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Implementation of STEAM in Science Learning: A Systematic Literature Review

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Abstract. The development of science and technology is growing rapidly in the 21st century. The development of science and technology is needed to support human resources to produce quality education. Integrated learning is important to improve student learning outcomes. This research was conducted by analyzing data from articles to find out: 1) the objectives, methods, and results of research on the implementation of STEAM (Science, Technology, Engineering, Art, and Mathematics), 2) the application of science concepts and the level of education in the implementation of STEAM, and 3) the integration of learning models/media in the implementation STEAM in science learning. A systematic literature review articles using the Prisma design in the 2015-2020 period in the Scopus and Google scholar databases found 11 articles related to the implementation of STEAM in science learning that met the criteria. The results showed that there were three categories of research objectives in the implementation of STEAM, the experimental method was the most widely used and all research results showed learning outcomes in accordance with the research objectives. The application of concepts in the implementation of STEAM in science learning is divided into fields of science such as physics, chemistry, and biology. Senior high schools dominate the implementation of STEAM in science learning, followed by junior high schools and elementary schools. In addition, the implementation of STEAM can also be integrated with various models, modules and learning media. Next, STEAM learning can be designed for prospective elementary school teacher students to gain experience for learning in the classroom later.

Key words: STEAM education; science learning; systematic literature review.

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INTRODUCTION

The 21st century is known as the era of science and technology. Knowledge and technology are needed in the 21st century to support the quality of human resources. The quality of human resources can be realized through education. Through education, a person can pass on his experiences and habits so that it is useful for training abilities and skills. Humans need education to become intelligent, noble, independent, and useful individuals for society and the nation. The integration of STEAM (Science, Technology, Engineering, Art, and Mathematics) into education can produce quality human resources who are able to compete in the 21st century.

STEAM is an acronym for Science, Technology, Engineering, Art, and Mathematics. The STEAM approach is expected to be able to bring new energy to the learning process in the modern classroom. Science, Technology, Engineering, Art, and Mathematics (STEAM) can be defined as a teaching approach in which students demonstrate critical thinking and creative problem solving in the fields of science, technology, engineering, art, and mathematics. STEAM is an approach to learning; STEAM is also a way for students to engage with interdisciplinary topics and to integrate the arts into the school curriculum.

In general, the characteristics of STEAM itself are as follows: (1) Introducing the concept of a Scientific approach, namely a learning approach that provides opportunities for students to gain learning experiences through observing, asking questions, gathering information, associating, and communicating. (2) Introducing learning with aspects of Science, Technology, Engineering, Art, and Mathematics. (3) Involving the natural environment as the main media to introduce learning that has STEAM elements. (4) Activities are collaborated with the curriculum and themes that have been identified by the institution. (5) This approach is implemented by utilizing existing materials in the surrounding environment, in the form of learning activities whose content and delivery media are linked to the natural environment, social environment, and cultural environment.

Several studies have shown advantages regarding the application of the STEAM approach in learning. According to Nurhasanah & Zelela (2021) through STEAM innovative learning in elementary schools, students have direct experience so that they build a more meaningful understanding of learning materials.

Wijayanti & Fajriyah (2018, 2020) stated that STEM Project Based Learning can improve scientific work skills and scientific literacy skills. The application of STEAM is needed both in the disciplines of science, technology, engineering, art, and mathematics as well as in everyday life. The results of the research conducted showed that the experimental group students who applied STEAM showed the physical characteristics of scientists from a broader perspective (Duban et al., 2018).

The application of integrated thematic learning and scientific approaches to the 2013 curriculum in elementary schools can be integrated with the STEAM approach. Learning activities in the 2013 curriculum have been developed based on themes, sub themes and lesson content that are adapted to the lives and environment of students. Teachers can invite students to relate the material being studied with real experiences or examples in students' daily lives, so that students are able to identify and analyze the knowledge gained, express ideas and determine attitudes to create simple works as a real embodiment of achieving cognitive, affective, and learning outcomes. psychomotor on an ongoing basis. STEAM learning has an influence on students' creativity and can be a learning solution for students in dealing with technological developments that are combined with science. In addition, there is also the effect of STEAM learning through Problem Based Learning on student learning outcomes (Arsy & Syamsulrizal, 2021; Widodo et al., 2021).

Several studies related to STEAM still have limitations, such as only determining the effect or effectiveness of one dependent variable, limited to one material or subject, carried out at one grade level. Based on this description, the authors are interested in conducting a systematic review related to the implementation of STEAM in science learning and the effect or effectiveness of STEAM learning on student learning outcomes. This study analyzes several studies that discuss the effect of STEAM education on student learning outcomes. The application of STEAM in learning in schools is the subject of discussion in this study. This integration of STEAM learning combines two or more disciplines in learning that follows a real-world context. Students will more easily understand the lessons at school.

