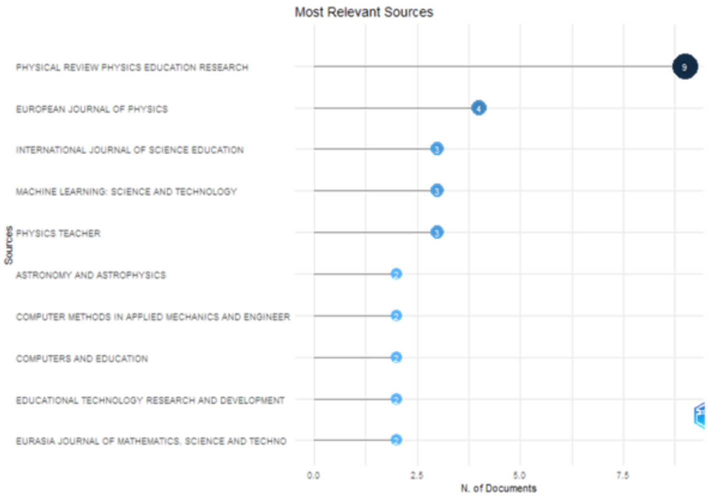

***Fig 6**. Top 10 Relevant Sources Chart*

Based on the above figure in Fig. 6, shows the top ten sources that have relevant publications about multiple representations, the data is taken in the last ten years, the results of relevant journals according to the keywords focused, the top ten relevant sources include Physical Review Physics Education Research (9), European Journal Of Physics (4), International Journal Of Science Education (3), Machine Learning: Science And Technology (3), Physics Teacher (3), Astronomy And Astrophysics (2), Computer Methods In Applied Mechanics And Engineering (2), Computers And Education (2), Educational Technology Research And Development (2), Eurasian Journal Of Mathematics, Science And Technology Education (2). So it can be seen that the source that has the most relevant publications is Physical Review Physics Education Research with a total publication of 9 articles.

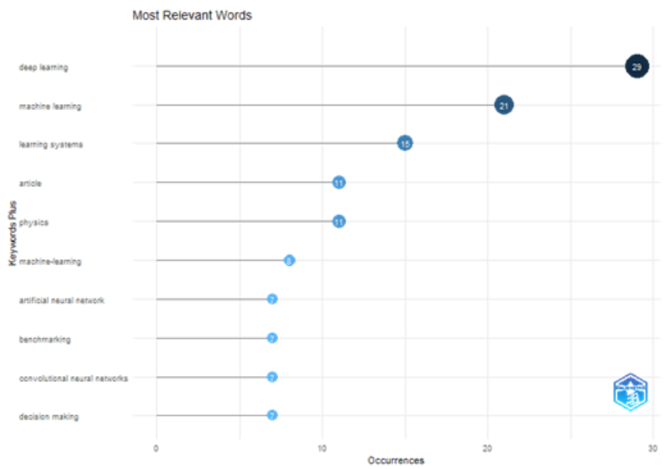

***Fig 7**. Top 10 Word Discovery Chart*

In Fig. 7 obtained results using Rstudio from 121 documents (Scopus) obtained the top 10 findings, among others: deep learning (29), machine learning (29), learning system (15), article (11), physics (11), artificial neural network (7), benchmark (7), convolutional neural networks (7), decision making (7). Furthermore, the data is visualized using RStudio as in the following figure:

