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Educational technology using multimedia in science learning: A systematic review

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ABSTRACT

This systematic review aims to provide a systematic review of the scientific published studies that examined different multimedia tools in the science teaching and learning process to identify the existing multimedia-based tools and understand their usage, application areas, and impacts on the education system. There are 60 articles extracted from the Scopus database from 2012 to 2022. This review generates six averments about the current study; (1) The most numerous multimedia components are text components; (2) the learning process and application of the use of multimedia in science education can be applied at various levels of education; (3) The majority of the study was conducted in the United States; (4) the current use of technology that is most widely used is the use of power points; (5) the role of technology in the learning process as learning tools, teaching tools, assessment, and evaluation; and (6) the most science content conducted in multimedia research is chemistry.

1. Introduction

The classroom learning experience is changing dramatically as a result of rising technology trends in education [1]. Despite a long history in educational research, emotional variables in multimedia learning studies have been rather disregarded. This might be because the classic multimedia theory is built on a chilly cognitivist paradigm that ignores motivation's regulating responsibilities in cognition. Researchers have attempted to determine if the use of educational technology had a substantial and consistent influence on student success since educators first began to utilize computers in the classroom. In their search for an answer, researchers discovered that technology cannot be treated as a single independent variable and that student achievement is measured not only by how well students perform on standardized tests, but also by their ability to use higher-order thinking skills such as critical thinking, analyzing, making inferences, and problem-solving. According to [2], while building a learning experience, three primary criteria must be considered: I reducing additional cognitive load, (ii) creating material that supports all types of students, and (iii) developing a helpful learning environment. Subject, pedagogy, user experience, and interaction should all be considered while designing student learning experiences. Furthermore, if students are interested in the learning material that might assist them in their studies, their learning motivation will emerge [3].

Judging the impact of any particular technology necessitates knowledge of how it is used in the classroom and what learning goals the educators involved hold, knowledge of the types of assessments used to evaluate improvements in student achievement, and an understanding of the complex nature of change in the school environment. The question of whether or not technology should be employed

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in classrooms is no longer an issue in education. Instead, the present focus is on ensuring that technology is used properly to offer new learning opportunities and increase student accomplishment. However, educational technology is not and will never be transformational on its own. It necessitates the support of educators who integrate technology into the curriculum, link it with student learning objectives, and employ it in projects involving engaged learning.

To bring broad change to occur, instructors must incorporate the potential of new technology infrastructure into their overall curriculum thinking. The classroom teacher's involvement is critical in the complete development and usage of technology in schools. Teachers must have a range of discourse structures and approaches to lessons. They must comprehend what is most appropriate for assisting the acquisition of complicated knowledge and skills in a range of settings with ever-increasingly complex educational objectives [4]. Educators will be able to make educated decisions about which technologies will best suit the individual demands of certain schools or districts if they use the accumulating information about the situations under which technology supports the wide definition of student accomplishment. They will also be able to guarantee that teachers, parents, students, and members of the community understand the function that technology plays in a school or district and how its effect is measured. Finally, they will be able to justify their technological expenditures [5].

With the introduction of cutting-edge electronic teaching and learning tools, technology has profoundly altered the educational landscape. We elevate educational technology as the major driving force behind learning, from browsing the Web to participating in virtual settings. In general, "educational technology" refers to both the subject of study and the technology used to promote learning. Educational technology has been characterized as the use of technology for teaching and learning [6]. Recently, there has been a tremendous increase in the use of technology in schools [7]. Because of the rapid rate of growth in educational technologies, the use of technology is high on the priority list of educational managers, administrators, and staff members. Concern for educational technology may contribute to a better knowledge of the role of technology in learning and teaching, as well as the role of educational technology in the pedagogic process. Technology is referred to as an important teaching tool. As an educational tool, technology may help to learn in several ways. Technology may be extremely beneficial in the areas of material presentation and accomplishment evaluation. In the rare situations where instructional technology was used, it was often viewed as a complement to instruction. There are three separate technical domains that have the potential to increase human understanding. They are simulations, games, lab equipment, computer-assisted instruction (CAI), and discourse technology.

To properly account for education as a highly emotional and human activity, educational technology debate must extend beyond the 'intellectual' components of the educational process (such as discussions of the informational, cognitive, or neurological aspects of teaching and learning). If quick improvements in educational technology are implemented without contemplating the consequences, there may be unintended consequences [8]. Technology-based education is increasingly seen as an inherently selfish effort. Now, students have access to personalized formative cycles and feedback loops due to digital technologies. Students, lecturers, and scholars are all expected to become diligent self-improvers who are motivated by external goals and working to raise their performance.

There are many opportunities for learning to take place outside of the classroom due to the considerable rise in Internet access and computers inside and outside of classrooms [9]. Several meta-analyses revealed encouraging findings about the usefulness of technology in the classroom. Furthermore, educational content can be delivered in a wide range of technological contexts. [10] In general, the historical trajectory of social work education technologies and media has shifted away from content and the improvement of teaching methods and materials which increase the opportunities for educational programming without spatial or temporal limitations and the widespread dissemination of learning. The analysis and development of effective communication skills, as well as improving students' in-class and field learning experiences through, for instance, the evaluation of process recordings, were the main focuses of early social work technical history. Self-paced learning materials with an emphasis on performance and learning proliferated in the 1970s and 1980s, with traditional instructional technologies progressively integrating with computer programs to provide multimedia content presentation and simulations of real-world social work practice [11]. Without a doubt, educational technology will continue to play a bigger and bigger role in the coming years. The question then becomes how to best integrate various educational technology apps into classroom settings rather than whether or not teachers should use educational technology [12].

