

 Review Article

Enhancing Science Literacy in Secondary School Physics: A Systematic Review of Multimedia Integration Strategies and Resources

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Abstract

Empirical research shows that multimedia can be used to enhance science literacy through developing high-level cognitive skills such as problem-solving, hypothesis testing, decision making, self-reflection, and critical and creative thinking among students. This is a systematic review that aimed at exploring the common instructional designs and resources used when integrating multimedia in secondary school physics teaching, to enhance science literacy. The review involved a critical search of relevant studies from three scientific databases, including Dimension, EBSCOHOST, and Scopus. Manual search was also involved in the study. The search was limited to research articles published between January 2020 and May 2024. 1121 publications were identified by literature search. 243 publications were screened, whereby 66 of them were sought for retrieval. 27 publications were assessed as eligible for the study. Finally, 7 publications were found most relevant for inclusion in the study. The review found out that the instructional designs employed include: integration of virtual laboratories with traditional demonstration methods; integration of PBL with e-learning tools; integration of inquiry-based instruction with virtual simulations; integration of traditional methods with simulations; and integration of traditional lab, virtual lab, and simulations. Apart from desktop computers and projectors which have been noted to have been included in the studies, also multimedia tools like virtual laboratories, simulation software, and interactive multimedia applications have been identified. Therefore, in order to enhance science literacy in physics teaching, multimedia needs to be integrated with actual practical works to bridge the gap between theory and practice. Additionally, integrating multimedia learning with innovative pedagogies such as project-based learning (PBL) and inquiry-based instruction is effective for developing science literacy. Finally, it is important to incorporate collaborative learning and discussions when teaching with multimedia.

Keywords: Instructional Design, Physics Education, Multimedia Integration, Science Literacy, Science Education, Educational Technology

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1. INTRODUCTION

Developing science literacy among secondary school students stands as a fundamental goal of physics education. This literacy entails not only comprehending scientific concepts but also engaging in scientific reasoning, and applying acquired knowledge to real-world scenarios (OECD, 2019). Scientifically literate students are anticipated to exhibit curiosity, problem-solving skills and critical thinking abilities (Davies & Priestley, 2017). However, many students encounter difficulties in grasping complex physics concepts and fail to perceive the subject relevance in their daily lives (Wider & Wider, 2023). This challenge

has prompted educators and researchers to explore innovative teaching approaches capable of enhancing student engagement and deepening their understanding of scientific principles.

One promising strategy is the integration of multimedia technologies into physics instruction. Multimedia, characterized by the combination of text, audio, images, animations, and interactive elements, has the potential to create more dynamic and immersive learning experiences (Mayer, 2014). With the advancing technology, schools have been equipped with technological tools both software and hardware, thereby creating a conducive environment for multimedia integration in physics teaching and learning (Abdulrahman et al., 2020; Ngeze, 2017). By leveraging multimedia resources and tools, educators can address the diverse learning preferences of students, visualize abstract concepts, and foster active engagement in the learning process. Several studies have revealed that, since multimedia is multisensory stimulating multiple senses while allowing visualization of abstract concepts, it motivates students by raising their interest, enhancing understanding of complex concepts, and increasing memorability (Abdulrahman et al., 2020; Delima, Warsono, Supahar, & Jumadi, 2018). Multimedia integration into instruction has been associated with the development of the 21st century skills. Lambert and Cuper (2008) assert that the use of active learning multimedia tools engages students in using 21st century skills and provides a variety of creative, digital-age reflection opportunities. Through the use of multimedia students are actively involved in investigating and discovering concepts, analyzing problems, discussing and communicating ideas, read and write reports as results of their observations and findings (Bron & Barrio, 2019). Multimedia can enhance a person's level of cognitive skills including decision making, hypothesis testing, problem-solving, evaluation, self-reflection, as well as critical and creative thinking (Sudarsono et al., 2022).

