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Supported Technology on STEM-Based Science Learning: A Systematic Literature Review

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Abstract

This research aims to understand (1) the diversity of supported technology in STEM-based science education, (2) the application of supported technology in STEM-based science education, and (3) the advantages and disadvantages of supported technology in STEM-based science education. Supported technology refers to the tools and media used in education. This research is a qualitative systematic review using PSALSAR (Protocol, Search, Appraisal, Synthesis, Analysis, Report) method. The objects of this study are articles from Google Scholar, ERIC, and Scopus published between 2019 and 2023, referencing Yang & Baldwin (2020). The selection of articles followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. A total of 21 academic articles were examined. Validation was conducted by academic supervisors. The research findings revealed that the variety of supported technology is vast but has not been optimally utilized in Indonesia. The most commonly used media are e-modules and Google apps, which require mobile phones. Supported technology can create an engaging and non-monotonous classroom atmosphere, but if not controlled, it can foster individualism among students. Supported technology significantly assists educational activities, but still requires collaboration between schools, governments, and students.

Introduction

Affordability, dynamic, and participatory are making it possible to develop the information and communication technology industry quickly, basically on education field. Focaccia & Perez (2022) explained that every aspect of education has been profoundly impacted by the technology revolution, which involves the use of software, applications, and online platforms. The use of technology can be a daily habit for education students by reflecting the integration of technology in their learning experience. Technology can increase student motivation and positive beliefs regarding to students' individual needs on learning (Meisuri, et al., 2023). In science education, information or learning materials are easier to be accessed by technology. Digital technology enables science learning to be more interactive and involves students' engagement.

Science learning has interdisciplinary characteristics or the integration of science concepts, namely physics, chemistry, biology, earth and space science, technology, environment, and health and safety. This means that

science material is not studied monodisciplinary, but as an integration of all or some part of science fields. Hewitt, et al. (2013) stated that science is presented with a contextual approach. In this case, it means that science learning is related to daily life and contains problem solving that does not leave integrative properties with other fields. Therefore, strategies, approaches, methods, models, and learning techniques applied in science learning need to refer to these characteristics.

STEM (Science Technology Engineering Mathematics) is one of the approaches that can support science learning. Bybee (2010) states that STEM generates an understanding of disciplines that contain processes of inquiry, design, and analysis to recognize how STEM shapes the human life physically, intellectually, and socially. Wahyuni (2021) mentioned that the application of the STEM approach has been proven to be able to make learning atmosphere to be more active, which has a good impact on improving student learning outcomes. In addition, research by Fakhrudin, et al., (2023) stated that STEM encourages students to have problem solving skills, higher order thinking, loving nature, independent, and be responsible. STEM can integrate two or more disciplines in science learning. Educators who implement STEM-based science learning act as mentors who direct students to solve problems (Lathif, et al., 2019). The implementation of STEM learning cannot be separated from technology. Supported technology in learning is a tool that is used to manage, shape, teach, and activate students in learning activities. This study only focuses on learning tools and media.

The purpose of this study is to determine the diversity of supported technology, the application of supported technology, and the advantages and disadvantages of supported technology in STEM-based science education. This study used a systematic literature review method. Literature review is a written assessment activity of the researcher that displays the results of literature identification and analysis. The scope of the literature review includes a variety of complex and comprehensive subjects including findings from several studies (Syukri & Saepul, 2020). Kosztyán, et al. (2021) classified literature review in several types, that is narrative review, descriptive review, scoping review, critical review, meta-analysis, qualitative systematic, umbrella review, theory development, and realist review. This study applied a qualitative systematic literature review because it differs from traditional review that attempt to summarize the results of a number of studies. Systematic review uses clear and rigorous criteria to identify, critically evaluate, and synthesize all the literature on a particular topic. Parahoo (2006) proposed that systematic review should describe the time frame for selecting the literature as well as the techniques used to assess and synthesize study results. Reviewers should present appropriate standards for formulating research questions, setting inclusion or exclusion standards, selecting and obtaining literature, assessing the quality of literature included in the review, and analyzing, synthesizing, and disseminating review findings (Ramdhani, et al., 2014).

