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Multiple Representation Approach in Elementary School Science Learning: A Systematic Literature Review

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Abstract. The paper investigates the multiple representation approach as used in elementary school science learning. A systematic literature review (SLR) method and preferred reporting items for systematic review and meta-analysis (PRISMA) protocol were employed in this research. This included systematic review stages, eligibility and exclusion criteria, review process procedures, and data abstraction and analysis assisted by Publish or Perish 7, VOSviewer, and NVivo 12 Plus applications. The search for publications on Scopus through the Publish or Perish 7 application yielded 605 publications, and for the ERIC database, there were 2018 publications, making 2623 publications. The publications were then filtered according to compatible themes and 50 were selected to be used as material for the SLR. The 50 publications were analyzed according to the assigned topics through the NVivo 12 Plus application, and the results are described in this paper. According to literature, multiple representations is a learning approach that involves using more than one or two representations. This is done by utilizing text, video, tables, audio, animation, diagrams, analogies, cartoons, movements, formulas, and graphs to reflect, interpret, and solve scientific problems in elementary science learning. The multiple representation approach is implemented through task assignment, visualization technology; representation of images, symbols, tables, pictures, and graphs; scientific investigations; engineering design; technological skills; applications; recordings; and written symbols. The impact that the multiple representation approach has in elementary science learning is an increase in reasoning skills, critical thinking skills, communication skills, solving of science problems, concern for nature conservation, and social and

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visual intelligence. This paper contributes to research examining multiple representations in elementary school science learning.

Keywords: elementary school; multiple representation approach; science learning

1. Introduction

Many studies have examined multiple representation learning approaches in science and mathematics learning in elementary school (Darmaji et al., 2020; Fatimah, 2017; Nurrahmawati et al., 2021; Opferman et al., 2017; Taher et al., 2017). However, among the research on multiple representation learning approaches, few have studied the topic systematically in elementary school science. Research on similar topics has been investigated, such as multimodality in natural science (Pantidos et al., 2021), problem-based learning (Batlolona & Souisa, 2020; Permatasari et al., 2019), cognitive and metacognitive learning (Tanti et al., 2020), and virtual learning (Rashid et al., 2020), yet multiple representation learning approaches have not been studied comprehensively.

Science learning using multiple representation models is maximal and guided in pedagogical performance. This means that there is still a need to integrate teachers' abilities in science learning based on a multiple representation approach. Multiple representation learning can maximize the development of conceptual understanding in learners (Altınbaş et al., 2023; Hasbullah et al., 2019). It has been suggested that learning science in schools is more accessible when multiple representations are employed, with learners being faster at connecting verbal, visual, and mathematical models to develop scientific knowledge, concepts, and processes (Bakar et al., 2020; Ibda et al., 2022).

Science learning that applies the multiple representation approach has an impact on many aspects. Research on 80 studies in the period 2000–2014 has indicated that science learning using multiple representations has an impact on multimedia principles, representational competence, learning strategies, and mental models. It also brings about a pedagogical shift from science instruction as information transmission to a constructivist approach because students are encouraged to build concepts and knowledge (Tippett, 2016). Recent research on science learning has shifted from a traditional cognitivist perspective to multiple representation learning in quality learning. The pedagogical practice developed refers to students' needs to explore representations in science learning (Flegr et al., 2023).

A preliminary analysis of thematic associations to the publications used in this study was done to strengthen the relevant research arguments using the VOSviewer application. The initial analysis of thematic associations (see Figure 1) shows that the multiple representation learning approaches have a very complex association pattern.