The application of a computer to input, process, store, transmit and display data types like text, graphics, animation, and digitally preserved images as well as audio, video, and speech is known as multimedia [13]. The idea of multimedia as a technique is to deliver information to the user using all possible data kinds, including audio, video, animation, image, and others in addition to conventional methods, such as text, with the use of a computer [14]. Using words and images to promote learning is referred to as multimedia instruction. Some common uses of multimedia in e-learning include an animation, video, or static graphic with accompanying narration; an animation, video, or static graphic with accompanying onscreen text; or a computer-based interactive game, simulation, or another learning tool. The words can be spoken (such as narration) or printed (such as on-screen text); the pictures can be static (such as illustrations, diagrams, maps, or photos) or dynamic (such as animation or video) [15]. Audio, image, and video are examples of unstructured aspects of multimedia data. Such large and unstructured data must be transmitted through networks with limited bandwidth and computational power, necessitating an effective and clever network layout [16]. The presentation of information using text and graphics or the incorporation of several forms of digital content (text, image, sound, and video) into an interactive program are two ways that researchers define multimedia [17]. The majority of scientists view multimedia technologies—which provide information not only in text format but also in the form of images—as tools for improving the effectiveness and quality of teaching. When it comes to multimedia technologies, we'll define them as a group of computer technologies, with the aid of specialized hardware and software, implementing a variety of information environments, including graphics, video, texts, photographs, animation, and sound [18]. The usage of multimedia encourages pupils' independence, activity, and mobility. These relatively liberated circumstances inspire pupils to handle the assignment responsibly and with more creativity. Students' readiness and enthusiasm for the subject rose after the inclusion of multimedia technology in the learning process [19]. Universities and colleges have been using multimedia technologies, particularly video, more and more for online and blended learning. Numerous research studies have shown that the usage of multiple media resources instead of just one improves student learning.

The practice of learning through multimedia instructional messages—communications that use more than just words and include images, animations, narrators, and videos--is known as multimedia learning [20]. Online and blended learning both increase the usage of multimedia. The justification for multimedia learning is that active learning—relevant cognitive processing like paying attention to the lesson's learning materials, mentally organizing them into a coherent cognitive presentation, and mentally integrating them with previously acquired knowledge—increases the likelihood that learners will comprehend the learning materials [21]. The only way to achieve the teaching effect of getting twice the result with half the effort is to naturally combine traditional teaching and multimedia teaching as an adjunct and supplement one another [22]. Bring Your Device (BYOD), Blended Learning, Flipped Learning & Flipped Classrooms, and Online Learning is all viable options for delivering coursework, depending on the needs of the students and the resources available to the schools/districts [23]. In actuality, new technologies have been included in the delivery of education. Remember that the technological mix employed in today's classrooms includes more than just PCs [10]. For many teachers and students, the term "new technology" has expanded to include things like document cameras, LCD and DLP projectors, online multimedia, electronic readers, portable audio/visual players, and interactive whiteboards [24].

In this paper, science learning is defined as acquiring and developing conceptual and theoretical knowledge of science concepts [25]. In addition, science learning was adopted into sub-disciplines such as physics, biology, chemistry, earth and space science, and integrated science [26]. These sub-disciplines lead us to the development of each topic in every sub-discipline, which brings us to clear division in every topic discussion. Science learning mostly covered all levels of education especially basic education from elementary until high school. Rapid science and technological advancements, globalization, and emerging complexities in societal structure and influencing and changing the social dynamics concerning economics, politics, and environment, and the way science is organized and operated. such changing circumstances pose challenges to future science educators as to how morality, values, ethics, and character education can be presented through curriculum development and implementation. research has proven that science teaching and learning practices may be applied while fostering morals, values, and ethics. There are several multimedia often used in science learning, such as PowerPoint, animation, and simulation, to the complex multimedia such as 3D images and Virtual Reality.

Therefore, this paper aims to provide a systematic review of the scientific published studies that examined different multimedia tools in the science teaching and learning process intending to identify the existing multimedia-based tools, understand their usage, application areas, and impacts on the education system. In order words, the study, through a systematic review of literature, aims at identifying the existing multimedia-based tools for teaching and learning, listing the multimedia components used in the learning process, and understanding their roles, and application areas including nation, level of education, and science topic. To this end, the study is guided by the following research questions:

- What type of multimedia component was used in the science learning process?
- How is the distribution of the usage of multimedia at every level of education?
- How is the distribution over the countries?
- What are the existing multimedia technologies in teaching and learning?
- What are the roles of multimedia in the learning process?
- What are the science contents that can be put on the multimedia?
- What are the trends and issues on educational technology in science learning?

2. Method

A systematic literature review was adopted as the research methodology in this study. According to the study of [27], a continuation of [27] the systematic review adheres to the guidelines in the Preferred Reporting Items for Systematic Reviews and Meta-analysis for Protocol (PRISMA P) 2015 guideline. The goal of the guideline is to make it easier to conduct a meticulously planned and documented systematic review in a way that supports review articles' integrity, consistency, and accountability. Additionally, the protocol for the study comprises selecting the data sources, search terms, and inclusion criteria. Key points from the discovered articles are summarized in tables, and quantifiable components are examined to aid in the synthesis of the articles.

First, we need to prepare search keywords related to the research. Then, we start to surf the literature according to the listed keywords. Some constraints are utilized to filter the findings, and we manage them. After that, we categorize them based on the taxonomy that was proposed. In this case, we manage research/literature on using multimedia in science education by looking at the manufacture and use of the technology.

The data sources utilized to identify the articles to be chosen for the review are where a systematic review's quality evaluation begins. This necessitates a thorough review of the published literature from numerous academic databases and journals. Scopus is one of the academic databases and publications taken into account for this review. We conducted on Scopus from 2011 to 2022. The journals and conference papers that are indexed in these databases are recognized as reliable bibliographic sources, and they are thought to be of high caliber. The search terms for relevant literature in the academic database and journals are “Multimedia”, “Science”, “Biology”, “Physics”, “Chemistry”, “Student”, “Learning”, “Education”, “Instruction”, and “Training”. The literature that was gathered was restricted to those that showed up on the first page of relevant search results. Since English is widely used in the scientific community , we only included works that were written in English, as can see in Fig. 1.