This study uses a literature review that is presented systematically, the selection of articles included in the analysis is carried out based on defined criteria and explained with specific criteria (Higgins et al., 2019). In addition, the selection process was designed according to the PRISMA design.

The questions used to compile a systematic review of STEAM implementation in science learning include:

1. What are the objectives, methods, and results of research on the implementation of STEAM in science learning?
2. How is the application of the concept of science and the level of education in the implementation of STEAM in science learning?
3. How is the integration of learning models/media in the implementation of STEAM in science learning?

METHODS

This study aims to identify the implementation of STEAM in science learning. Relevant research data were collected from Scopus with the keywords 'steam education', 'science learning' during the period 2015-2021. Search using vosviewer to retrieve Scopus and Google Scholar databases.

The article selection procedure using the article selection process is designed according to PRISMA principles. A literature search was performed using an electronic database search and a manual search of specific journals to ensure more complete coverage. Articles will be excluded, if they do not involve the practice of implementing STEAM in science learning. A total of 1120 sourced from the Scopus and Google Scholar databases, have been identified into 11 articles that meet the established criteria.

The inclusion criteria applied to the search results are as follows:

1. Journal articles or international seminar articles are written in English.
2. Articles using the terms STEAM, STEAM education, science, science learning, appear in the title, abstract or keywords.
3. The article presents the implementation of STEAM in formal education to achieve learning objectives
4. In the article there are instruments to measure the dependent variables related to learning outcomes such as understanding concepts, motivation, creativity, and so on
5. In the article there are conclusions regarding the impact of STEAM implementation on the dependent variable

The data extraction procedure based on predefined criteria is shown in the following flowchart:

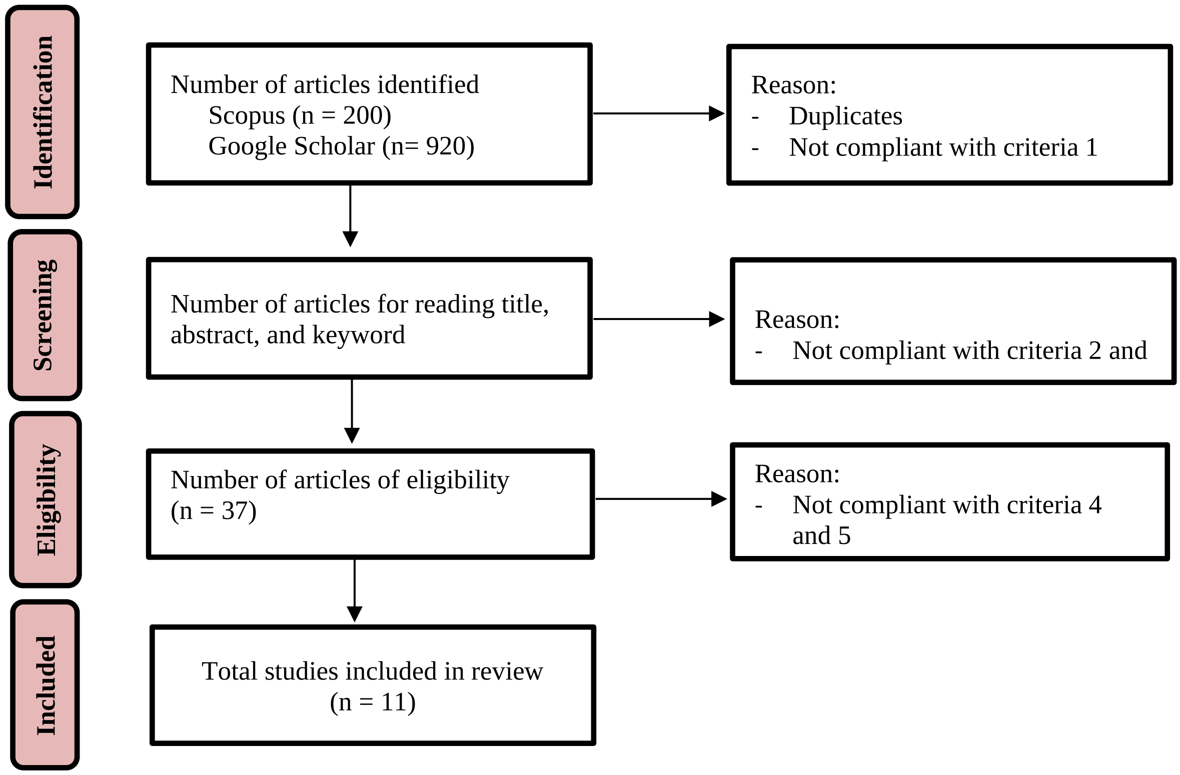

Figure 1. Article Selection Procedure Flowchart

RESULTS AND DISCUSSION

Table 1 shows the identification of synthesis data from 11 studies on the implementation of STEAM in science learning that are included in the systematic review including: name of author, year of publication, country, research objectives, model/media/tool, and level of education stage.

