A REVIEW OF THE EFFECT OF INTEGRATED STEM OR STEAM EDUCATION IN INDONESIA

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Abstract. STEAM (Science, Technology, Engineering, Art, and Mathematics) or STEM education is one of the education approaches to create critical thinking for students and teachers. This paper adopted a systematic review of the literature in Scopus from 2013 to 2023, using preferred reporting items for systematic reviews and meta-analysis (PRISMA). Based on predefined inclusion criteria, a total of 9 articles published within the last decade were analysed in detail. The findings of this review indicate that STEAM education is determined by students' attitudes, teacher attitudes, and teaching creativity. The results also confirm that there is a link between steam education and thinking skills among students in Indonesia. This paper also highlights the trends in steam education for primary and secondary students in Indonesia. The findings of this paper are to allocate avenues for future research on the theme of steam education for building better human capital in Indonesia.

Keywords: STEAM education, teaching creativity, thinking skills, systematic literature review.

INTRODUCTION

Globally, national education programs increasingly place a high premium on students' understanding of STEM (Science, Technology, Engineering, and Mathematics) subjects (Kelley & Knowles, 2016). It is envisaged that through integrating scientific domains, students' problem-solving abilities will be strengthened (Guzey et al., 2017; Hoeg & Bencze, 2017). Researchers have established STEAM as a more comprehensive interdisciplinary curriculum by expanding STEM by fusing liberal arts subjects into STEM (Chien & Chu, 2018; Chu et al., 2019; Thuneberg et al., 2018).

Design and engineering practice are acknowledged as essential components of scientific education by the Next Generation scientific Standards (NGSS) in the United States (NGSS Lead States, 2013). Additionally, the UK has proposed an agenda for educational policy that encourages the integration of STEM (science, technology, engineering, and mathematics) both inside and outside of educational institutions (STEM Learning, 2018). In order to support STEM education at all educational levels, both official and informal, Germany also established a national STEM forum (Nationales Forum, 2014).

Since the late 1990s, the South Korean government has likewise seen a fall in young people's expectations for STEM careers and a low level of student interest in science (Martin et al., 2017). Students in high school tend to favor humanities or social subjects over science, and colleges are compelled to accept students with lesser qualifications for STEM degrees. Concerns regarding national competitiveness in the global economy are raised by this. Initiatives for STEAM change have arisen as a result of their research's influence. Two major areas of focus for significant national financing for STEAM research and development are the creation of STEAM curricula and teacher professional development (Jho et al., 2016).

The distinctive amalgamation of STEM and arts science, encompassing fine arts, language arts, liberal arts, and physical arts, implies that all academic topics are encompassed in the STEAM curriculum in South Korea. Offering more diverse learning options is the aim. While most STEAM programs concentrate on school instruction, integrated STEAM projects in South Korea incorporate education both inside and outside of the classroom (Jho et al., 2016). Upcoming career-focused STEAM courses will cover the most recent advancements in STEM in a variety of industrial and occupational domains, including blockchain technology, data mining, and intelligent farming (Kang, 2019).

In Indonesia, the education ministry has changed the curriculum with the independent curriculum (Kurikulum Merdeka). Curriculum changes are necessary to adapt current developments to their needs. This is reinforced by the fact that more than a third of the important job skills in 2015 have changed. The element of creativity jumped to number 3 in 2020, previously at number 10 in 2015. Industrial Revolution 4.0 where massive developments in technology and knowledge have changed the way we live (Costello, 2017).

Educational institutions are a place to prepare superior human resources, especially in skills and creativity. The Ministry of Education and Culture as the education provider has launched the Independent Curriculum as the national curriculum. The Independent Curriculum gives educators the freedom to create quality learning according to student's needs and learning environment (Kemdikbudristek, 2022).

Indonesian students' competency results for Reading, Mathematics and Science are 371, 379 and 396. Meanwhile, the international average for these three competencies is 487, 489 and 489 respectively (Schleicher, 2018). This also encourages the Ministry of Education and Culture to innovate the national curriculum. It is hoped that this curriculum change will be able to advance the quality of human resources in Indonesia.