The number of articles from the keyword search database minus the excludes feature on Scopus. The number of articles obtained was 2,978. We then limit the subject area, document type, keyword, and source type in the Scopus feature. Resulting in 404 articles. Then the exclude that is selected in this case is the elimination based on the direction of the article after reading, causing a reduction from 404 to 60.

Based on the selection mechanism, 60 articles were shortlisted for analysis. Each article was reviewed and information was extracted from it for tabulation. The information sought included the following: the type of multimedia Component, Level of Education, Corresponding Country, Multimedia Technology, how the technology was created, and how the tool was applied. The data processing steps was shown in Fig. 1.

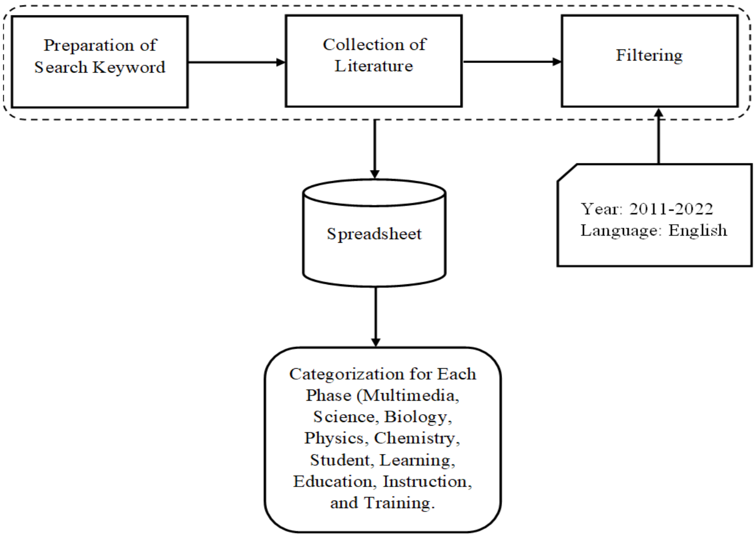

Fig. 1. The systematic literature review flowchart

3. Results and Discussion

A literature review article analyzes each problem formulation based on the spread of research with some previous considerations. Martín-Páez, Aguilera, Perales-Palacios, and Vílchez-González (2019) stated that the investigation of the spread of research based on the similarity of substance characteristics is an important part of preparing a literature review article. Research distribution is divided based on the following characteristics: multimedia component, education level, countries implementing research, multimedia technologies, the role of multimedia, and science content.

3.1. Multimedia Components in Multimedia Science Learning

Based on the results of a literature review that we extracted from various indexed journals for the articles analyzed regarding which multimedia components were used. The results are presented in Fig. 2. Various multimedia tools were identified in the analyzed articles. The multimedia components found, namely text, audio, video, images, animation, 3D, illustrations, and graphics that have been developed can also improve teaching and learning skills and are used in learning environments.

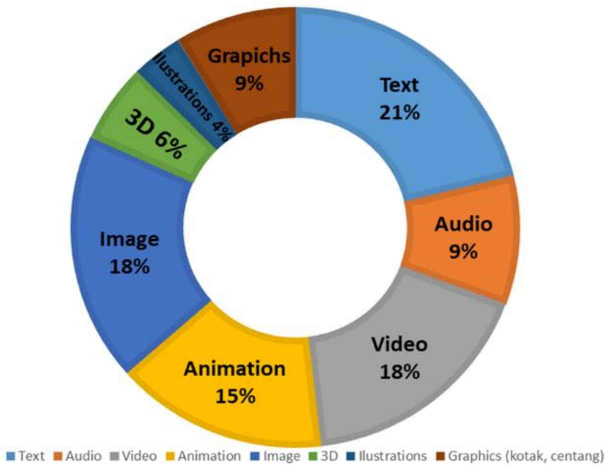

Fig. 2. Distribution of research based on the multimedia component

As shown in Fig. 1, several multimedia are identified. The most numerous multimedia components are text components, namely as many as 29 articles because the text is very simple and is the most basic multimedia component [28]. Text is the most practical and simple component for conveying information. Typically, text in multimedia is packaged in typography [18]. Then the second most are images, namely 25 articles because images are also relatively easy to find and make yourself, besides that image components are often used to attract the attention of readers and viewers. This is because most people are more attracted to visuals [29].

In addition, images are also able to make information easier to understand [30], [31]. While the fewest parts are illustrations, namely as many as 5 articles because illustrations are relatively difficult to find [32]. Because Fiorella and Zhang drawing may require students to use more cognitive resources in making images and it takes more time; imagination can cause cognitive load by requiring students to constantly remember information and may not have sufficient cognitive resources to envision entire structures or processes; Reading with the provided pictures may be passive, but the provided pictures allow students to visualize structures and processes directly, which can compensate for students' low spatial abilities. In one article there is not only one multimedia component but several multimedia as in the research by [33] which combines text, images, and videos. However, there is no incorporation of 3D multimedia components in the [34] article. Animation is also embedded as part of the multimedia tools developed for visualization [35], for teaching [28], virtual techniques, CAD, and augmented reality [34].

It is undeniable that multimedia technology can make a big impression in the fields of communication and education because it can integrate text, graphics, animation, audio, and video. Multimedia has developed teaching and learning processes in a more dynamic direction [32]. But what is more important is understanding how to use these technologies more effectively and generate ideas for teaching [34], [36] and learning.

Nowadays, teachers need to have the skills and confidence to use this technology in the most effective way [35]. An atmosphere of interactive teaching and learning promotes more active communication between various things [37]. The use of multimedia computers in the teaching and learning process is aimed at improving the quality of teaching and learning [34], [36]. With the development of multimedia technology, video, sound, text, and graphic elements can be packaged into one through Computer Based Learning (CBL) [34].