With the growing interest in multimedia integration in physics education, several studies have focused on exploring the multimedia strategies in education including Mayer (2020) and Plass et al., (2019). However, few have specifically examined the role of multimedia promoting science literacy for sustainable development. Science literacy is crucial for fostering informed decision-making and empowering individuals to address global sustainability challenges (UNESCO, 2017). The instructional process on multimedia should also take into account the available multimedia tools and resources. Limited studies have shown the best instructional design in relation to the available multimedia facilities, therefore, there is a need for a comprehensive review of the existing literature to better understand the instructional designs and multimedia resources employed, and their impact on the development of science literacy.

This systematic review aimed at addressing this gap by synthesizing the current evidence on the use of multimedia integration in secondary schools' physics education. The review is guided by two key research questions:

1. What instructional designs are commonly used in a physics classroom that involve multimedia integration in secondary schools, to develop science literacy?
2. What types of multimedia resources and tools are commonly used in secondary schools' physics education and how are they integrated into teaching?

By addressing these research questions, this review provides valuable insights into effective approaches for leveraging multimedia technologies to promote science literacy among secondary school students. The findings inform the development of evidence-based practices and guide educators, instructional designers, and policymakers in their efforts to enhance physics education and foster scientific understanding.

2. METHODS

The systematic review was conducted in a transparent manner to establish various evidences from several studies regarding the integration of multimedia in physics teaching to enhance science literacy. According to Pollock and Berge (2018) a systematic review includes identification of primary research studies and critical assessment and synthesis of studies that meet the eligibility criteria with the aim to bring evidence together to answer a pre-defined research question. In analyzing the common instructional designs and resources used when integrating multimedia in secondary school physics teaching to enhance science literacy, consideration was on both qualitative and quantitative empirical studies. The review was made following seven steps of systematic review as suggested by Evidence for Policy and Practice Information and Co-ordinating Centre (2010).

The first step was the development of inclusion criteria. In the context of this review, the consideration was based on the following:

- Inclusion of original articles focusing on multimedia integration in physics
- teaching to enhance science literacy. Published reports and review papers were
- excluded;
- Inclusion of articles only in English language and from the field of education,
- curriculum and pedagogy were included;
- Inclusion of articles published between 2020 to 2024; and
- Inclusion of peer reviewed journal articles.

The second step was searching for studies relevant to the topic. The critical search of relevant studies was conducted from three scientific databases and manual search. The databases included Dimension, EBSCOHOST and Scopus. The search was limited to research articles published between Jan, 2020 and May 2024. A search with specific keywords was carried out from mentioned scientific databases to obtain relevant research articles related to multimedia integration in science teaching to enhance scientific literacy in secondary schools. The search terms used included “science literacy” OR “physics education” OR (multimedia or simulation or animation) integration, secondary OR elementary school, teaching strategies OR instructions. The initial search yielded 1121 references of which the elimination of 57 duplicates was carried out, 821 marked as ineligible by automation tool, 177 were excluded after title and abstract scanning, 39 publications were not retrieved, and 20 studies were excluded because of other reasons which resulted in 7 articles representing multimedia integration in secondary school physics teaching to enhance science literacy.