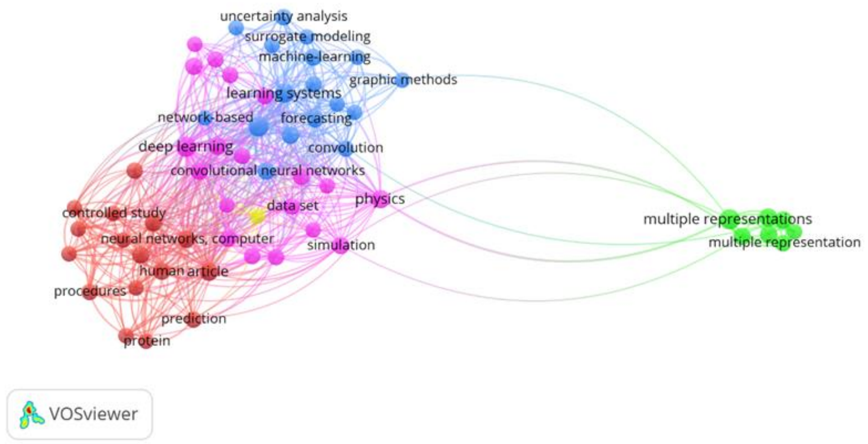

Fig 8. *Visualizing Multiple Representation Networks in Physics Learning*

In Fig. 8, shows an overview of research on multiple representations in physics learning over the past ten years. Researchers around the world produced five clusters, three major clusters (purple, blue, and red) and two minor clusters (green and yellow). The first purple cluster consists of machine learning, learning systems, machine learning, benchmarking, forecasting, complex networks, neural networks, uncertainty analysis, graph neural networks, classification (of information), data driven, graphic methods. The second cluster in blue obtained results including deep learning, article, physics, artificial neural networks, convolutional neural networks, neural networks, computer, brain, neural networks, brain, neural intelligence, convolution, deep neural networks, image enhancement, prediction, long short-term memory, network-based. The third cluster in red obtained results including decision making, reinforcement learning, learning algorithms, dynamics, then there is also the first minor cluster in green which consists of human, diagnostic imaging, male, procedures, algorithms, controlled study, and medical imaging, while the last cluster is yellow which consists of inverse problems, students, e-learning, multiple representation, and conceptual understanding. So we can see that in the word multiple representation there is a second minor, and can be used as a novelty in education.

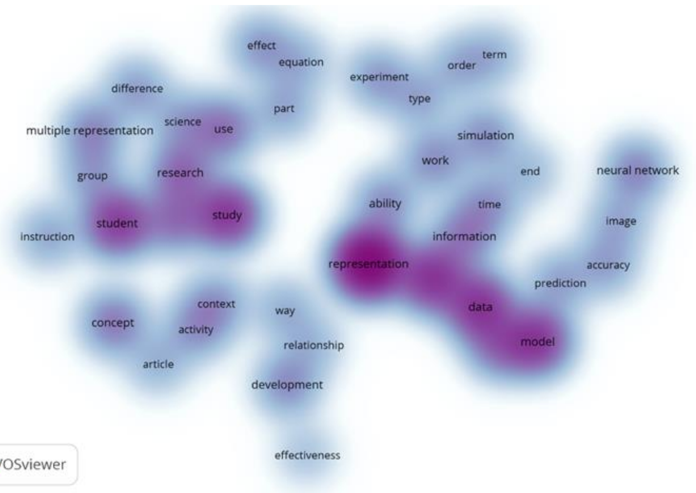

Fig 9. *Visual Density of Multiple Representations in Physics Learning*

Figure. 9 is a display of the density of multiple representations in physics learning, in the image that is solid purple has a dominant meaning or things that often appear or are most relevant to the existing keywords, namely multiple representations, words that often appear or dominant include representation, data, models, and study. As for the faded purple, it means that it still does not appear much in the focus of research, for words that do not appear too much include neural network, image, accuarcy, prediction, time, information, order, time, experiment, difference, multiple representation, group, instruction, article, activity, context, way, relationship, development, effectiveness, science, ability, work, relationship, use, equation, effect. So that based on the visual density that has been displayed above, the faded purple color can be used as a novelty for future researchers, especially for focusing on multiple representations in physics learning.

CONCLUSION AND SUGGESTION

Based on the results and discussion previously presented, using bibliometric analysis, with the keywords multiple representations and physics learning for the period 2013-2023, it was found that there were indications of several interrelated parameters between variables to see trends in multiple representations in physics learning. It was also found that in recent years multiple representations in learning have become one of the trends and options in the learning process in schools. This can be seen based on the results of publications and discussions on multiple representations in physics learning, where the results are able to improve students' ability to abstract, scientific complex abilities, student understanding, problem solving, and metacognition skills. The limitation of this research is that it is only sourced from Scopus. Further research is expected to involve other scientific data sources.

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