Table 1. Article Synthesis Data Identification

Author	Year	Country	Aims	Model/ Media/Instrument	Level/Class/ Ages
Gulbin Ozkan & Unsal Umdu Topsakal	2020	Turkey	to investigate the effectiveness of STEAM education on fostering 7th-grade (aged 13–14 years) students' conceptual understanding of the topics of force and energy.	-	7th-grade
Gulbin Ozkan, Unsal Umdu Topsakal	2021	Turkey	to develop a science, technology, engineering, art, mathematics (STEAM) design process program for teaching 7th grade middle school students to enhance their verbal and figural creativity	-	7th Grade students at a Middle School in Istanbul, Turkey
Peng-Wei Hsiao, Chung-Ho Su	2019	Taiwan	To integrate STEAM education into VR-aided traditional culture experience	Integrate experiential VR	Elementary School

			courses and investigate the effects of this immersive system on the students' learning motivation, satisfaction, and outcomes.		
Wachirawit Ritmuan et al.	2020	Thailand	This study aims to examine students' understanding of ceramic after the implementation	Based learning activity	High School Chemistry
Yangyang, et al.	2020	China	This research designed an integrated STEAM and Maker approach to primary education by utilizing the framework of engineering design to understand whether students' learning motivation, selfefficacy, and acquisition of interdisciplinary STEAM	-	Third-grade pupils
Anjar Putro Utomo et al.	2020	Indonesian	to examine the effectiveness of STEAM-based biotechnology module.	based biotechnology module equipped with flash animation	Biology Learning in High School
Ni Komang Dina Suciari et al.	2020	Indonesian	to examine the effect of biology learning	PjBL, making aquaponic and greenwall project	Biology Learning in High School
Adriyawati et al.	2020	Indonesian	to find out how the integration of STEAM-Project-Based Learning (STEAM-PjBL) was applied with the aim of developing students' scientific literacy.	PjBL	Elementary School
Liliawati et al., 2018	2021	Indonesian	to apply STEAM approach to learning with 'Theme Water and Us' to know the improvement of mastery of science concept of junior high school students.	-	Class VII junior high school.
Chien-Liang Lin, Chun-Yen Tsai	2021	Taiwan	to enhance the project competence and learning motivation of the students in the experimental group	designed PBL learning activities	High school
Achmad et al.	2021	Indonesian	to develop higher order thinking skills, information and literacy skills, self-direction, and collaborative skills	project-based learning model	High school class 10 and 11.

Table 2. Aims and Research Design

Aims	Research Design
Research Aim 1	- mix method - experimental research using the one-group pre and post-test design - design model for development of r2d2 with one group pre and post-test design - descriptive statistics were applied to the data and a paired-sample t-test was run to determine the self-efficacy changes before and after the course - quasi with nonrandomized control group pre and post-test design
Research Aim 2	- pre-experimental with one group pre and post-test research design - a quasi-experimental design was adopted in the study - qualitative methodology
Research Aim 3	- a pre-test/post-test quasi-experimental design, - a qualitative research method

1. Objectives, methods, and research results of STEAM implementation in science learning

The results of the analysis of the research objectives of the articles in table 1 can be categorized into 3 research objectives. The results of the analysis of the research objectives of implementing STEAM in science learning are the first to determine the effectiveness of STEAM learning on various types of learning outcomes, such as understanding the concept of force and energy, understanding ceramic concepts, student learning motivation, self-efficacy, and scientific literacy of 54.54%. The second research objective is to improve conceptual understanding, grow project competence and learning motivation and to develop higher order thinking skills, information and literacy skills, self-direction, and collaborative skills by 27.27%. The purpose of the next research to develop and determine the implementation of STEAM in science learning is 18.18%.

Table 2 shows the research design used in the three categories of research objectives. The results of the analysis of the first research objectives were to determine the effectiveness of STEAM learning on various types of learning outcomes using a mix method design, experimental research using the one-group pretest-posttest design, design model for development of r2d2 with one group pretest-posttest design, descriptive statistics were applied. to the data and a paired-sample t-test was run to determine the self-efficacy changes before and after the course, quasi experiment with nonrandomized control group pretest-posttest design. The second research objective is to improve conceptual understanding, grow project competence and learning motivation as well as to develop higher order thinking skills, information and literacy skills, self-direction and collaborative skills using a pre-experimental design with one group pretest-posttest research design, a quasi-experimental design was adopted in the study, and qualitative methodology. The third research objective is to develop and determine the implementation of STEAM in science learning using a pre-test/post-test quasi-experimental design, a qualitative research method.