The current review of the literature on STEM or STEAM education in Indonesia only looks at how much teachers know about the subject after receiving training, how experienced they are in choosing the most effective approach, how to find inexpensive media, and how they work with subject matter experts in STEAM learning (Sit, 2022). Another discovery pertains to the correlation between the STEM or STEAM learning paradigm, which includes inquiry-based learning, project-based learning, and problem-based learning (Ilma et al., 2023). As a result, the impact of STEM or STEAM education on the courses taught in elementary, junior high, and senior high schools is the main emphasis of this literature review.

Based on the educational needs and problems that exist in Indonesia, the STEM or STEAM education approach has been implemented in Indonesia. In looking at the trends and impact of STEM or STEAM education in Indonesia, the author conducted a literature study to see how much influence STEM or STEAM education has on learning. In comparison to other education levels, it can become the basis for further research in developing STEM or STEAM education in broader fields.

RESEARCH METHOD

This study uses a systematic literature review to answer the questions that have been asked. By using this method, the reporting system used in this systematic literature review is meta-analysis. This method can provide a systematic display of repeaters and flow diagrams to increase the accuracy of the literature review. This method has two stages, namely:

1) Search criteria and databases
   The search criteria adopted use terms that are by the concept of steam or stem education in Indonesia. This literature search uses leading databases in the Scopus Index
2) Selection process
   The protocol in writing this study was to ensure that the results were transparent and of high quality. In this case, the author sets criteria in the selection process, including:
   a. Scientific work related to steam education, stem education, and education in Indonesia;
   b. Scientific work that has empirical results and can be accounted for;
   c. Scientific work written in international language and published in less than 10 years.

RESULT AND ANALYSIS

1.1 Result

There were 236 articles filtered from the Scopus data search conducted from 2013 to 2023. In this study, the author used the PRISMA strategy using Watase Uake to identify relevant articles in answering questions in previous research. Based on this, 9 articles were found that met the criteria regarding steam or stem education in Indonesia.