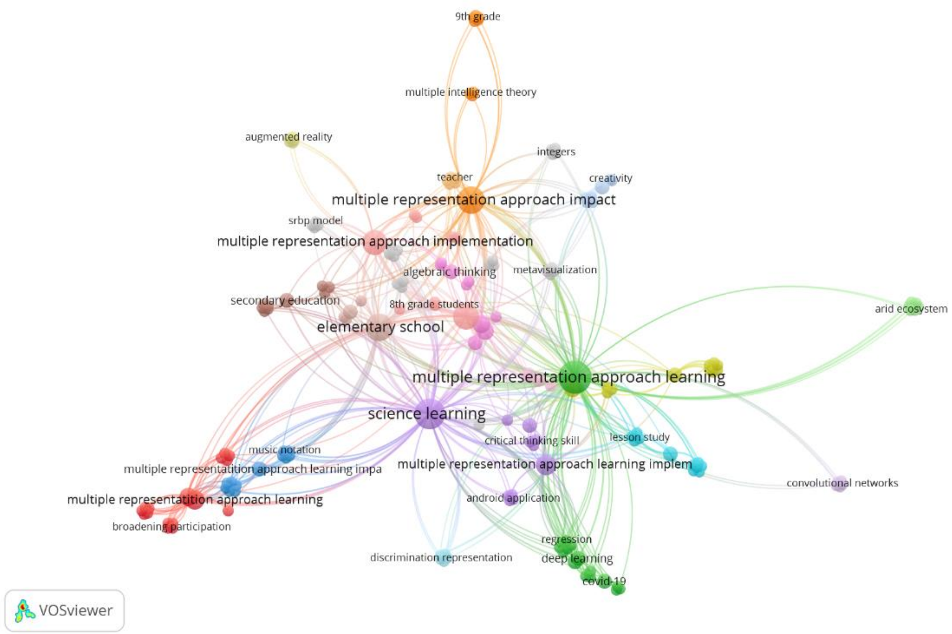

Figure 1: Initial network visualization

Figure 1 shows a network visualization related to the multiple representation learning approaches in relation to several other study topics that are connected directly or indirectly. These include multiple representation approach implementation, multiple representation approach impact, elementary school, android application, deep learning, broadening participation, inquiry-based learning, multiple intelligence theory, augmented reality, and other topics. The relationship between the study of multiple representation approaches and multiple representation approach impact, multiple representation approach implementation in science learning, multiple representation approach impact in science learning, and elementary school is direct and very close. This shows that the concept, performance, and implementation of the multiple representation approach needs to be studied in depth (Ainsworth, 2014; Sankey et al., 2011). Contrarily, the topics of convolutional network, deep learning, Covid-19, augmented reality, multiple intelligence theory, and ERIC ecosystem show indirect associations. This is because the studies did not investigate multiple representation learning approaches in depth, with further in-depth research thus being needed.

Learning more systematically about the multi-representational learning approach in elementary science is essential. This is because studies on the multi-representation concept, implementation, and impact in elementary school science learning are carried out minimally using SLRs. This is further strengthened by the trend of shifting from a monodisciplinary paradigm towards multidisciplinary and multimedia learning, with consequences on elementary school science learning (Abrosimova, 2013; Baker et al., 2021; Ktoridou et al., 2018; Lombardo, 2014; Mavrikios et al., 2019; Vogt et al., 2020).

This background generally delved into an overview of the multiple representation learning approach in elementary science learning by reviewing and analyzing publications using the SLR method. The expected result is to provide an overview of the concept of multiple representation learning approaches in elementary school science learning. To achieve this, the research asked the main research question: How is the current literature informed on the multiple representation approach in elementary school science? Specific research sub-questions were:

1. What is the concept of multiple representation approach learning?
2. How is the multiple representation approach implemented in elementary school science learning as per the selected publications?
3. How does the multiple representation approach impact elementary school science learning as per the selected publications?

2. Literature Review

2.1 Multiple Representation Approach

A multiple representation approach is an approach that emphasizes several points of view of meaning in the form of verbal representations, images, diagrams, equations, tables, and graphs. Multiple representations can be integrated into several models, media, strategies, and learning methods (Danday, 2023; Gao et al., 2022; Xu et al., 2021). There are three representational constructions to succeed in science learning in schools (Chung & Pan, 2023; Davis & Dunn, 2023; Zhao et al., 2022). The first construction is semiotic – the use of features from symbolic and material tools of participants in constructing meaning in science. The second is epistemic – which relates to a broader picture of the practice of building knowledge of inquiry in one discipline area. The last representational construction is epistemological – that is, how and what students understand through their participation in the challenge to represent causal relations.

Research in Denmark has shown that the development of a start-up didactic design through digital multimodel representation increases student productivity in learning and science culture (Anderson & Munksby, 2018). This approach invites students to build visual models of biological material. They solve the problems that occur when drawing. Students experience five primary constructs from this process: affective, behavioral, cognitive, subjective norm, and action control (Scherb & Nitz, 2020). Multiple representation learning impacts students' skills in constructing and interpreting science texts. The role of the teacher, here, in learning is to guide the student in building their model of the science text (Fatmawati et al., 2022, 2023).