All research results show learning outcomes in accordance with the expected research objectives. There are 2 research results that mention research weaknesses, such as the relatively small sample size and applied to certain classes and levels (Ozkan et al., 2020; 2021). The results of the STEAM learning research study show that STEAM learning has a positive influence on several learning outcomes, such as conceptual understanding, higher-order thinking skills, cooperative skills, self-efficacy, learning motivation and scientific literacy. High-level thinking skills as critical and creative thinking (Ariyana et al., 2018). Critical and creative reasoning is a dimension of the Pancasila student profile, so STEAM learning can be used to support the achievement of student profiles that are able to analyze and evaluate all information and ideas well obtained, able to evaluate and reflect on their own reasoning and thinking, understand and solve social problems as opportunities to improve the quality of life for themselves and their communities (Fisher, 2011; McPeck, 2016; Hasibuan et al., 2022; Manikutty et al., 2022).

2. Application of the concept of science and level of education in the implementation of STEAM in science learning

The application of concepts in the implementation of STEAM in science learning which is divided into several fields of science. The implementation of STEAM in science learning Physics on force and energy, Chemistry on hydrocarbons and ceramic concepts, and Biology on Biotechnology are 18% each. The implementation of STEAM in science and mathematics learning was 9%, and 36% did not mention the details of the material presented in the lesson.

High school was the most common place for research studies (45%), followed by junior high school and elementary school each (27%). These results indicate that there has been no research related to STEAM that has been carried out at the tertiary level for prospective teachers, especially prospective elementary school teachers.

In implementing STEAM learning to the fullest, it can be started by identifying student characteristics to meet student needs. The results of the research study have not found STEAM learning that accommodates the needs of students in detail. Differentiation learning is a learning model framework that pays attention to students' potential to meet the diverse needs of students (Tomlinson, 2014: Porta et al., 2022). The use of learning strategies that are appropriate to student learning styles will help students understand the material and focus on learning in class (Morgan, 2014).

3. Integration of learning models in the implementation of STEAM in science learning

Table 1 shows the integration of the learning model in the implementation of STEAM in science learning. From 11 articles, it was found that 36.36% of STEAM implementation in science learning was carried out without the integration of any model or media, the implementation of STEAM in science learning using PBL and PjBL (Project Based Learning) integration was 18% each. Implementation of STEAM in science learning using virtual reality experiments, module-based using flash animation media and learning activity-based each of 9%.

The application of STEAM learning can be equipped with complete learning tools, such as learning implementation plans using project-based learning model syntax, teaching materials, learning media, student activity sheets, and assessment sheets, so that they can meet the expected learning outcomes. STEAM learning can also be linked to students' local wisdom. STEAM learning media with local wisdom can improve student learning outcomes (Fatchurahman et al., 2022). Pebriani et al (2022) added religious value to STEAM learning so that it became STREAM. STREAM-based teaching materials using SAC 3 are proven to increase students' scientific literacy. STEAM learning which contains religious values in it is expected to be able to train students or students in growing one of the Pancasila student profiles namely faith, fear of God Almighty, and noble character. In addition, applying local wisdom to learning can train students' nationalism (Yoseptry, 2022) so as to train the profile of Pancasila students on the dimensions of global diversity.

The project-based learning model is the most widely used learning model in STEAM implementation. Project-based STEAM learning is carried out in groups to complete projects together. In group activities students are trained to be able to work together with friends and be able to share together (Owens & Hite, 2022; Harjanty & Muzdalifah, 2022). This is in accordance with the elements of the mutual cooperation dimension in the Pancasila student profile so that project-based STEAM learning can be used as an alternative in growing the profile of Pancasila students on the mutual cooperation dimension.

CONCLUSION

The results of the literature review show that there are three categories of research objectives in the implementation of STEAM, the experimental method is the most widely used and all research results show learning outcomes that are in accordance with the research objectives. The results of the analysis of the objectives of the research article show that the implementation of STEAM can improve conceptual understanding, student learning motivation, self-efficacy, scientific literacy, and develop higher order thinking skills, information and literacy skills, self-direction, and collaborative skills. The application of concepts in the implementation of STEAM in science learning is divided into fields of science such as physics, chemistry, and biology. Senior high schools dominate the implementation of STEAM in science learning, followed by junior high schools and elementary schools. In addition, the implementation of STEAM can also be carried out without integration and is integrated with models, modules or learning media, such as PBL, PjBL, virtual reality experiments, module-based using flash animation media and learning activity-based. Next, STEAM learning can be designed for prospective elementary school teacher students to gain experience for learning in the classroom later.

The results of the STEAM learning research study show a positive or effective influence on several learning outcomes that are in accordance with the dimensions and elements of the Pancasila student profile, so that STEAM learning can be applied to grow the profile of Pancasila students. In addition, it is also necessary to design and develop STEAM learning that can accommodate the needs of students, namely with differentiated learning.

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