A literature review by Yang and Baldwin (2020) is a similar research that discussed the use of technology to support integrated STEM learning at the kindergarten to university level. Literature sourced from EdITLib (Education and Information Technology Digital Library), EBSCO (Education Research Complete), ERIC (Education Resources Information Center), Web of Science, and Google Scholar were published starting in 2000. The article was published in 2019, so our study continues by setting a limit of 2019 - 2023. According to a Google search, EdITLib is the University of British Columbia's digital library that is not accessible to researchers. EBSCO

is a database center with hundreds of additional databases, and Yang and Baldwin's (2020) article did not mention which databases are used specifically. Web of Science is also a database center in which searches do not yield journals or articles. Google Scholar and ERIC did not give significantly affect or obstacle on database accessing and journal article searching. Since Google Scholar and ERIC did not provide optimal search results, one additional database was added between Science Direct or Scopus. Science Direct's scope is not wide enough because journal articles only contain Elsevier publications, so Scopus was chosen as an additional database. Scopus is an international database and covers more publishers. Therefore, the databases used were from Google Scholar, ERIC, and Scopus.

Method

This systematic literature review research is a qualitative research with a literature review method in the form of journal articles. Specifically, the method applied is PSALSAR (Protocol, Search, Appraisal, Synthesis, Analysis, Report) which refers to Mengist, et al (2020). The sampling technique used the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The data collection technique was carried out by handpicking, namely by analyzing the contents of journal articles through skimming and regular reading techniques. The validity test was carried out by triangulation and checked by the validator.

The first stage of PSALSAR is protocol. The protocol includes determining the scope of the research, formulating research questions (problem formulation), and making research limitations. The scope of this research is supported technology in STEM-based science learning with limitations only in the form of learning tools and media. While the research questions are 1) How is the diversity of supported technology in STEM-based science learning from journal articles published on Google Scholar, ERIC, and Scopus? 2) How is the application of supported technology in STEM-based science learning from journal articles published on Google Scholar, ERIC, and Scopus? 3) What are the advantages and disadvantages of supported technology in STEM-based science learning from journal articles published on Google Scholar, ERIC, and Scopus?

The second stage is searching. The literature search was carried out using PRISMA stages which include identification (data collection), screening (filtering and selecting), and including (the stage of producing literature). The first search utilized the keywords that were input in the search field. There are 3 main keywords that are derived due to the needs of the search system in the databases, there are STEM, supported technology, and science education. Even though the derived keywords did not stray away from the core keywords.

Table 1. Keywords and Its Derivatives in Journal Article Searches

Main Keywords	Derivative Keywords
STEM	STEM = STEM education, STEM approach, STEM learning
Supported technology	Supported technology = technology, technology use, educational technology, learning technology
Science education	Science education = science, science learning

Based on the derived keywords above, a keyword test was conducted on the database which finally obtained the keywords that gave the most optimal results listed in the Table 2.

Table 2. Search Journal Articles by Keyword

No.	Database	Search keywords
1.	Google Scholar	STEM learning AND science education AND technology
2.	ERIC	STEM AND education AND science AND "technology use"
3.	Scopus	STEM AND education AND science AND "learning technology"

PRISMA cannot be separated from the inclusion and exclusion criteria that make it easier for researchers to select journal articles. If a journal article meets the inclusion criteria, it will be accepted, and if a journal article contains these criteria, it will be eliminated.

Table 3. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Journal articles on the topic of technology use in science learning	Journal articles that cannot be accessed
Journal articles that published on Google Scholar, *ERIC, Scopus*	Duplicate journal articles (previously found)
Journal articles published in 2019 - 2023	Journal articles that are not complete (not full text)
	Journal articles in the form of literature reviews, books, websites.

Appraisal is an assessment stage that includes literature assessment and quality assessment. Literature appraisal involves re-checking the inclusion criteria and exclusion criteria. While the quality assessment consists of 2 questions as follows:

QA1: Does the journal article that was discussed support technology in learning?

QA2: Is the journal article in the form of Classroom Action Research or contains classroom experiments?