2.2 Multiple Representation Approach in Elementary Schools

The multiple representation approach or multiple modes of representation can be implemented in elementary schools through images, science conventions, and communication in visual representations. Using this approach, students can build meaning related to the specific scientific topic, for example, the structure and function of carnivorous plants. This approach assists students in the epistemic practice of drawing for science communication (Wilson & Bradbury, 2021). Research in Brisbane, Australia on 248 students from 26 Grade 6 classes in 9 elementary schools concluded that learning that directs the interpretation of science representation is essential when students want to reason scientifically. The students learn to communicate understanding in science (Gillies et al., 2015). A multiple representation approach (models, graphs, diagrams, text, etc.) can improve students' coding and reasoning skills for representation, achievement, and knowledge attainment in science (Huang & Bo, 2023; Hubber, 2017; Watts et al., 2022).

A professional development program for elementary school teachers is designed through increasing skills in developing a multi-representation approach that begins with planning, guaranteeing pedagogical aspects, developing quality learning ideas, and improving pedagogical practice through representational learning (Benedetič, 2018; Hubber & Preston, 2021; Hubber & Tytler, 2017). Applying a multiple representation approach enables teachers to communicate detailed information to students, interrogate understanding, and challenge student thinking. As a result, students are more focused on using primary and scientific language, and spend time focusing on completing tasks, which is an indicator of the success of science learning (Gillies & Baffour, 2017).

3. Methodology

3.1 Research Design

An SLR was used as research method for this study. The goal was to describe the concept, implementation, and impact of the multiple representation approach regarding learning in elementary science (Ibda, Syamsi, & Rukiyati, 2023). The study used the preferred reporting items for systematic review and meta-analysis (PRISMA) method (Ibda, Wulandari et al., 2023; Santhanasamy & Yunus, 2022). This section discusses the methods applied to report on the concept, implementation, and impact of multiple representation approach learning in elementary school science learning. The PRISMA method in this study used Scopus and ERIC databases to run systematic reviews, eligibility and exclusion criteria, review process procedures (identification, screening, eligibility), and data abstraction and analysis (Kusmaryono & Maharani, 2022; Mohd Rashid & Wong, 2023; Nizhenkovska et al., 2022).

3.2 Inclusion and Exclusion Criteria for Selection of Publications

We set specific criteria for including publications in the study. First, the publication had to be written in English. Second, articles had to be published in international journals and conference proceedings in international seminars, have gone through a review process, published between January 2018 and December 2022, and indexed by Scopus and ERIC databases. Third, Scopus-indexed publications were searched using the Publish or Perish 7 application and ERIC-indexed publications on their website. Fourth, the publications were searched only according to the research theme based on keywords. Fifth, editorial materials, books, or book chapters were excluded from the analysis.

3.3 Screening and Eligibility Assessment for Data Analysis

The results were filtered on the Scopus and ERIC databases by eliminating publications with similar topics. Furthermore, the publications were filtered according to the title, abstract, and keywords. Tags were screened because they are relevant according to the keywords applied. The abstract of each publication was read when selecting publications according to the inclusion and exclusion criteria. Keywords in each publication were copied to be incorporated into Mendeley and VOSviewer for initial network mapping. This action is supported by research stating that the abstract and keywords of the publication are read to determine the relevance of the research topic (Santhanasamy & Yunus, 2022; Xiao et al., 2019). The two databases (Scopus and ERIC) yielded 2623 publications. Publications were then selected according to the theme of the multiple representation learning approach in elementary science. After similar publications were eliminated, 214 pieces remained, with further screening bringing the number down to 112 publications. This number was further decreased by including only full publications (89) and then only those with themes studied in qualitative synthesis (70). Lastly, we were left with 50 publications, which were analyzed using the NVivo 12 Plus application by research questions. The keywords used to find relevant publications on the two databases can be seen in Tables 1 and 2.