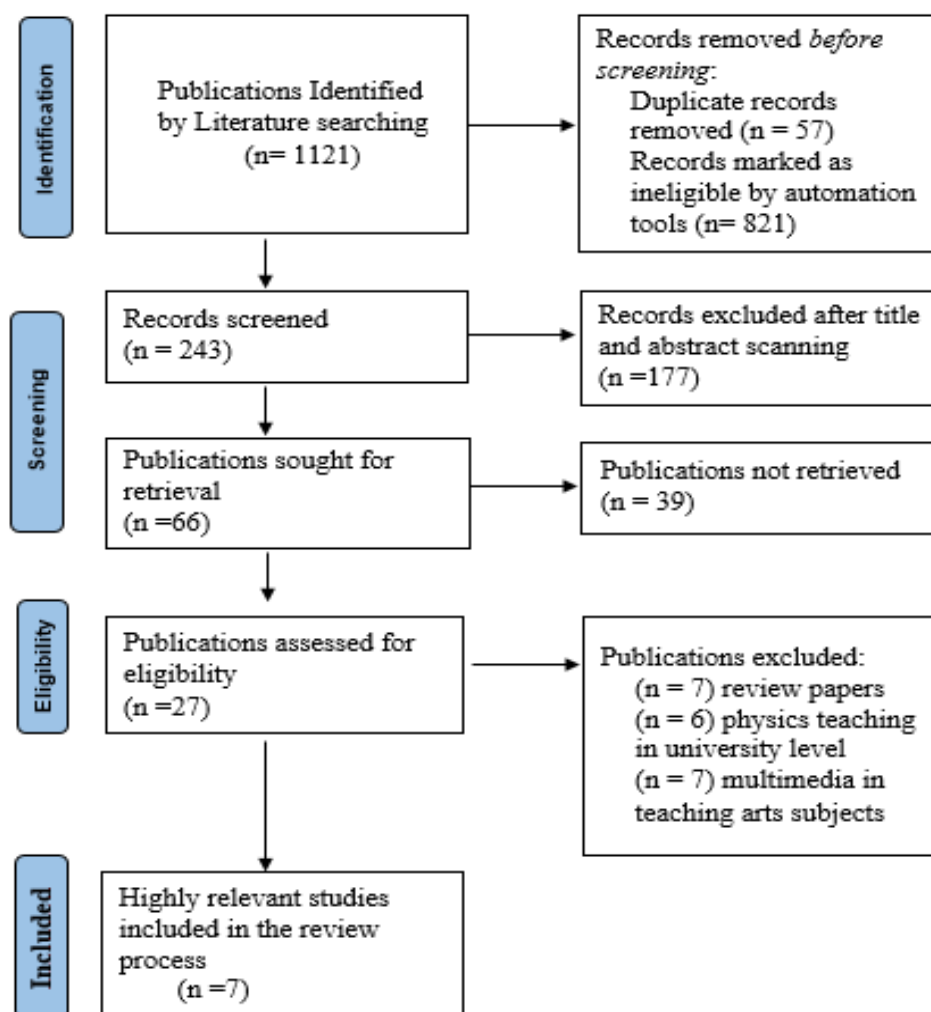


Figure 1. Article Selection based on PRISMA Framework

The third step involved screening the articles in accordance with the first inclusion criteria. Under this step, the researcher, in collaboration with assistant researchers, screened the abstracts as well as full texts to see how to answer the specified research questions. This screening of abstracts resulted in a total of 27 full articles that met the criteria for inclusion. After screening the full articles, only seven (7) articles met the criteria for inclusion in the analysis, as reflected in Figure 1.

The fourth step was descriptive mapping, which involved checking the alignment of the research articles with the research questions. This was followed by the fifth step, which included an appraisal of the quality of the identified research articles. Two independent reviewers appraised the research articles. The rubric strategy was used, whereby each article was examined based on the theoretical, methodological, and contributions of the article to the current analysis (Charmaz & Thornberg, 2021). Peer reviews were conducted through regular exchanges among reviewers, where consideration was based on the guidelines provided that reflected the quality of the research article (Laws, 2010).

The sixth step was synthesizing the findings. For a meaningful summary, a table was developed to summarize various instructional strategies regarding the multimedia integration in secondary school physics teaching. In this phase, several instructional strategies for multimedia integration in physics teaching were identified, as well as the multimedia resources used, as summarized in Table 1.