3.2. Level of Education used in Science Learning

The sample of participants in the article was analyzed to determine the distribution of the study by educational stage. It aims to provide an overview of the distribution of previous research related to multimedia learning in science education based on education level. The elementary school level consists of students aged around 6-12 years. The middle school level consists of students who have graduated from elementary school at the age of about 12-15 years. The high school level consists of students who have graduated from junior high school at the age of 15-18 years. The undergraduate level consists of students who have graduated from high school and continue their studies to the college level at the age of about 18 years. Meanwhile, postgraduate students are students who have graduated from tertiary institutions at the age of 22 years or more. The complete data can be seen in Fig. 3.

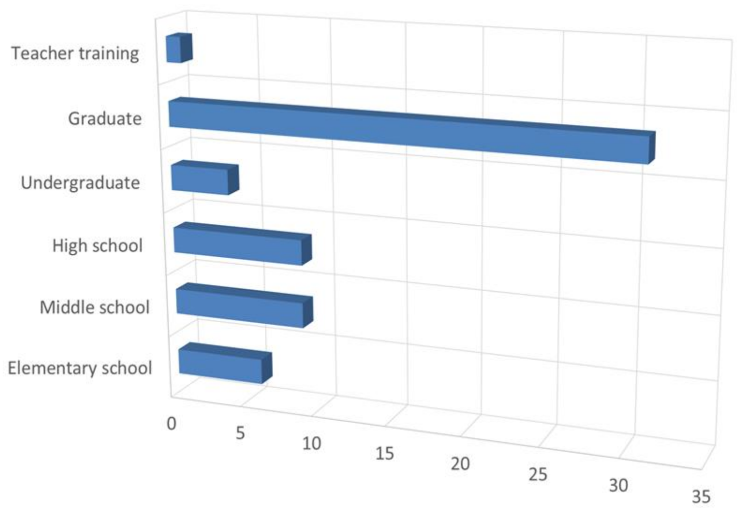

Fig. 3. Multimedia research based on the level of education

Based on Fig. 2, it can be seen that there were 24 articles whose participants consisted of students; 6 articles with elementary school samples; and 9 articles with SMP samples; 9 articles with a sample of high school students; 4 arts with a sample of undergraduate students. The distribution of research based on the highest level of education was found in junior and senior high school students in 9 articles. The lowest comes from undergraduates with only 4 articles. Then for teacher participants, there were 32 articles whose samples or participants were teachers; 31 articles with undergraduate or diploma samples; and 1 article with PPG.

The distribution of research based on the highest level of education is found in undergraduate or diploma students with a total of 31 articles. This is because teachers use more multimedia to help students improve their learning in class. With this innovation, students will slowly start to think critically and not miss lessons. besides that, the science needs are higher than those of students and the laboratories at universities are more complete than at the elementary and middle school levels [38]. The lowest was from PPG with only 1 article. This is because PPG was only carried out for a short time, so little research has been conducted.

From these data, it can be concluded that the learning process and application of the use of multimedia in science education can be applied at various levels of education. However, the implementation at the teacher level is still not much compared to the teacher level (graduates). This emerges from the analysis showing that implementation at the teacher level is still small compared to primary, secondary, and teacher education. Therefore, there are still many gaps to seek opportunities from implementing the innovation plan prepared in teacher training. Research by [31] shows that there are fewer studies for teachers than others.

3.3. Corresponding Countries as the research objects

The distribution of locations for implementing multimedia in science learning is important in informing the distribution of students who have implemented multimedia by country. We summarize the corresponding country based on the multimedia test location. The multimedia tools employed were reported in studies from wide-ranging countries, including Australia [37], [39], [40], Mexico [33], Canada [41], Malaysia [42], [43], Pakistan [30], and so on. Fig. 4 simply depicts the wide-ranging country distributions.

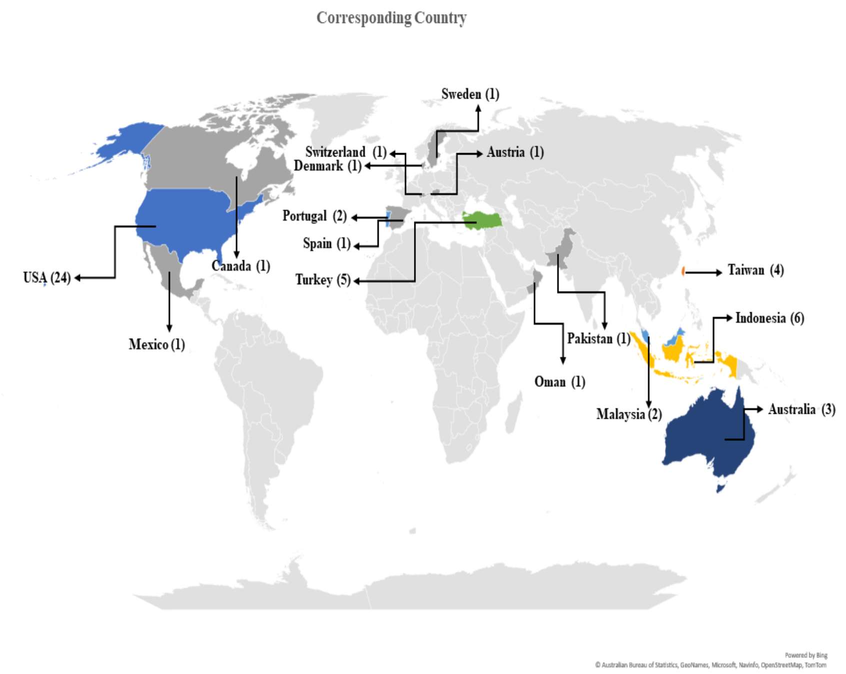

Fig. 4. The Distribution of Technology Test Location

Based on Fig. 3, the majority of the study was conducted in the United States, with Indonesia, Turkey, and Taiwan following closely after. Table 1 shows the entire data set.

Table.1 The distribution of research on multimedia in science education is based on countries.