Table 1: Keywords used to find relevant publications in the Scopus database

No.	Keyword	Year of publication	Quantity
1	Multiple representation	2018–2022	200
2	Multiple representation learning	2018–2022	200
3	Multiple representation approach learning	2018–2022	200
4	Multiple representation approach in elementary school science learning	2018–2022	5
	Total		**605**

Table 2: Keywords used to find relevant publications in the ERIC database

No.	Keyword	Year of publication	Quantity
1	Multiple representation	2018–2020	483
2	Multiple representation	2021	138
3	Multiple representation	2022	26
4	Multiple representation learning	2018–2020	256
5	Multiple representation learning	2021	77
6	Multiple representation learning	2022	14
7	Multiple representation approach in elementary school science learning	2018–2020	256
8	Multiple representation approach in elementary school science learning	2021	679
9	Multiple representation approach in elementary school science learning	2022	89
	Total		**2018**

3.4 PRISMA Flow Diagram

Themes and subthemes were identified in the 50 publications. Furthermore, the title, abstract, keywords, method, results, and conclusion of all selected publications were studied and examined. Flow analysis applies qualitative content analysis using the NVivo 12 Plus application. The themes were identified in the 50 publications related to the multiple representation learning approaches in elementary school science learning, which were then presented in the form of narratives. Next, we organized the subthemes around the central themes established by each typology. We applied thematic analysis to identify findings from previous studies by grouping findings according to relevance and categorizing them (Adams et al., 2021; Rahman et al., 2021). The flow diagram of the study was adapted from Moher, which can be seen in Figure 2.

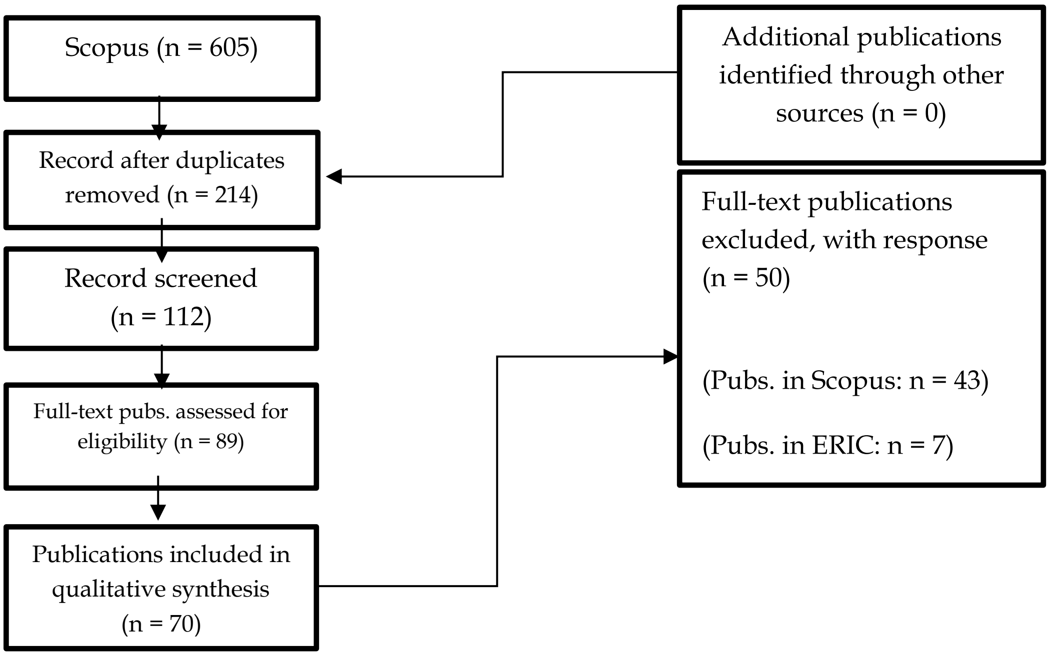

Figure 2: PRISMA flowchart for systematic review

Generally, the primary learning elements, namely the multi-representation approach and learning science in elementary schools, emphasize more than one or two representations. This is manifested using text, videos, tables, animations, audio, diagrams, analogies, cartoons, and other methods. The results will be explained in detail based on the three research sub-questions. Before presenting the qualitative results, it is necessary to present an overview of the selected publications based on the type of publication, author/s, methodology employed, and database it was retrieved from (see Table 3). The table also indicates to which research sub-question (RQ) the publication is relevant, namely 3.1) multiple representation approach learning concept; 3.2) multiple representation approach implementation in elementary school science learning; and 3.3) multiple representation approach impact on elementary school science learning.