The synthesis stage consisted of extracting and classifying data from the selected journal articles, which were then processed and classified in tables. The analysis stage involves evaluating the synthesized data and extracting meaningful information and summarizing the selected journal articles. At this stage, the research questions formulated will be answered. The last stage, namely reporting, consists of a description of the procedures followed and public presentation which results are like journal articles.

Results and Discussion

The results of searching for journal articles using the PRISMA stages are in Figure 1. The results obtained 21 journal articles. These results have gone through the quality assessment (QA) stage as the final assurance that the journal article qualifications are in accordance with the needs. The diversity of supported technology contained in

the 21 journal articles is shown in Table 4.

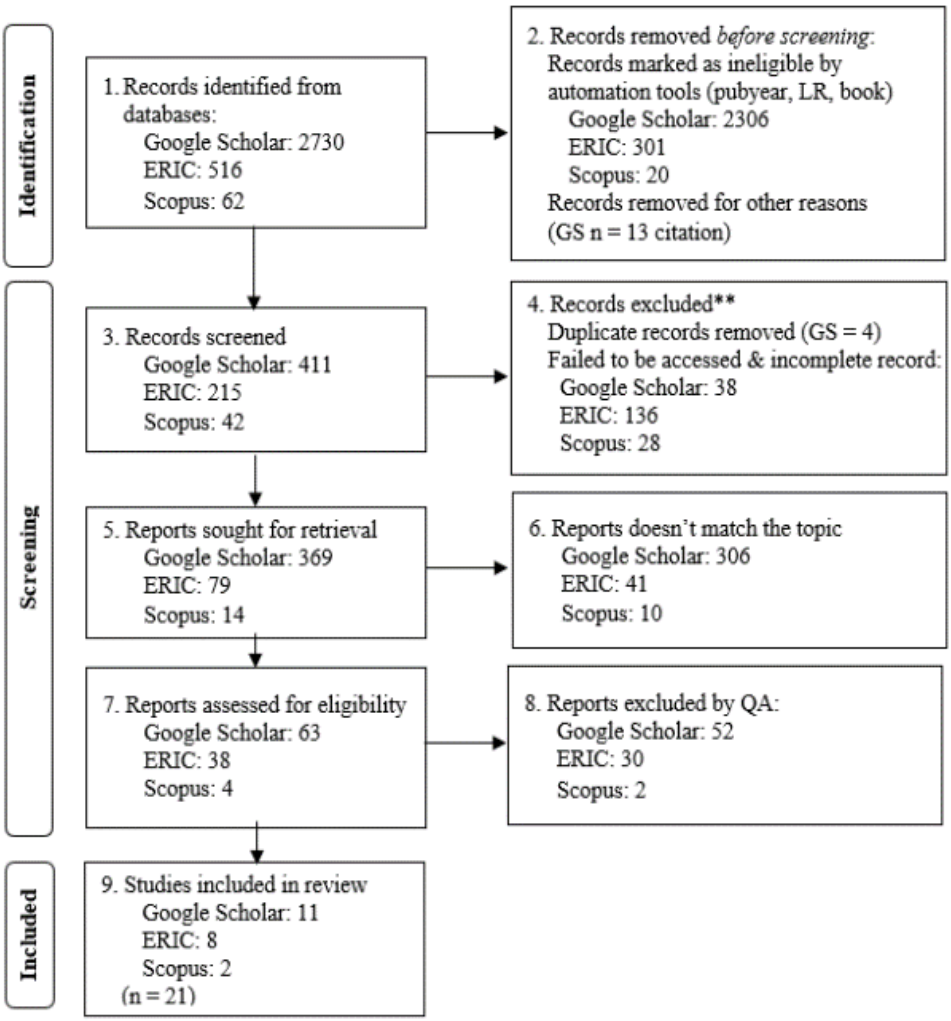

Figure 1. Result of Article Search Using PRISMA 2020

Table 4. Types of Supported Technology Used in Journal Articles

Number	Author Name	Name of Supported Technology
1.	Weni Anissa Putri, Eliyawati, Yayan Sanjaya	Google Meets, Whatsapp, Digital Storytelling Video – Media
2.	Imam Setiawan, Sudarmin, dan Partaya	Learning modules, internet, Whatsapp – Media Device – Tool
3.	Riski Inayah, Prima Aswirna, Allan Asrar	E-modul – Media Canva
4.	Dyah Pramesti, Riezky Maya P., Nurma Yunita I.	Learning stimulation video – Media
5.	Z Zulirfan, Y Yennita dan M Rahmad	*Smartphone*, *internet* – Media
6.	Darul Agustiana Ma'rifah, Eka Cahya Prima	Android mobile phone, Arduino UNO - Media
7.	Firdha Sarah Kartini, Ari Widodo, et al.	Zoom Meeting, Google Classroom, Whatsapp - Media