References (citation)	Country
Li Cheng & Carole R. Beal [44]; Chuhao Wu et al. [45]; Jennifer Wiley [32]; Richards-Babb, et al.; Harrison et al.; Lees et al.; (Gray et al.); (Olitsky et al.); (Homer & Plass [46]); (Traver et al.); (Kristian); (Ohn-Sabatello), August et al. [47]; Jordan et al. [29]; Jacobs, Dalal, & Dawson [48]; Moore [49]; O'Keefe, et al. [46]; Franco & Provencher; VandenPlas, et al. [50]; Ranga; Parong & Mayer; Amaral, et al.; (Hight et al.); Sullivan & Puntambekar [4]	USA
Hsin-Kai Wu et al.; Sheng-Chang Chen, Mi-Shan Hsiao, & Hsiao-Ching She; Chen; Lai, Chen, & Lee [51]	Taiwan
Ögren et al.	Sweden
Gunawan et al.; Sulisworo et al. [28]; Manurung & Panggabean [52]; Syawaludin, Gunarhadi, & Rintayati; Ahied, et al.; Dwiningsih et al;	Indonesia
Iqbal & Sami [30]	Pakistan
Unterbruner, Hilberg, & Schiff [31]	Austria
Zuarni et al.; Daud, Hamat, & Ahmad [43];	Malaysia
(Zhan & So); (So et al.)	Hongkong
Andre, P; Fonseca, Zacarias, & Figueiredo	Portugal
Makransky, Terkildsen, & Mayer	Denmark
Dilara Sahina and Rabia Meryem Yilmazb; Debbag, M., Cukurbasi, B., & Fidan, M.; Uzun, A. M., & Yıldırım, Z.; (Uyulgan & Akkuzu); Fidan & Tuncel	Turkey
Heitzler, et al.	Switzerland
Urquiza-Fuentes, J., & Velázquez-Iturbide, J. Á. [53]	Spain
Salas-Rueda et al [33]	Mexico
Nader Said Shemy [35]	Oman
George Hatsidimitris; Jolley et al. [39]; Levonis et al. [40]	Australia
Pölloth et al.	German
Moozeh et al.	Canada

Based on Table 1, multimedia technology is mostly employed in the USA. This finding is relevant to other educational technology reviews in higher education [54], artificial intelligence in higher education [54], e-learning [55], mobile learning. The USA started to integrate technology into educational practice by launching the National Information Infrastructure (NII), which was the basic step to the widespread use of ICT in education in the USA in 1991. In addition, STEM Education which integrates technology in a scientific context has been stable in the USA as faculty. The USA also employs advanced tools to create multimedia learning. On the other hand, developing countries, such as Indonesia, Portugal, Mexico, Pakistan, and Malaysia are emerging to develop multimedia in science learning but using more simple technology or tools.

3.4. Multimedia Technology used in Science Learning

The systematic review allowed us to extract information from the reviewed articles about the type of multimedia tool described in the article and the technology used by the tool. We summarize multimedia technology or tools based on their function in creating, developing, operating, or even as science material resources. Fig. 5 summarizes the findings. The reviewed research papers contained numerous multimedia tools. Possibly as a result of advances in multimedia technology, several applications have been developed and deployed to improve teaching skills and learning environments in a variety of fields of study.