Table 3: Overview of the 50 selected publications

No	Issue type	Methodology	Database	RQ
1	*International Electronic Journal of Mathematics Education* (Afriyani et al., 2018)	Qualitative explorative methods	Scopus	3.2
2	*Journal of Physics: Conference Series* (Bakri & Muliyati, 2018)	Research and development	Scopus	3.1
3	*Journal of Educational Computing Research* (Hsu et al., 2018)	Mixed-method case study	Scopus	3.2
4	*Journal on Mathematics Education* (Kusumaningsih et al., 2018)	Quasi-experimental study	Scopus	3.1
5	*Computers & Education* (Dasgupta et al., 2018)	Exploratory case study	Scopus	3.2
6	*Canadian Journal of Learning and Technology* (Gebre, 2018)	Descriptive case study	Scopus	3.1
7	*International Electronic Journal of Elementary Education* (Kara & Incikabi, 2018)	Case study method	Scopus	3.2
8	*Jurnal Pendidikan IPA Indonesia* (Sunyono & Meristin, 2018)	Factorial design	Scopus	3.3
9	*International Journal of Evaluation and Research in Education (IJERE)* (Kartikasari et al., 2018)	Quasi-experimental investigation	Scopus	3.2
10	2018 IEEE International Conference on Robotics and Automation (ICRA), May 21–25, 2018, Brisbane, Australia (Sermanet & Hsu, 2018)	Self-supervised approach	Scopus	3.1
11	Mathematics Education Research Group of Australasia (Ngin, 2018)	Exploratory research and analysis	ERIC	3.1
12	*Science Education International* (Kurnaz & Bayri, 2018)	Descriptive and qualitative research	ERIC	3.1
13	*Computers & Education* (Wu et al., 2019)	A quasi-experiment	Scopus	3.1
14	*Journal of Turkish Science Education* (Abdurrahman et al., 2019)	Quasi-experimental research	Scopus	3.3
15	*International Electronic Journal of Mathematics Education* (Alkhateeb, 2019)	Content analysis approach	Scopus	3.2
16	CoNECD 2019 – The Collaborative Network for Engineering and Computing Diversity, Crystal City, Virginia (Nche et al., 2019)	Experimental research	Scopus	3.2
17	*Jurnal Pendidikan IPA Indonesia* (Susilaningsih et al., 2019)	Descriptive-qualitative method	Scopus	3.3
18	*Journal of Experimental Education* (Azaryahu & Adi-Japha, 2020)	Experimental research	Scopus	3.1
19	*IEEE Transactions on Medical Imaging* (Kang et al., 2020)	Proposed and compared method	Scopus	3.3

No	Issue type	Methodology	Database	RQ
20	*International Journal of Geo-Information* (Han et al., 2020)	Experimental method	Scopus	3.1
21	ASEE Annual Conference and Exposition, Conference Proceedings, June 22–26, 2020 (Singleton et al., 2020)	Examining method	Scopus	3.1
22	*Frontiers in Marine Science* (Chabanet et al., 2018)	Design-based research	Scopus	3.3
23	*Computers in Biology and Medicine* (Amyar et al., 2020)	Descriptive research	Scopus	3.3
24	*International Journal of Science Education* (Åhman & Jeppsson, 2020)	Larger project method	Scopus	3.2
25	*CBE – Life Sciences Education* (Hansen & Richland, 2020)	Survey method	Scopus	3.1
26	*AIP Conference Proceedings* (Herawati et al., 2020)	Quasi-experiment	Scopus	3.3
27	*Sustainability* (Cai et al., 2020)	Quantitative method	Scopus	3.3
28	*Applied Intelligence* (Zheng et al., 2020)	Deep canonical correlation analysis (CCA)-based method	Scopus	3.1
29	*Computer-Supported Collaborative Learning Conference (CSCL)* (Danish et al., 2020)	Analysis and interview method	Scopus	3.1
30	*Acta Didactica Napocensia* (Yusuf, 2020)	Descriptive research	ERIC	3.3
31	*Journal of Science Learning* (Eliyawati et al., 2020)	Descriptive research	ERIC	3.2
32	*LUMAT: International Journal on Math, Science and Technology Education* (Mohamed et al., 2021)	Systematic review	Scopus	3.2
33	*International Journal of Science Education* (Tytler et al., 2021)	Design experiment methodology	Scopus	3.1
34	*Investigações em Ensino de Ciências* (Nunes Bica & Roehrs, 2021)	Systematic investigation and action research	Scopus	3.2
35	*Journal of NeuroEngineering and Rehabilitation* (Olsson et al., 2021)	Experimental research	Scopus	3.1
36	*Education Sciences* (Conceição et al., 2021)	Systematic investigation	Scopus	3.2
37	*International Journal of Progressive Education* (Çetin et al., 2021)	Quantitative research method and the study group	Scopus	3.1
38	*Exceptionality: A Special Education Journal* (Lee & Shin, 2021)	Evaluation research	Scopus	3.2
39	*European Journal of Educational Research* (Suryandari et al., 2021)	Mixed-method research (quantitative and qualitative)	Scopus	3.1
40	*International Education Studies* (Masmali & Alghamdi, 2021)	Quantitative method	ERIC	3.3