The seventh step involved a discussion of the findings and conclusions of the study. The findings were summarized, followed by a discussion that addressed the instructional strategies used during the integration of multimedia in physics teaching to enhance science literacy. Additionally, the discussion included emerging recommendations and opportunities identified in several studies, which could serve as lessons to improve future practices in classroom teaching with multimedia. The review process adhered to the four-phase flowchart for data extraction and filtration recommended by Rashid et al. (2021) (summarized in Figure 1). The search terms initially identified 27 distinct eligible articles, 7 of which met the criteria for multimedia integration in physics teaching to enhance science literacy. Twenty papers were excluded due to their lack of relevance to the subject.

3. RESULTS

The seven studies from the three scientific databases and manual search represent several studies on instructional strategies during multimedia integration in physics teaching to enhance science literacy. All the articles were extracted from peer-reviewed journals presenting empirical research findings on the matter. The evidence from the 7 studies addressing the instructional strategies and resources used on multimedia integration in physics teaching is summarized in the following Table 1.

Table 1. Summary of Instructional Designs and Multimedia Resources used in Multimedia Integration in Physics Teaching to Enhance Science Literacy

Author & Publication Year	Title	Design/ Approach	Location/ Study Site	Participants	Measures	Procedure	Resources & Tools Used	Data Analysis Plan	Main Findings
Lestari et al. (2023)	Effect of science virtual laboratory combination with demonstration methods on lower-secondary school students' scientific literacy ability in a science course	Quasi-experiment	Yogyakarta, Indonesia	Lower secondary school students	Pretest and Posttest to both control groups and experimental groups	3 groups taught with 1. Virtual lab and demonstration method 2. Virtual lab only 3. Demonstration only (control group)	Laptop, projector, screen, demonstration tools, Virtual Laboratory	20 Multiple choice questions were used to test scientific literacy ability. (indicators adopted from PISA 2018) Used ANOVA to determine effectiveness of virtual lab plus demonstration in improving scientific literacy	Combination of Virtual lab and demonstration method is most effective in improving science literacy compared to virtual lab only or demonstration only.

Author & Publication Year	Title	Design/ Approach	Location/ Study Site	Participants	Measures	Procedure	Resources & Tools Used	Data Analysis Plan	Main Findings
Solvang & Haglund (2021)	Learning with Friction-Students' Gestures and Enactment in Relation to a GeoGebra Simulation		Sweden	19 Upper secondary school students	Recording video during teaching/learning process	Teaching physics with a GeoGebra simulation of friction	Video cameras, computers, simulation software	Analysis of the recorded video data to detect the effect of students' interaction with a GeoGebra simulation of friction on exploring students' gestures, enactment, and problem interpretation. Test results were analysed by IBM SPSS 21 statistical analysis software, also Sphinx v5 software were used to process data.	Simulation in Physics teaching is important as it stimulates students' reflection on their understanding of the phenomenon
Hamamous & Benjelloun (2023)	Impact of using computer-assisted experimentation (CAEx) on learning physical sciences in secondary schools in Morocco	Mixed method design	Morocco	40 students	Pretest and Posttest to experimental and control group, interview, and Questionnaires	Teaching with and without CAEx in experimental and control group respectively	Computer, Data studio software, tools for LRC circuit		CAEx integration had a positive effect on student learning. plays an important role in the grasp and assimilation of scientific concepts, enhance problem solving skills, making students more attentive and curious
Gerháťová, Z, Perichta P & Palcut M. (2020)	Project-Based Teaching of the Topic "Energy Sources" in Physics Via Integrated e-Learning—Pedagogical Research in the 9th Grade at Two Primary Schools in Slovakia		Slovakia	155 students	Pretest and Posttest, also interview	Integrated e-Learning (INTe-L)—through project-based physics teaching	Computer, simulation software, e-learning materials	Calculated F-test and T-test of the test results	Project-based teaching through INTe-L is effective strategy to improve Physics teaching
Eviota J. & Liangco M. (2020)	Students' Performance on Inquiry-Based Physics Instruction through Virtual Simulation	Quasi-Experiment	Philippines	141 students	Pretest and Posttest of 24 multiple choice questions which consisted of picture analysis, computations and table analysis	By using 5E model, 3 groups were taught using 1. Inquiry-based instruction through virtual simulation 3. Virtual simulation only	Computers and simulation software	SPSS was used to analyse data, calculating mean, standard deviation, and F-Test to determine the significance difference in students' performance.	The inquiry-based instruction through virtual simulations help students improve their performance in Physics.