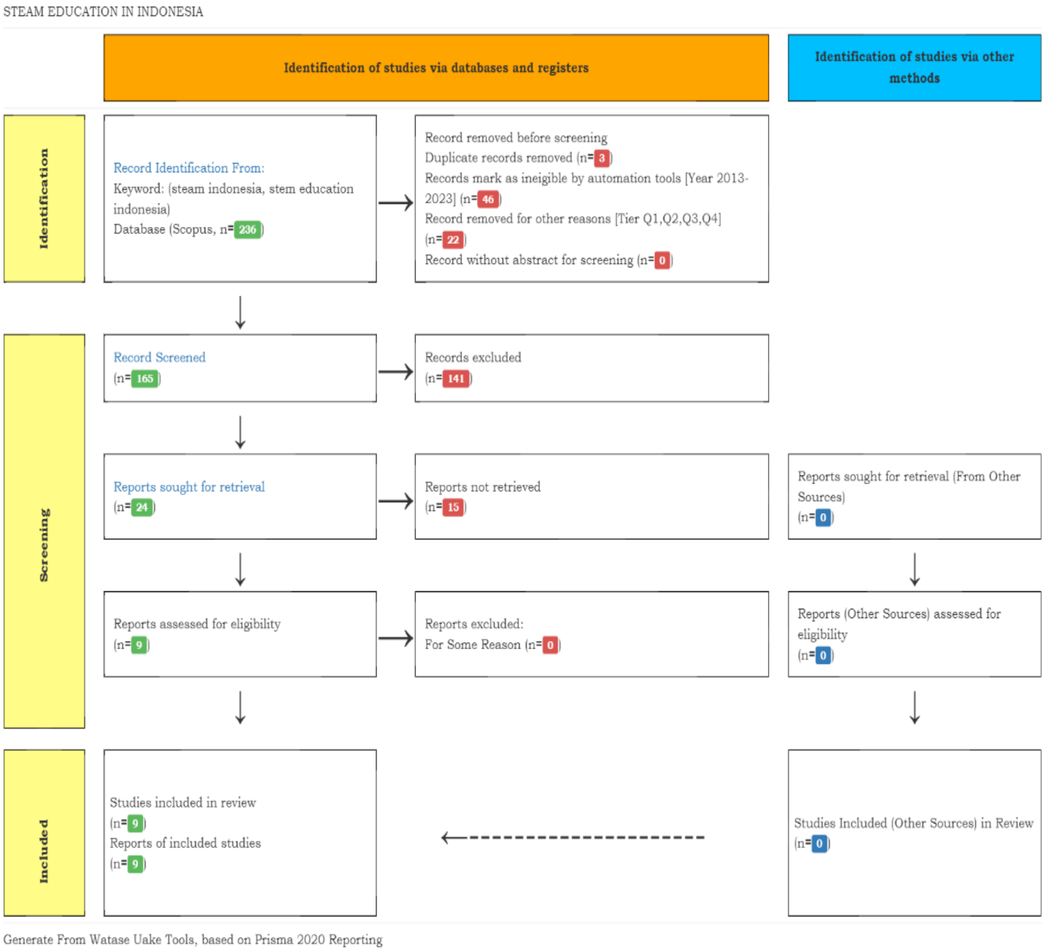

Fig 1. PRISMA Analysis

The author conducted a two-step filtering process on the articles, based on the criteria that are shown in Figure 1. The titles and abstracts of the identified publications were filtered using the aforementioned filters as the initial step. Once an item passes the preliminary review stage and is found to be relevant, it moves on to the second screening stage, which is a full-text review, which evaluates the article's eligibility. Please only submit articles that describe how steam or stem education is being implemented in Indonesia.

The articles that have met special requirements and will be used in this study are summarized in the table below:

Table 1. Articles that meet the requirements

No	Authors	Year	Title	Journal	Journal Rank
1	Wahono et al.	2021	Teaching socio-scientific issues through integrated STEM education an effective practical averment from Indonesian science lessons	International Journal of Science Education	Q1
2	Zhao et al.	2022	Factors Influencing Student Satisfaction toward STEM Education Exploratory Study Using Structural Equation Modeling	Applied Sciences	Q2
3	Wahono and Chang	2019	Assessing Teacher s Attitude, Knowledge, and Application	Sustainability	Q1

			(AKA) on STEM An Effort to Foster the Sustainable Development of STEM Education		
4	Chai et al.	2020	Indonesian Science, Mathematics, and Engineering Preservice Teachers Experiences in STEM-TPACK Design-Based Learning	Sustainability	Q1
5	Hasani et al.	2020	Conceptual Frameworks on How to Teach STEM Concepts in Bahasa Indonesia Subject as Integrated Learning in Grades 1-3 at Elementary School in the Curriculum 2013 to Contribute to Sustainability Education	Sustainability	Q1
6	Rahmawati et al.	2022	Students Engagement in Education as Sustainability Implementing an Ethical Dilemma-STEAM Teaching Model in Chemistry Learning	Sustainability	Q1
7	Siregar et al.	2023	The impact of an integrated STEAM project delivered via mobile technology on the reasoning ability of elementary school students	Journal of Technology and Science Education	Q2
8	Sudarmin et al.	2023	Chemistry project-based learning for secondary metabolite course with ethno-STEM approach to improve students conservation and entrepreneurial character in the 21st century	Journal of Technology and Science Education	Q2
9	Ananda et al.	2023	Critical thinking skills of Chemistry students by integrating design thinking with STEAM-PjBL	Journal of Technology and Science Education	Q2

From the nine papers selected according to the criteria, continued with the classification based on the level of education, subject, and the results of the application of STEM or STEAM education integration. The grouping of the number of entries, subjects, and education level is summarized in the table below:

Table 2. STEM or STEAM Education, education level, and results

Kinds of STEM /STEAM	Object	Education Level	Subjects	Results
STEM-SSI	Students	Junior High School	Science	1) STEM-SSI can improve students' comprehension, performance, drive, and self-awareness; 2) Support science instructors in organizing, analyzing, and assessing student learning in the classroom.
STEM	Students	Senior High School	-	Attitude is the main factor influencing a student's acceptance of and

				satisfaction with STEM education.
STEM	Teacher	Junior High School & Senior High School	Science	The sustainable implementation of STEM education requires instructors to possess fundamental knowledge and attitudes in these areas.
STEM-TPACK	Teacher	Junior High School	Science	Learning by design, using the TPACK framework in the collaborative environment of interdisciplinary STEM communities, may be advantageous for preservice teachers.
STEM	Students	Elementary School	Bahasa Indonesia	The theoretical foundation for teaching technology through reading.
Ethical Dilemma STEAM Teaching Model	Students	Senior High School	Chemistry	In addition to learning deeply about chemistry, students also gained collaborative decision-making abilities, critical reflective social thinking, and a greater understanding of the importance of environmental protection for the sake of sustainable development.
STEAM via mobile Technology	Students	Elementary School	-	Give advice and information on how to create learning models that could enhance reasoning skills.
Ethno-STEM	Students	Senior High School	Chemistry	Practical and successful in fostering pupils' entrepreneurial spirit and conservation ethic, meeting both moderate and high standards depending on the N-gain score.
STEAM-PjBL	Students	Senior High School	Sciences and Mathematics	In order to solve contextual difficulties pertaining to the redox reaction of water pollution in the Ciujung River due to the use of detergent waste, Design Thinking offers a more straightforward and proactive approach to generate project-based solutions.

1.2 **Analysis**

1.2.1 PjBL Concept

Project Based Learning (PjBL) is one of the models in interactive learning strategies (de la Torre-Neches et al., 2020). This project-based learning makes the learning process come alive for learners. PjBL refers to an inquiry-based teaching method that involves learners in the construction of knowledge and how they complete meaningful projects in real life. PjBL has positive influences including driving questions, focus on learning objectives, participation in educational activities, collaboration between learners, use of scaffolding technology, and creation of real products (Maros et al., 2021). The creation of real products is the most important thing in problem solving, PjBL is learner-centered with problem-based. In Ralph's research (2015) PjBL increased the development of learners' knowledge and skills. The PjBL model is considered to be an efficient method for developing 21st-century skills.

Project-based learning or PjBL refers to learner-centred learning through projects conducted in team or group collaboration (Kokotsaki et al., 2016). With the collaborative inquiry-based PjBL model learners integrate, apply and build on their knowledge while working together to build solutions to complex problems. The current PjBL model trains learners to critically address future global environmental issues. PjBL rests on four important ideas namely 1) actively building learners' understanding, 2) working collaboratively, 3) authentic learning environment, and 4) cognitive tools (Priantari et al., 2020). Chen and Yang's (2019) research shows the PjBL model successfully provides higher academic achievement than traditional teacher-led teaching.

The PjBL model allows learners to appreciate the relationship between scientific practice and the real world, the importance of learning, conducting investigations, and the openness of the problem under study. The main characteristics of the PjBL model according to Krajcik and Shin (2014) include 1) driving questions, 2) learning objectives, 3) scientific practices, 4) collaboration, 5) use of technological tools, and 6) product creation (Crespi et al., 2022). According to Stoller (2005), the process of project-based learning starts from the stages of 1) teachers and learners determine the theme of the project, 2) teachers and learners determine the final output, 3) teachers and learners structure the project, 4) teachers prepare learners to collect information, 5) learners collect information, 6) teachers prepare learners to collect and analyze data, 7) learners collect and analyze information, 8) teachers prepare learners to go to the core activity (presentation), 9) learners make the final product presentation, 10) learners evaluate the project (Shin & Han, 2011).