No	Issue type	Methodology	Database	RQ
41	*Education Quarterly Reviews* (Aydeniz, 2021)	Qualitative research	ERIC	3.3
42	*Acta Didactica Napocensia* (Erdoğan et al., 2021)	Quantitative research	ERIC	3.1
43	*Pegem Journal of Education and Instruction* (Priyanto & Dharin, 2021)	Qualitative approach	ERIC	3.3
44	*EURASIA Journal of Mathematics, Science and Technology Education* (Munfaridah et al., 2021)	Systematic review	Scopus	3.1
45	*Science Education* (Chang, 2021)	Qualitative approach	Scopus	3.1
46	*International Journal of Instruction* (Chusni, 2022)	Pre-experiment method	Scopus	3.3
47	Proceedings of the 5th International Conference on Current Issues in Education (Pebriana et al., 2022)	Descriptive study	Scopus	3.3
48	*Research in Science Education* (Nielsen et al., 2022)	Interpretive approach	Scopus	3.1
49	*Participatory Educational Research (PER)* (Nur et al., 2022)	Design-based research	Scopus	3.2
50	*EURASIA Journal of Mathematics, Science and Technology Education* (Sibgatullin et al., 2022)	Systematic review	ERIC	3.3

5. Discussion

5.1 Multiple Representation Approach Learning Concept

Several experts in the selected publications referred to multiple representations as learning approaches, models, and strategies. However, many asserted that multiple representations is a different approach to learning with one or two representations. Using multiple representations aims at improving learning outcomes better than a single representation. This is because of abstract information in different types or examples of representation. However, a disadvantage of this approach is that it can incur more costs than a single representation (Azaryahu & Adi-Japha, 2020). Multiple representations learning is an approach or learning strategy that utilizes text, animation, diagrams, graphs, audio, tables, videos (Sermanet & Hsu, 2018), and pictures (Han et al., 2020) in learning physics or science in general. This approach invites students to reflect on, interpret, and solve science problems (Bakri & Muliyati, 2018).

Representation involves processes and products. The so-called processes concern the internal thinking in the minds of teachers and students when working with representations. Concerning the product, representation in learning refers to external forms of representation, such as graphs, diagrams, and symbols. Representation can thus be seen as a means of communicating ideas of science or mathematics (Ngin, 2018). The scope of multiple representations takes the form of models, spaces, symbols, and visuals to achieve the purpose of science learning epistemically (Chang, 2021).

As an approach, multiple representations is conceptually built to code the systems of thinking and mechanical reasoning, because the value of systems thinking becomes a cross-cutting concept in science that describes the level of phenomena in science represented by students (Danish et al., 2020). Multiple representations is an approach that refers to the use of different visual tools, texts, and diagrams and means data and ideas that illustrate phenomena in science learning. Several scientists have proposed multiple representation learning to apply infographic-based instruction in various disciplines for thorough student understanding (Gebre, 2018; Zheng et al., 2020).

Science learning, such as biology, is a field of study that is not just a set of separate facts but a complex system of equally relevant concepts. As such, biology learning must be integrated according to the purpose of science by building multiple representations through animations, visuals, images, or diagrams (Hansen & Richland, 2020). Before the prospective students of elementary school teachers learn science, they are conceptually provided with an understanding of the theory and techniques of multiple representations, science learning media, practicum reports, learning performance, and completion of science projects and logbooks. According to Suryandari et al. (2021), multiple representations in learning science can help to interpret data using graphs, tables, etc. and build the relationship with the concept of science. In didactic anthropological theory, multiple representation-based learning supports teachers in conditioning the classroom and improves students' understanding of the concepts teachers teach (Kurnaz & Bayri, 2018).