Number	Author Name	Name of Supported Technology
8.	Inayah Al Fatihah, Murni Ramli, Dwi Teguh Rahardjo	ThinkLink platform, internet, Google Form - media
9.	Dwi Prasetyo, Aditya Marianti, Siti Alimah	*E-module*, Mobile Android Phone - Media
10.	Jaka Afriana	Digital media, internet, Google Form, Powerpoint, Google Site - Media
11.	Yatin, Zaenal Abidin, Asep Ginanjar Arip	E-Module, Canva - Media
12.	Ahmad F. Saad	Blog (web 2.0) - Media
13.	Alexander C. Chang, Noelle J. Machnicki, et al.	Science Discovery Lab, Cisco WebEx, Zoom - Media
14.	Randall Spain, Carlos Penilla, Elizabeth Ozer, et al.	Health Quest Career Adventure Game - Media
15.	Garth Groshans, Patricia Carbajales-Dale, Elena Mikhailova, et al.	ESRI digital story map, Powerpoint - Media
16.	Jane Elizabeth Casey, Lisa K. Pennington, Dallas Lopez	Floor Robot – Tool
17.	Bekir Yildirim, Gokhan Arikan, et al.	Virtual Reality Cardboard (Google Cardboard) - Media
18.	Tine Pajk, Karel Van Isacker, et al.	Perangkat EEG (electroencephalography) – Tool Mobile application - Media
19.	Margarida M. Marques dan Lúcia Pombo	Mobile phone, Augmented Reality Games– Media
20.	L A Sanjaya, I Nurkho-lis, B H Iswanto, et al.	E-module – Media
21.	Nittayaporn Kinboon	Website, internet, multimedia, e-book - Media

The use of smartphones, video conference (Google Meet, Zoom Meeting) and social media such as Whatsapp is very familiar in learning and has become more prevalent since Covid-19 emerged. This pandemic has brought the impact of the development of technology quickly through the world. Technological advances in the field of education are able to encourage educators to further increase their creativity in selecting or making media or using learning technology. Research by Imam Setiawan, et al. (2023) explained that the use of Whatsapp groups was chosen because students find it easier to communicate and understand instructions via Whatsapp. Zulirfan, et al. (2020) used Android in online learning during Covid-19 because 75.3% of students have Android and 90.6% of students are able to operate it and its flexible use.

International journal articles show a higher variety of supported technologies when compared to Indonesian research journal articles. The level of difficulty and challenge of implementing these technologies is also higher. The use of high-level technologies such as Augmented Reality, Virtual Reality, Games, Virtual Laboratories, and others are not yet massive. Margarida, M et al (2021) held a workshop first to equip teachers in Portugal about making AR Games. The survey also showed that many teachers had never used AR or game-based learning before.

When viewed from the intensity or quantitatively, e-modules and Google apps (Google Classroom, Google Site,

Google Form, Google Meet) are most often used to support the learning process. Then followed by Whatsapp, apps (Electree and ThingLink), Zoom, and so on. So, it can be concluded that the use of the top three technologies is quite massive among STEM-based science learning, especially in Indonesia because all three are found in Indonesian research. A quantitative comparison of the use of supported technology reviewed from journal articles can be seen in Figure 2.