Author & Publication Year	Title	Design/ Approach	Location/ Study Site	Participants	Measures	Procedure	Resources & Tools Used	Data Analysis Plan	Main Findings
Shofawati et al. (2023)	The use of Multimedia Interactive to improve Student's Science Literacy in the New Normal Era	Pre-experimental design with a One-Group Pretest-Posttest Design.	Indonesia	31 students	Observation, tests, and questionnaires	-teaching with interactive multimedia using 5M in the following stages; 1) Organizing students to learn and carry out discovery activities, 2) Guiding problem-solving activities in groups, 3) Guiding students to develop and present the results of activities, and 4) Guiding students to analyze and evaluate the problem-solving process.		Descriptive and quantitative analysis of students' science literacy pretest and posttest data using N-gain.	learning using interactive multimedia improves students' science literacy skills
Abdelmoneim et al. (2022)	Effectiveness of virtual laboratories on developing expert thinking and decision-making skills among female school students in Palestine	Quasi-Experimental design	Pakistan	100 students	Expert thinking skills test, and the decision-making scale Questionnaires	Control group were taught through traditional lab, while experimental group were taught through virtual lab, simulation, and traditional lab	Computers, simulation and virtual lab software, laboratory tools and instruments	IBM SPSS v22 were used. Kolmogorov-Smirnov and Shapiro-Wilk tests were performed to assess the normality of data distributions. Mean, standard deviation, and percentage were analyzed. The differences in pre- and post-tests for each group was evaluated using paired t-test.	Using virtual laboratory and simulation applications had a positive impact on improving students' scientific knowledge, scientific process, decision-making ability and developing expert thinking skills.

Source: Author

4. DISCUSSION

The findings from the included studies as indicated in the table above reveal various effective approaches and highlight several key themes related to the integration of multimedia in physics teaching.

4.1. Instructional Designs for Enhancing Science Literacy with Multimedia

The studies reviewed employed diverse instructional designs, each leveraging multimedia to foster science literacy among students. The integration of various technological tools into the educational process highlights the innovative approaches being utilized to enhance learning outcomes in the sciences. In this review, the instructional designs employed include: integration of virtual laboratories with traditional demonstration methods; integration of PBL with e-learning tools; integration of inquiry-based instruction with virtual simulations; integration of traditional method with simulations; and integration of traditional lab, virtual lab, and simulations.

4.1.1. Integration of Virtual Laboratories with Traditional Demonstration Methods

One notable approach involved the combining virtual laboratories with traditional demonstration methods. This strategy was found to be highly effective in improving students' science literacy as evidenced by the quasi-experimental study by Lestari et.al (2023) in Indonesia also Abdelmoneim, Hassounah, and Radwan (2022) in Pakistan. In this study, the use of virtual labs allowed students to engage with complex scientific concepts in a dynamic and interactive manner. By providing a simulated environment where students can manipulate variables and observe outcomes, virtual labs make abstract concepts more tangible. This interaction is further enriched by traditional demonstration methods, which offer a concrete reference point, helping to bridge the gap between theory and practice. With this approach, students are able to visualize and interact with complex scientific concepts, thereby enhancing their understanding and retention. Pramonol, Prajanti and Wibawanto (2019) comment that application of virtual laboratories in science learning has proven to be effective in increasing students' understanding.