The multiple representation approach or strategy consists of the stages of orientation, exploration, internalization, and evaluation in learning (Kusumaningsih et al., 2018). Teaching science, especially physics, is very challenging. The teacher must master the concept of the multiple representation approach with learning references that apply different representation modes, such as text, formulas, simulations, graphics, analogies, cartoons, diagrams, movements, physical 3D models, and 2D images (Wu et al., 2019), to communicate scientific concepts in science (Munfaridah et al., 2021).

Multiple representations should be applied through product-based multimedia aspects (such as online searches, websites accessed, paper notes, artifacts, images) and digital explanations as products (video recordings, audio, photos) of the diverse student knowledge construction process (Nielsen et al., 2022; Singleton et al., 2020; Tytler et al., 2021). Multiple representations is a deep-learning approach, assigning multiple tasks according to the chosen representation and inviting students to represent according to their abilities (Olsson et al., 2021). Baker et al. (2021) concluded that multiple representations is a holistic approach applying graphical, verbal, and tabular representations.

5.2 Multiple Representation Approach Implementation in Elementary School Science Learning

Students' understanding of science and mathematics material can be increased by providing multiple representation tasks that are strengthened with flexible subject matter (Afriyani et al., 2018). Science learning is strongly supported by the role of multiple representations and visualization technology. This approach allows students to study more deeply the concept of science by making products that are not too visible (Åhman & Jeppsson, 2020). The multiple representation approach is implemented through the representation of images, symbols, models, and audio, which can be practiced by teachers in science and mathematics learning and model representation (movement from model to number mode) (Alkhateeb, 2019; Kara & Incikabi, 2018).

Multiple representations can be used as an evaluation system from the perspective of studying skills, interpreting from the aspect of the representation of tables, graphs, and drawings (Çetin et al., 2021). Several studies have indicated that applying multiple representations helps students conceptualize scientific concepts/theories in science. It helps students to understand real-life conditions and everyday phenomena. Multiple representation learning invites students to learn scientific ideas and abstract images with objective reality, impacting the science concepts students build (Conceição et al., 2021). According to Dasgupta et al. (2018), multiple representation learning helps teachers and students develop science inquiry, mathematical reasoning, engineering design, and technology skills.

Learning science through the multiple representation approach improves when supported by applications such as SmartChem to explain several acid-base chemical representations. The scope of student representation is constructed through symbolic, macroscopic, and submicroscopic representations of acid-base matter (Eliyawati et al., 2020). Hsu et al. (2018) explained that at the elementary level, multiple representation learning can be integrated with contextual, multimodal, and interactive augmented-reality approaches. Applying multiple representations is easier when utilizing science-based science, technology, and society textbooks in elementary schools (Kartikasari et al., 2018).

In inclusive education, technically, the teaching of children with disabilities requires a relevant approach, that is, multiple representations. This is because it adapts textbooks and teaching materials according to learners' representational needs through use of diagrams, videos, recordings, images, and more in classical and individual learning (Lee & Shin, 2021). The multiple representation approach must accommodate students' different levels of understanding of representation. The approach does not include only representations of elements, such as manipulative tools, oral aspects, written symbols, pictures, and real-world situations, but also the interactions between components in the learning process (Mohamed et al., 2021).

Multiple representation-based learning supports the learning needs of many students concerning age and grade in elementary school. Multiple representations learning helps students learn to understand concepts with a direct approach to the objects represented by students (Nche et al., 2019). Applying multiple representations in elementary science learning makes evaluation easier for teachers because of thorough student understanding. Nunes Bica and Roehrs

(2021) explain that this impacts the assessment practices developed during the teaching-learning process, as assessment is not done at the end of learning only. Multiple representation learning has an impact on students' ability to build and apply concepts to various problems (Khaizaar & Hidayat, 2022).

5.3 Multiple Representation Approach Impact on Elementary School Science Learning

Multiple representations is an approach used to improve the reasoning ability of learners through the activity of creating images to find representations related to ideas, reflections, and judgments. Images serve to inform the reasoning, communication, and critical thinking skills of elementary school students in learning science (Abdurrahman et al., 2019). Using multiple representations also impacts the multi-tasking of students positively. Information provided by the tasks can improve the performance of students and how they handle problems (Amyar et al., 2020).