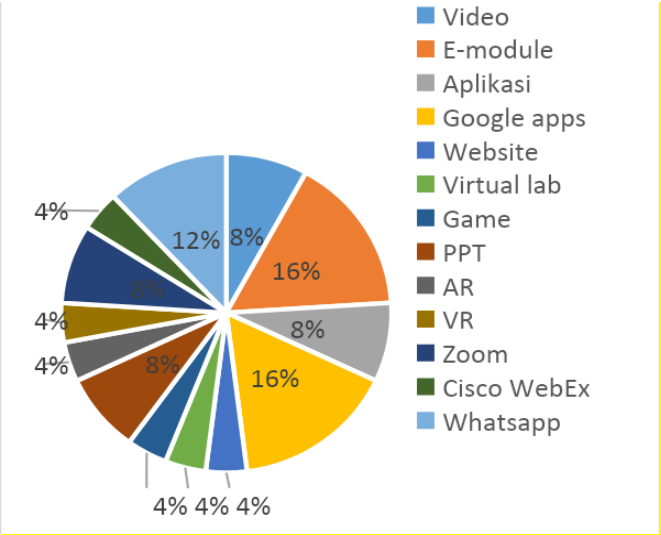

Figure 2. Graph of Supported Technology Types

The application of supported technology in journal articles is in Table 5.

Table 5. Types of Supported Technology Used in Journal Articles

Number	Supported Technology	The Application of Learning Technology
1.	Google Meets, Whatsapp – Media Digital Storytelling Video – Integrasi STEM	Google Meets, Whatsapp as online learning tools. Digital Storytelling Video is a learning output from students in the form of a video of them telling stories about additives in food.
2.	Learning modules, internet, Whatsapp, device - Media	Modules with traditional food ingredients are presented in flipbook form with pictures and videos (QR code). This module is shared through Whatsapp group during online learning.
3.	E-module – Media Canva	This e-module was created with the help of Canva which combines STEM with local wisdom, namely the Gordang Sambilan musical instrument. This e-module is used for vibration, wave and sound materials.
4.	Learning stimulation video - Media	Videos about global warming and energy crisis were shown at the beginning of the lesson to stimulate students in formulating problems.
5.	*Smartphone, internet* - Media	A total of 90.6% of students can access smartphones for online learning, the rest are given printed versions of books and delivered

Number	Supported Technology	The Application of Learning Technology
		manually. Smartphones that had internet access were used.
6.	Application, Android mobile phone, Arduino UNO – Media	The Electree application contains electricity material customized to the syllabus, projects using Arduino UNO and quizzes. Then access the application using Android for each teacher and student.
7.	Zoom Meeting, Google Classroom, Whatsapp - Media	Online learning takes place through Zoom meetings and Google Classroom, while Whatsapp is used as a communication medium only.
8.	ThinkLink platform, internet, Google Form - media	ThinkLink contains material information, along with project assignments connected to Google Form.
9.	*E-module*, Mobile Android Phone - Media	E-modules contain environmental pollution material that is accessed via mobile phone.
10.	Media digital, internet, Google Form, Powerpoint, Google Site - Media	The experimental class used digital media with internet access such as smartphones/tablets to search for cement sources meanwhile control class only used books. Google Form as a platform to measure student learning outcomes in both classes. In addition to the test, students also worked on the final project on the topic of environmentally friendly technology by creating Powerpoint presentation media uploaded through Google Site.
11.	E-Modul, Canva - Media	The use of e-modules was not explained in detail, the researcher/writer only explained that e-modules were used in learning environmental pollution material in the experimental class.
12.	Blog (web 2.0) - Media	Blogs have been used since September 1, 2018 to train students to get used to using electronic media before data collection. The 2nd blog is accompanied by a project to make a smart home prototype using the Arduino system.
13.	Cisco WebEx, Zoom Meetings, Google Classroom - Media	Labs for conducting research or experiments related to biochemistry, immunology and immunotherapy, public health are transformed into video conference labs. Cisco WebEx and Zoom as discussion media. Google Classroom to upload presentation slides, Q&A documents, and materials.
14.	Health Quest Career Adventure Game - Media	A 3D commercial game filled with narrative and exploration of health and science careers. The game consists of several episodes with virtual characters that students can interact with in a given problem. It also includes a video role model.
15.	ESRI digital story map and Power point (PPT) - Media	Both are used as learning media and their effectiveness will be compared through posttest and survey. This story map is a combination of storytelling and geovisual analysis, so it is