4.1.2. Integration of Project-Based Learning (PBL) with E-Learning Tools

Similarly, the project-based learning (PBL) model, has shown significant promise in advancing science literacy. The research conducted by Gerhátová, Perichta, and Palcut, (2020) in Slovakia, illustrates the effectiveness of PBL, particularly when it was integrated with e-learning tools in enhancing students' understanding of physics concepts. Project-based learning involves students in real-world projects that require them to apply scientific principles to solve problems. This hands-on approach not only deepens conceptual understanding but also fosters critical thinking and problem-solving skills both, which are crucial components of science literacy. In the Slovakian study, students engaged in projects that required them to utilize both traditional learning materials and digital resources, thereby gaining a multifaceted understanding of physics. The integration of e-learning tools provided additional layers of interaction and feedback, enabling students to explore concepts at their own pace and according to their individual learning styles. This blended approach highlights the potential of PBL in creating a more interactive and personalized learning experience that can cater to diverse student needs.

4.1.3. Integration of Inquiry-Based Instruction with Virtual Simulations

Inquiry-based instruction, particularly when combined with virtual simulations, also has been shown to significantly enhance students' performance in science subjects. The study conducted by Eviota and Liangco (2020) in Philippines demonstrates the efficacy of this method in teaching physics. In this study, 5E model were used in teaching physics through IBL and virtual simulations. The 5E model involve various stages in teaching which are Engage, Explore, Explain, Elaborate, and Evaluate (Duran & Duran, 2004). Inquiry-based learning encourages students to ask questions, conduct experiments, and draw conclusion based on their observations. When coupled with virtual simulations, this method becomes even more powerful. Virtual simulation provides a safe and controlled environment where students can experiment with different variables and observe the effects without the constraints of a physical lab (Aljuhani, Sonbul, Alhabiti, & Meccawy, 2018). This allows for a deeper exploration of scientific phenomena and promotes a better understanding of complex concepts. Eviota and Liangco (2020) found that students who engaged in inquiry-based learning with virtual simulations performed better in physics assessments compared to those who did not. This approach not only enhances cognitive skills but also promotes a deeper interest in the subject matter, making science more accessible and enjoyable for students.

4.1.4. Integration of Traditional Lab, Virtual Lab, and Simulations

Integration of traditional labs (actual practical works), virtual labs, and simulation has been identified as an approach which significantly enhances science literacy by combining their unique strengths to create a comprehensive learning environment. Traditional lab offers hands-on-experience with physical equipment fostering a deep understanding of experimental procedures, while virtual labs provide a safe, cost-effective platform for exploring complex experiments and simulations enable visualization of abstract concepts. A study by Abdelmoneim et al. (2022) evidence the effectiveness of combining the three as among

the best approach of enhancing science literacy to students, where students are able to develop expert thinking skills and decision making.

4.2. Multimedia Resources and Tools Integrated in Physics Education

The studies reviewed highlighted a range of multimedia resources and tools used to support physics teaching. Apart from desktop computers, laptops, and projectors which have been noted in included studies, also multimedia tools like virtual laboratories, simulation software, and interactive multimedia applications have been identified. Each of these multimedia tools is contributing uniquely to the enhancement of students' learning experiences and outcomes, making a shift towards more dynamic and engaging teaching methodologies. One significant study by Hamamous, Benjelloun, and Mohamed (2023) in Morocco, demonstrated significant positive impacts of computer-assisted experimentation (CAEx) which utilizes computer technology for hands-on experimentation in a virtual environment. The study revealed that CAEx significantly improves students' understanding of complex scientific concepts by allowing interactive manipulation of variables and observing real-time results, thus mitigating traditional lab limitations, like resource constraints and safety concerns. Similarly, the integration of GeoGebra simulations, as investigated by Solvang and Haglund (2021) in Sweden, showed how interactive mathematical software, facilitates the visualization and understanding of physical concepts through dynamic simulations, promoting deeper and more intuitive comprehension.