Research at five elementary schools in New Caledonia has shown that multiple representation learning through images has an impact on children's understanding of compound sociocultural profiles, reflects on nature and the marine environment, and provides children with hands-on experience to care for coral reefs. This impacts environmental education and conservation and incites students to care more about nature (Chabanet et al., 2018). Referring to Gardner's 1999 theory of multiple intelligences, the application of multiple representations supports the achievement of multiple intelligences. This can be seen in the profile of student curriculum intelligences, for example mathematical or science-based intelligence, social intelligence (interpersonal), and visual intelligence (spatial) (Aydeniz, 2021). Similarly, multiple representations simultaneously explores ecosystem responses to natural, climate, and weather changes because it looks at it from multiple perspectives (Cai et al., 2020).

The multiple representation approach impacts students' ability to understand science concepts. Through representations with graphs, tables, diagrams, or drawings, students are helped to understand the material and solve science problems (Chusni, 2022). According to Priyanto and Dharin (2021), the development of creativity of elementary school students in Indonesia is said to be influenced by the learning process supported by the multiple representation approach applied by teachers to achieve educational goals through student involvement in learning. Multiple representation learning by integrating inquiries supports electrochemical learning in students due to increased critical thinking skills (Herawati et al., 2020).

Furthermore, multiple representation learning invites students to explore the information in complete and various types of materials. Student knowledge advancement is significantly achieved when teachers implement multiple representations. This approach has the disadvantage of not guaranteeing that the information and material structure delivered by the teacher are complete (Kang et al., 2020). The impact of digitalization on learning should make teachers rethink the implementation of multiple representations for elementary students.

Although online learning is very flexible, making students independent, active, and interactive, it has adverse effects (Masmali & Alghamdi, 2021).

In science learning, especially physics, multiple representation-based learning is recommended because it improves students' dual representation ability. This is done through natural-phenomena video-analysis activities, concrete virtual learning, simulation, and utilization of android applications (Pebriana et al., 2022). This approach improves students' writing skills and reasoning development (Sibgatullin et al., 2022). Multiple representations learning has a greater impact on students' understanding of chemical bonding than the discovery and problem-based learning models (Sunyono & Meristin, 2018). The multiple representation approach supported by suitable teaching materials has the ability to produce excellent students, as it helps students to solve chemical problems more easily (Susilaningsih et al., 2019). Using multiple representations is very important in learning complex chemical concepts, because they are very effective in helping students understand these concepts (Yusuf, 2020).

Based on the discussion above, this research differs from other recent studies which did not use and study multiple representations in elementary schools. These include research on 3D multiple representations with M3DETR (Guan et al., 2022), representation learning on multiple family quantile regression material (Feldman et al., 2023), and multimodal representation and correlation learning (Mai et al., 2023). Our findings provide a more comprehensive concept because it discusses the approach, implementation, and impact of multiple representations in elementary school science learning. The findings of this paper can thus be used as a conceptual framework for implementing multiple representations in elementary school science learning.

6. Conclusion

Multiple representations is a learning approach that uses more than one or two representations by utilizing text, video, tables, audio, animation, diagrams, analogies, cartoons, movements, formulas, and graphs to reflect, interpret, and solve science problems. In elementary science learning, the multiple representation approach is employed in assigning tasks; visualization technology; representation of images, symbols, models, audio, tables, drawings, and graphics; science investigations; engineering designs; technological skills; applications; recordings; written characters; and others. Applying multiple representation approaches in elementary science learning has the impact of improving students' reasoning, critical thinking, and communication skills; solving of science problems; concern for nature conservation; social and visual intelligence; and other skills. The novelty of this article is that it confirms that the concept of multiple representations can be implemented in elementary school science learning and positively impact reasoning, critical thinking ability, and scientific problem-solving.

7. Limitations and Recommendations

This study was limited to multiple representation learning in elementary schools as reviewed from literature indexed by Scopus and ERIC databases only. This study was also limited to publications between 2018 and 2022. This study did not review literature that presents multiple representation learning in elementary schools which is more comprehensive in all levels of learning. Future research can examine multiple representation learning approaches in elementary science according to close themes that have rarely been studied. The topic reviewed in this study is still being researched by researchers and elementary school teachers to improve student learning.

8. References

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