Number	Supported Technology	The Application of Learning Technology
		interactive. The story map is in the form of pages, different from PPT which is in the form of slides.
16.	Floor Robot – STEM Integration	The Roamer floor robot has a code on its surface to make it move. While the Thymio robot has color clues that have meaning in each color.
17.	Virtual Reality Cardboard (Google Cardboard) - Media	This VR technology requires a smartphone or tablet and is assisted by the Google Expedition app. The teacher guides the expedition while students act as explorers through 3D videos. This VR can be used to visualize astronomy, biology, literature, mathematics, foreign languages, geography, and physics.
18.	EEG Device (electroencephalography) – Measuring tools Mobile applications - Media	EEG serves to measure the brain's electrical activity (concentration intensity) with electrodes attached to the participant's head during the stages. Monitoring was conducted using Neuro Experimenter software version 6.1.4.
19.	Mobile phone, Augmented Reality *Games*– Media	The teacher workshop developed a mobile AR game and then applied it in learning. The process of creating or using the technology was not explained in detail, including the materials and classes that were used.
20.	*E-module* – Media	The e-module is in the form of a website with the name WoPI (Website of Physics Instructional) which can be accessed through various devices. There are several topics in the STEM-based rotational dynamics e-module. Topics that have been studied will change color to green while those that have not been studied or have not been accessed are gray.
21.	*Website*, internet, multimedia, *e-book* - Media	The media is used by students in order to find more information related to material content.

Almost all journal articles stated that the use of technology helps the learning process to be interactive. Six of the eleven Indonesian journal articles applied the Project Based Learning (PjBL) model with positive results. It means that the integration of STEM PjBL and the application of technology was successful.

One of the applications of STEM PjBL is in the research of Imam Setiawan, et al. (2023) which used e-module media. Imam and his team made an e-module for junior high school students with simple and communicative Indonesian language, illustrations, and several videos which connected via QR codes. The integration of technology in Ethno-STEM (STEM based on local wisdom) was also quite strong here, namely by introducing bomb calorimeters and glucometers. The e-module applied local wisdom to the topic of food ingredients which contains local food exploration projects. The application of this e-module implemented in online learning. Yatin, et al. (2023) mentioned that Canva application were used in making the e-modules. The students' response questionnaire regarding the use of e-modules with Canva media produced a percentage of 94%, which means

students felt a positive influence from this e-module.

The use of the Electree application made by Darul Agustiana Ma'arifah and Eka Candra (2020) received good responses from teachers and students. Of course, the Arduino project also contributes a big role in the implementation of electrical concepts by students. The Arduino lab setting platform was chosen because of its simple programming form and the variety of equipment make it suitable for beginners such as junior high school students.

Virtual lab used in VRTP (Virtual Research Training Program) by Chang, et al. (2021) transformed a science lab into a movie studio with the separation of lecture and laboratory demonstration areas. This demonstration can be done whenever the students are going to do the experiment. So, the form of the demonstration is like live streaming via WebEx video conference which is also uploaded on Youtube afterward.

Margarida M. Marques and Lúcia Pombo (2021) held a workshop for teachers in Portugal on Augmented Reality (AR) games for STEM learning which will then be implemented by teachers in their respective classrooms. Margarida and Lúcia did not explain much as they were not directly involved in the classroom. Instead, they monitored from the outside and investigated the results after the lesson was over. Nonetheless, this case study succeeded in providing a new breakthrough because none of the twelve teachers who participated in the workshop had previously implemented game-based learning by utilizing AR.

In contrast to AR, Virtual Reality (VR) applied by Yildirim, et al. (2020) gave a more detailed impression because the learning process is explained. The subjects in Yildirim, et al. research are teachers, the same subject as the article from Margarida, et al. There are seven teachers who apply Google Cardboard and Google Expeditions to implement VR. Google Cardboard version 3.0 is connected with *smartphone* to runs VR applications and displays 360° videos. VR Cardboard is a set of head-mounted devices to observe the visualization of objects.

The application of technology certainly has both positive and negative effects on learning. An analysis of the advantages and disadvantages of supported technology helps dissect them. Table 6 shows an analysis of some supported technology.