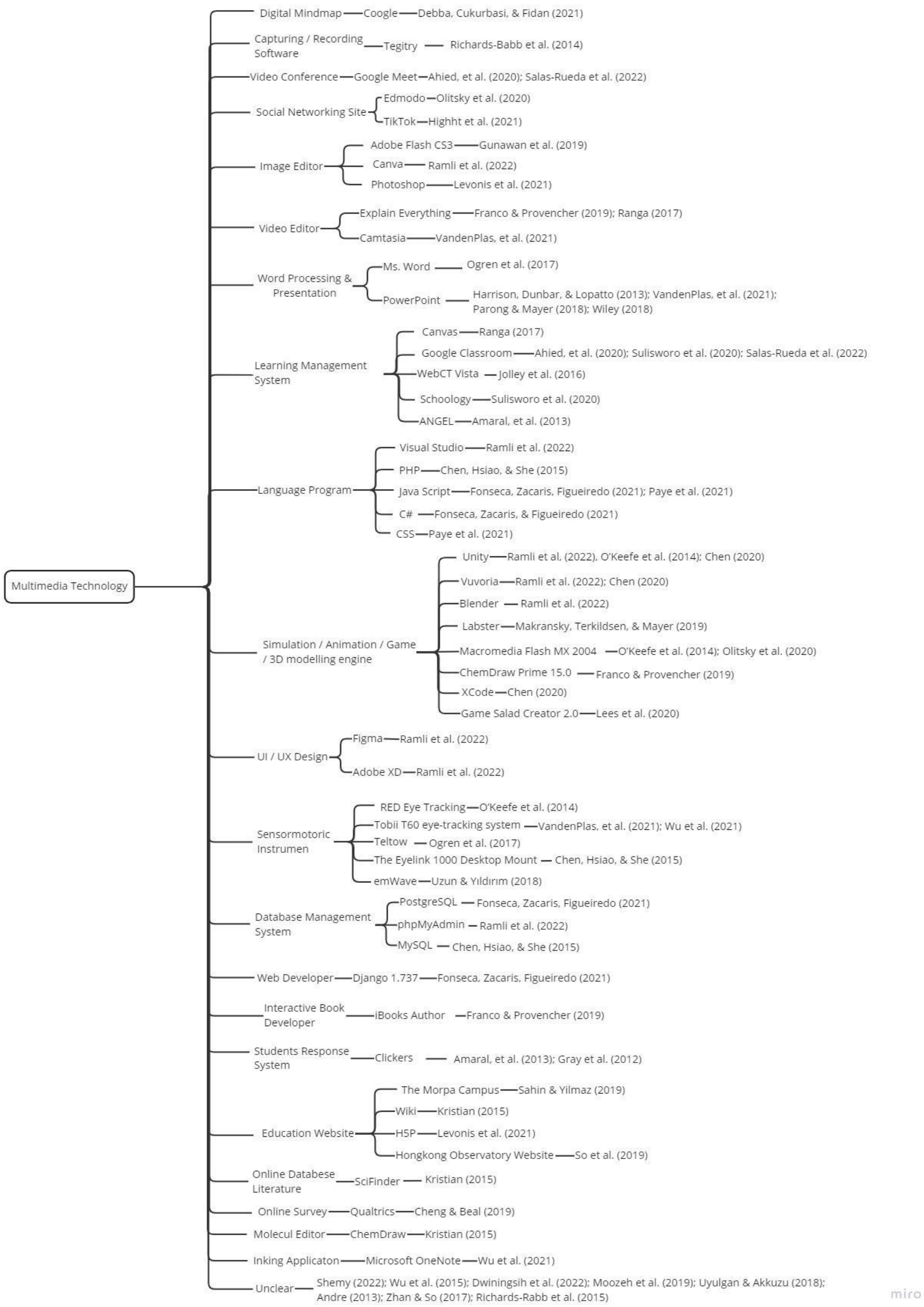

Fig. 5. Summary of Multimedia Technology for Science Education Studies

Based on Fig. 5, it can be seen that the distribution of the use of technology in multimedia development is very diverse and has received a lot of attention from researchers in the field of science education. The most conventional to the latest, simple to complex technologies have been applied to science learning. In addition to utilizing existing multimedia, multimedia development research has also fulfilled the science learning literature.

Powerpoint is a presentation program that is widely used in scientific research [50]. In the context of teaching materials, the review shows that there are studies that make use of content that is already available on popular educational websites, such as SciFinder, The Morpa Campus [34], H5P [40], Hong Kong Observatory Website, and Wiki. The reviewed studies also used some popular learning management systems in conducting blended learning in science classrooms, such as Schoology [28], Google Classroom [28], [33], ANGEL , Canvas, and WebCTVista [39]. Specifically, in the field of chemistry, there is a particular application designed to draw chemical molecules, ChemDraw.

Advanced technology tools started to be employed in developing 3D-dynamic simulations in visualizing science concepts and phenomena, either language program package or database management system, in the simulation builder application. The advanced technology also appears to be used as a tool for emotion detection and eye movement as an indicator of several important learning processes in scientific research. The technologies employed are emWave, RED eye-tracking, Tobii T60 [50], Teltow, The Eyelink 1000 Desktop Mouth. In addition, learning interactivity is also supported by the use of clickers to get real-time responses from students, as reported by Amaral et al. and Gray et al.

There are a lot of findings regarding the identification of technology used to develop or operate multimedia, but it turns out that there are still several studies that do not explain what types of multimedia technology or tools are used or developed in science learning [35].

3.5. Roles of Multimedia used in Science Learning

Articles involving the role of multimedia were examined to identify the role that multimedia has in learning. Detailed information is presented in Table 2. Mayer (2009) states that the role of multimedia can optimize student learning activities.

Table.2 Roles of multimedia in science learning

Roles of Multimedia	Technology Form	References
Learning Tool	E-module	Li Cheng & Carole R. Beal [44]; Jennifer Wiley [32]; Sullivan, S., & Puntambekar, S. [4]; (Moore [49]);
	Video	(C. Wu et al.); (Gunawan et al.); (Richards-Babb et al.,); (Ramli et al. [42]); (Levonis et al. [40]); (Jolley et al. [39])
	Augmented Reality	(Sahin & Yilmaz [34]); (Ahied et al.); (C. H. Chen)
	Virtual Reality	(Makransky et al.)
	Animation	George Hatsidimitris; Nader Said Shemy [35]; (Unterbruner et al. [31])
	Simulation	(S. C. Chen et al.); (Urquiza-Fuentes & Velázquez-Iturbide [53]); (Homer & Plass [46]); (Vandenplas et al.[50]); (Okeefe et al); (Dwiningsih et al.)
	Pamphlets	Harrison, M. A., Dunbar, D., & Lopatto, D.

Roles of Multimedia	Technology Form	References
	Website	(Heitzler et al.); (Paye et al.); (Kristian);
	Game	(Lees et al.); (Traver et al)
	Virtual Laboratory	(Moozeh et al.); (August et al. [47])
	Digital Mind Map	(Debbag et al.)
	Social Media	(Olitsky et al.); (Hight et al.)
Teaching Tool	E-module	(Ögren et al.); (Franco & Provencher)
	Video	(Jordan et al. [29]); (Ranga)
	Augmented Reality	(Syawaludin et al.)
	Virtual Reality	(Parong & Mayer)
	Simulation	(Uzun & Yıldırım)
	Website	(Jacobs et al. [48])
Assessment & Evaluation	Pamphlets	(Harrison et al.)
	Website	(H. K. Wu et al.); (Gray et al.); (Zhan & So); (Richards-Babb et al.);
	Mobile app	(Ramli et al. [42]); (Fonseca et al.)
Learning Management System	Website	(Sulisworo et al. [28]); (Salas-Rueda et al. [33]); (Ohn-Sabatello); (Pölloth et al.); (Amaral et al.)

Based on Table 2, we divide the roles of multimedia based on four categories, which are learning tools, teaching tools, assessment and evaluation tools, and Learning Management Systems (LMS). Categorization is obtained through the results of a review of the role of multimedia in learning. Research in the field of multimedia learning has also shown that individual student differences can govern how effectively multimedia principles impact their learning (Mayer, 2009). The application of multimedia in learning can also help teachers overcome difficulties in visualizing abstract concepts.

There are several studies on the role of multimedia as a learning tool. Learning tools here means the tools that can help students understand learning material by themselves. One kind of multimedia that acts as a learning tool involves Augmented Reality (AR). A study by [34], revealed that the students were pleased and wanted to continue AR applications in the future. They also showed no signs of anxiety when using AR applications. The role of multimedia as a learning tool provides advantages for students with low cognitive levels by viewing multimedia presentations. Multimedia as a learning tool that represents the main characteristic of science is a virtual laboratory. Virtual laboratories could potentially help students reinforce concepts and theories. The use of virtual reality was implemented in a study by [47]. They established a Virtual Engineering Sciences Learning Lab (VESLL) that provides interactive objects and learning activities, multimedia displays, and instant feedback procedures in a virtual environment to guide students through a series of key quantitative skills and concepts.