Additionally, a study by Shofawati et al. (2023) in Indonesia, highlighted the benefit of using interactive multimedia tools during challenging times such as COVID-19 pandemic. These tools, including videos, animations, and interactive modules, create a multisensory learning experience that catered to various learning styles, thereby improving student engagement and comprehension. The study found that such tools significantly enhanced students' science literacy, providing an invaluable alternative to traditional classroom interaction during the pandemic. The versatility of multimedia tools extends beyond comprehension improvement, fostering critical thinking and problem-solving skills. Interactive simulations and multimedia content encourage students to think critically, ask questions, and explore different scenarios, promoting deeper cognitive processing level, essential for developing higher-order thinking skills. This integration of multimedia resources into education underscores their crucial role in transforming science education and improving student outcomes.

Despite the presence of several studies on the use of multimedia a few studies have explored specific multimedia strategies in improving physics literacy. For example, simulations, videos, augmented reality (AR) and virtual reality (VR). Moreover, most of the studies reviewed reflect short term cross-sectional designs; longitudinal studies can be conducted to explore the long-term effects of integration of multimedia in physics education, to explore the sustainability of the impacts in real life, in solving contextual problems.

5. CONCLUSION

The findings in this study provides strong evidence that in order to enhance science literacy in physics teaching, the following should be adhered: multimedia needs to be integrated with actual practical work to bridge the gap between theory and practice (Lestari et al., 2023). Additionally, integrating multimedia learning with innovative pedagogies such as project-based learning (PBL) (Gerhátová et al., 2020) and inquiry-based instruction (Eviota & Liangco, 2020) are effective for developing science literacy. Finally, it is important to incorporate collaborative learning and discussions when teaching with multimedia. These strategies create engaging and effective learning experiences that enhances students' understanding and application of scientific concepts. Continued investment in teacher training, research, and equitable access to technology will be critical to sustaining these improvements and ensuring all students benefit from multimedia-enhanced education.

For effective development of science literacy, it is recommended to integrate multimedia that are used as active learning tools to engage students in variety of innovative activities. Lambert, & Cuper, (2008) recommend the use of nonlinear multimedia tools that provides a room for interactivity in the construction of knowledge. Therefore, physics instructors should integrate multimedia elements with a range of teaching and learning strategies to involve students in active learning.

This review underscores the importance of strategically integrating multimedia into physics education to enhance learning outcomes. Educators and instructional designers should align multimedia tools—such as virtual labs and simulations—with specific educational goals and student needs, ensuring these resources directly support curricular objectives. To facilitate this, policymakers and curriculum developers must formally incorporate multimedia approaches into national education policies and curricula while investing in teacher professional development to equip educators with the skills needed to leverage these technologies effectively. Additionally, governments and institutions must prioritize equitable access by investing in digital infrastructure to support students' learning. Collaboration among educators, instructional designers, and policymakers is essential to developing and implementing effective, sustainable multimedia integration strategies that leverage their combined expertise to continuously improve physics education. Policymakers and curriculum developers should also prioritize funding for teacher training programs and equitable technology access to ensure multimedia tools are implemented effectively across diverse educational settings.

The review included identification and critical assessment of primary research studies that meet the eligibility criteria with the aim to bring evidence together to answer pre-defined research questions. The studies included are the most current from different locations, including Indonesia, Sweden, Pakistan, Philippines, Slovakia and Morocco. However, this study involved a critical search of studies from only three scientific databases leading to only seven (7) eligible distinct articles which met the criteria on multimedia integration in physics teaching to enhance science literacy with English language. The few studies included may not provide a good representation of the practices in the given locations. This makes the study very limited to cross over various contexts. Other studies can be conducted to involve more databases and languages to increase the scope of the literature on the use of multimedia.

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Research Ethics: This study is a systematic review of existing literature and did not involve direct interaction with human participants or primary data collection. Therefore, ethical approval from an institutional review board was not required. However, the review process adhered to ethical academic standards, including proper citation and analysis of publicly available studies.

Data Availability Statement: All data analyzed in this systematic review are based on previously published studies cited within the manuscript. No new datasets were generated during the current study.

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