Table 6. Advantages and Disadvantages of Supported Technology in Journal Articles

No.	Supported Technology	Advantages	Disadvantages
1.	Video story telling	Making video activity will increase students' creativity, in terms of animation, storytelling, and audience understanding.	Some students didn't put much effort into making the video so the results were rough and less than optimal.
2.	Whatsapp	Often used for online learning because it is simple and easy to use. The communication features can be through messages, voice	(Not explained)

No.	Supported Technology	Advantages	Disadvantages
		massages, video, and group video calls.	
3.	E-module	The flexible media, easily accessed by smartphones (Zulirfan, et al, 2020).	Because online e-modules require an internet network, it will cause difficulties for those who are network constrained (Yatin et al, 2023).
4.	Smartphone Android	It is making students not getting bored, the presence of images stimulates student curiosity, provides a new atmosphere (Yatin et al, 2023).	Not all students have smartphones or internet packages, so teachers have to keep working twice because they need to provide printed teaching materials (Zulirfan, et al, 2020).
5.	Application Electree	Fast and flexible usage (Zulirfan, et al, 2020).	(Not explained)
6.	Arduino Uno	It can encourage teacher and students' creativity effectively, efficiently, and flexibly (Prasetyo, et al, 2021).	(Not explained)
7.	Thinklink web service	Easily accessible to teachers and students, can be used by students to study at home, the material is easy to understand, attracts students' interest in learning.	(Not explained)
8.	Cisco WebEx	It can develop learning ideas, fast and easy to use by novice programmers, and increasing creativity	(Not explained)
9.	Streaming tools (laptop, camera, mobile phone, head-sets with microphone, audio, LED lights)	It is making diverse content (pictures, videos, music, text) and interactive (can be function like Powerpoint animation)	The equipment is not optimal but adequate. It will be equipped further.
10.	Health Quest Career Adventure Game	Easily accessible to students with computers and mobile phones, which are equipped with recording and Q&A features. Also to form small groups.	Students experience time constraints in loading the game page and talking with the teacher (the game will be made offline/ downloadable version). A demo account is needed for in order to master the game.
11.	Floor robot	It provides a new and modern experience.	Inadequate quantity of floor robot. The price of floor robots is expensive.
12.	VR Cardboard	(Not explained)	Teachers must have adequate

No.	Supported Technology	Advantages	Disadvantages
	(Google Cardboard and Google Expedition)		computerization skills. Socialization in learning is low because students rarely interact with their friends.
13.	AR Games	It can train the metacognitive skills of elementary school students. As a unique teaching tool that can attract students' interest.	Students are easily distracted. The quality of the internet network affects the smoothness of learning. Teachers often lack time to teach the whole material when applying this media.

Learning support technology provides significant advantages, such as easy access to information from anywhere and anytime, enabling students to learn at their own pace and style, and enriching learning methods through multimedia and interactive simulations. However, challenges such as the digital imbalance inequality can hinder equal access to technology, leading to an increase in the education gap. Moreover, over-reliance on technology can also disrupt the balance between technology use and social interaction, and increase the risk of mental and physical health problems. It is important for educators and policymakers to develop strategies that ensure effective and inclusive use of learning technologies, with a holistic approach that takes into account individual needs and supports equal access. As such, learning technologies can be a powerful tool in improving the quality of education and preparing future generations for the challenges of an increasingly complex world.

Conclusion

Supported technology is a product that can be used as a support or supporter of learning and teaching activities which specifically leads to media, tools, and technology integration of STEM in science learning. The analysis revealed that supported technology discussed in 21 journal articles which includes e-module, website, application, mobile, video conference, AR (Augmented Reality), VR (Virtual Reality), virtual lab, Google apps (Google Classroom, Google Site, Google Form), Microsoft PowerPoint, and games. The application of supported technology cannot be separated from the existence of basic technological devices such as smartphones, internet, and devices in order to access it. The use of supported technology certainly has a good impact on learning because it helps students to get a better understanding in science concepts, attract students' interest in learning, introduce students and teachers to technology literacy, etc. Each technology has its own advantages and disadvantages. Therefore, improvements and updates need to be made for progress, especially in the field of education.

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