Role of multimedia as teaching tools helps teachers to deliver learning materials. The reliability of teaching material delivered by the teacher in a multimedia format presents an interesting experience for students. Students who struggle with learning material review as needed, on their own time, and gain mastery that can be used to build their learning experience . Several multimedia platforms can facilitate the participation of students with different skills, such as customized YouTube videos were explored as teaching materials in place of face-to-face discussion sessions in General Chemistry courses . Another multimedia that is used as a teaching tool is AR. A study by was to improve abstract reasoning in science learning using interactive multimedia based on AR. AR facilitates the students to reason by exploring more realistic visual objects to ease student understanding of science concepts, associating inter-concepts and implementation of information analysis, and problem-solving.

There are three forms of multimedia that can be used as assessments, which are pamphletsThree forms of multimedia can-based assessments have great potential for increasing fidelity to the constructs of interest and provide opportunities to measure learning outcomes that are hardly or not possible to be tested in paper-and-pencil assessments. Website is the most widely used multimedia for assessment. The website established, namely FAMLE, is a learning environment with various assessment tasks involving multimedia that measure performance, learning and knowledge, and that provide detailed data records to be computationally analyzed an,d displayed so that learners and teachers can immediately use the information to improve learning. Another technology form that can be used as an assessment is mobile apps. One study that used mobile apps for assessing students' competence is by Fonseca et al. The mobile app allows its use anywhere and at any time, creating an almost permanent contact of the students with the topic and allowing them to learn by solving exercises.

Multimedia can also be used as a Learning Management System (LMS). LMS is software that is used to create web-based online learning materials and manage learning activities and their results [28]. LMS was very beneficial to apply during the COVID-19 Pandemic [33]. The system facilitates the realization of educational practices and activities in the distance modality. The results indicate that the use of integrated LMS, such as Google Classroom, smartphones, and Google Meet, positively influence the active role of the students during the realization of the school activitieinfluencese of LMS such as Google Classroom allows teachers to post clear, organized directions and assignments for students to follow at their own pace. Online optional meetings are an opportunity for students to receive assistance, ask questions, and practice, and for teachers to assess their understanding and provide additional support as needed.

3.6. Science Content in Multimedia

In general, the science content is divided into integrated science, physics, chemistry, biology, astronomy, and earth & space science. We try to classify the science content categories based on the reviewed articles. Here, we summarize the broad categories that this science content falls into as mentioned in Table 3. We also describe any specific science content in multimedia used in the studies described by the literature we collected.

Table.3 Science Content in Multimedia

Science Content	Specific Topic	Reference(s)	Number of Studies
Integrated Science	Human Body System	(Parong & Mayer)	1
	General Science	(Debbag et al.); (C. H. Chen); (Sulisworo et al. [28]); (Salas-Rueda et al. [33]); (Shemy [35]); (Makransky et al.)	6
Biology	General Biology	(Iqbal & Sami [30])	

Science Content	Specific Topic	Reference(s)	Number of Studies
	Neuroscience	(Olitsky et al.)	1
	Physiology and Anatomy	(Zhan & So); (Ahied et al.); (Cheng & Beal [44]);	3
	Animal	(Harrison et al.)	1
	Population & Conservation	(August et al.[47]); (Zhan & So)	2
Physics	General Physics	(Iqbal & Sami [30]); (H. K. Wu et al.)	2
	Electromagnetic & Thermodynamics	(Moore [49]); (Zhan & So); (Gunawan et al.); (C. Wu et al.)	4
	Waves	(Hatsidimitris [37]);	1
	Forces and Motion	(Sullivan & Puntambekar [4]);	1
	Work, Energy, Energy Conservation	(Uzun & Yıldırım); (Zhan & So)	2
Chemistry	Ideal Gas Law	(Homer & Plass [46]); (Okeefe et al.)	2
	Organic Chemistry	(Pölloth et al.); (Moozeh et al.); (Jacobs et al. [48]); (Jordan et al. [29]); (Fonseca et al.); (Franco & Provencher)	6
	Periodic table	(Traver et al.)	1
	Inorganic chemistry	(Kristian)	1
	Chemical Bonding	(Vandenplas et al. [50])	1
	General Chemistry	(Richards-Babb et al.); (Ranga); (Amaral et al.); (Hight et al.)	4
	Biochemistry	(Harrison et al.); (Uyulgan & Akkuzu); (Levonis et al. [40])	3
	Green Chemistry	(Richards-Babb et al.); (Ranga); (Amaral et al.)	3
	Kinetic molecular theory	(Homer & Plass [46]); (Dwiningsih et al.)	2
	Atomic Structure and Chemical structures	(S. C. Chen et al.); (Andre)	2
Earth & Space Science	Groundwater	(Unterbruner et al. [31])	1
	Seismic Wave	(August et al.[47])	1

Science Content	Specific Topic	Reference(s)	Number of Studies
	Plate Tectonic, Earthquakes, Volcanoes	(Gray et al.);	1
	Rock Formulation	(Gray et al.); (Syawaludin et al.)	2
	Map Projection	(Heitzler et al.)	1
	Earth's climate	(Wiley [32])	1

Based on the data in Table 3, it can be seen from 60 articles reviewed, the authors mostly use multimedia to explain topics in chemistry. Since most chemical concepts are abstract, using such technological tools facilitates the teaching of new concepts. Moreover, presenting experimental operations visually allows for efficient use of time in chemistry teaching. Chemistry can be a challenging topic to learn and retain, even if students have already been introduced to them in a previous course. To teach learning material that often has misconceptions like chemistry, the learning designer tries to improve the quality of learning with multimedia. The use of multimedia in organic chemistry learning was carried out by. They suggest that visual representations can enhance understanding of experimentally related chemical phenomena, which may be too small to see or too abstract to experience. This is important considering that sometimes students have difficulty understanding chemical reactions at the molecular level.

There are several articles that define the use of multimedia in integrated science. Several articles have defined maps. The results obtained show that participants generally report positive opinions, digital mind maps are useful in strengthening, assessing and visualizing learning in general, making lessons more entertaining and offering ease, of use. Integrating Google Classroom on general science topics allowed these students to review the contents, consult multimedia resources, send the tasks and establish communication from anywhere [33]. It is very helpful to do teaching and learning activity during the COVID-19 Pandemic [33], [35]. The reperactivities of the COVID-19 Pandemic on education have driven many researchers to find a different style to provide interactive science content [35].

In the field of biology, research by explored the implication of teaching learning with multimedia in which students were involved in research projects teaching-learning very activities and behavioral tests on rats. They used digital storytelling (DS) and Social Networking (SN) to communicate with high school students for one semester. Multimedia as learning media also has the benefit to render objects that are hard to imagine- ne and turn them into three-dimensional al models, which makes them easier to comprehend. Most students argue that the human respiratory system is one of the difficult concepts that is considered as abstract science content.

Physics is the second most popular option for the category of science content in the articles reviewed. Multimedia learning in physics as an instructional tool has been developed as a means towards reducing cognitive load in the learning process [49]. By mixing auditorofisual presentations, meaningful learning can take place by helping the learner make connections between multiple representations of the same content without taxing limited capacity memory channels. The multimedia was applied in these stages to support the problem-solving process. For example, to solve problems with thermodynamic material correctly, the information presented in the interactive multimedia provides a contextual example.

The last science content category obtained from the reviewed articles is Earth & Space Science. Based on the 60 articles reviewed, 10 articles discuss the application of multimedia in Earth & Space Science learning. Using personal response systems as multimedia in Earth & Space Science learning facilitates teaching practice that relies upon conceptually-based test questions to assess student learning and determine whether students should discuss a given topic. To date, few studies have investigated whether factors other than student content knowledge influence their response. Multimedia provides interactive objects and learning activities, displays, and instant feedback procedures in a virtual environment to guide students through a series of key quantitative skills and concepts [47]. In addition, the results [32] suggest that animation showed the most accurate comprehension monitoring because readers were prompted to engage in generative, spatial thinking activity.

3.7. Trends and Issues

Schools now use a lot of technology, and increasingly more teachers are incorporating it into their lessons. Teachers can now use several digital tools due to recent advancements in educational technology. Simulation is the most researched multimedia in science education literature, especially in its role as a learning tool. In terms of the technology employed, many technologies can be used to create simulations, from the simplest (PowerPoint animation) to the most complex (eg vuvoria). The rapidly expanding usage of personal computers in virtually every aspect of life has also had an impact on science education. Many science educators think computer animation, also known as computer simulation, has a lot of promise to improve the teaching and learning of science subjects. Simulation is most widely used in learning chemical concepts that require multimedia assistance in visualizing abstract chemical concepts. Powerful visualization tools for scientific phenomena and abstract details have been made possible by recent breakthroughs in information technology and graphics. Additionally, visualization technologies can be utilized to make the invisible observable because molecular processes and abstract concepts are known to be a cognitive burden for high school pupils.

By assisting students in visualizing abstract concepts, simulations can help solve the challenges they face when combining the particle level with macroscopic and symbolic representations. By highlighting and facilitating access to relationships between representation levels, the use of such visualizations might lessen the cognitive load on the learner. Additionally, dynamic representations like animations and simulations make the interactive character of chemistry more obvious, assisting students in comprehending the vital particle interactions [50]. Topic complexity and textual explanations incorporated into program simulations appear to significantly impact knowledge acquisition. Certain components in a multimedia simulation can aid in these learning processes and enable students to organize information in working memory, which helps with the comprehension of the subject matter. When students are learning from computer representations, the role of a teacher is to provide exercises and questions in a way that encourages them to consider the underlying ideas and connections that are being introduced in the simulations and animations.

In terms of content, only chemistry has content-specific technology that can be practically directly used in learning using multimedia, namely ChemDraw as a molecule editor [56] and SciFinder as a database chemistry literature [57]. In addition, the results of the review show that the most variation in content distribution is in the chemical field, while earth and space have the least variation in content distribution. The fewest multimedia components are 3D components and illustrations. At the educational level, multimedia is still rarely applied to high school students. Based on the results of the review that has been carried out, recommendations for future research include:

- It is necessary to use simulations in the science field other than chemistry, especially to visualize abstract, dynamic, and complex concepts.
- Development of content-specific technology in the field of science other than chemistry that can be used practically in learning [58].
- Multimedia development using 3D components and illustrations is needed to visualize concepts in science content that require spatial view.
- Multimedia research is needed in high school student learning because the development of the cognitive level of high school students has entered the concept abstraction stage so learning activities are expected to facilitate the development of student’s cognitive abilities.

4. Conclusion

This systematic review aims to provide a systematic review of the scientific published studies that examined different multimedia tools in the science teaching and learning process to identify the existing multimedia-based tools and understand their usage, application areas, and impacts on the education system. There are 60 articles extracted from the Scopus database from 2012 to 2022. This review generates six averments about the current study; (1) The most numerous multimedia components are text components, namely as many as 29 articles because the text is very simple and is the most basic multimedia component. (2) From these data it can be concluded that the learning process and application of the use of multimedia in science education can be applied at various levels of education. However, the implementation at the teacher level is still not much compared to the teacher level (graduates). (3) Multimedia is employed in science learning in wide-ranging countries, but the USA is the leading country with the most studies about multimedia in science classrooms. (4) The use of technology in learning that is used is very diverse, but the current use of technology that is most widely used is the use of power points. This is in accordance with the first research question that the most widely used technology component is the text component. (5) the role of technology in the learning process as learning tools, teaching tools, assessment, and evaluation; and (6) the Science content used in science learning is earth and space science, biology, physics, and chemistry. However, the most science content is chemistry.

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