1.2.1 STEM or STEAM Integration in Indonesia

STEM stands for mathematics, science, technology, and engineering. In an effort to increase the number of people working in STEM fields, create more STEM-literate citizens, and increase American competitiveness in the global arena of science and technology innovation, the US National Science Foundation (NSF) coined the phrase for the first time in the 1990s (Council National Research, 2011). To assist promote it, the word "STEM" was originally used instead of "SMET" (Sanders, 2009). Science, Technology, Engineering, and Mathematics are the four STEM fields, and they can be summed up as follows:

1) Science allows us to develop an interest in and understanding of the living, material, and physical world and develop skills of collaboration, research, critical inquiry, and experimentation.
2) Technology encompasses a wide range of fields involving the application of knowledge, skills and computational thinking to expand human capabilities and help fulfill human needs and wants
3) Engineering is the skills and knowledge to design and construct machines or equipment and processes that are useful for solving real-world problems
4) Mathematics equips us with the skills necessary to interpret and analyze information, simplify and solve problems, assess risk, make informed decisions and further understand the world around us through modeling abstract and concrete problems (Council National Research, 2011).

Improving the quality of learning, especially Science and Mathematics-based learning is an effort that cannot be delayed in line with the various challenges faced by students today, namely the challenges of the 21st century. One learning approach that can accommodate the characteristics of 21st century learning above is the Science, Technology, Engineering, and Mathematics (STEM) approach. STEM is an approach in which Science, Technology, Engineering, and Mathematics are integrated with a focus on real-life problem-solving learning processes. STEM learning shows learners how the concepts, principles of science, technology, engineering, and mathematics are used in an integrated manner to develop products, processes, and systems that provide benefits for human life (Council National Research, 2011). To prepare Indonesian learners to acquire 21st century skills, namely the skills of how to think through thinking critically, creatively, being able to solve problems and make decisions and how to work together through collaboration and communication, the STEM approach was adopted to strengthen the implementation of the National Curriculum (Curriculum 2013).

The results of Davidi's research (2021) show that learning for elementary school students in Wae Ri'i sub-district using the STEM-PBL approach makes a significant difference when compared to learning for students using other innovative approaches. The independent t test of the Control-Experiment group on the post-test score was conducted to determine the critical thinking skills of students in both the control group and the experimental group after learning activities using the STEM approach. Testing of the two hypotheses was carried out using the help of the SPSS16 application tool. Sig value. (2-tailed) Equal variances assumed 0.000 <0.05, it can be concluded that Ho is rejected and Ha is accepted, which means that there is a significant difference in critical thinking skills after learning between students who use the STEM-PBL approach and students who use the innovative K13 approach (Davidi et al., 2021).

Thus, the application of STEM through interactive learning models has a positive impact on improving student learning outcomes. STEM integration is not only a combination with other subjects but also learning approach models such as PjBL, PBL, and contextual learning. STEM integration can also be done with a combination of digital-based learning media such as learning applications and learning faction games. Broadly speaking, STEM is a strategy that follows the dynamics of 21st-century learning that has the potential to improve learning outcomes and national education output in Indonesia. STEM integration itself can be done at various school levels from early childhood, junior high, high school, and even in universities.

1.2.2 STEM or STEAM Analysis on Elementary School

STEM or Science, Technology, Engineering, and Mathematics is one of the priority programs in education globally (Kelley & Knowles, 2016). STEM learning itself is popularly introduced in the United States through engineering design and practice as the main element of science education. The UK has also put forward an education policy agenda that promotes the integration of science, technology, engineering and math (STEM) both in and out of school. It is named differently from STEM because of its emphasis on the arts (fine arts, language arts, liberal arts and physical arts) as an important component of integration. While the movement's STEAM reforms are in line with STEM reforms in other countries, its additional component, the arts, is inspired by the concurrent social discourse on education for creativity and well-rounded citizenship in the twenty-first century(Lei et al., 2022). The application of STEAM is useful for increasing students' thinking and reasoning power to achieve meaningful experiences. STEAM can be applied at various levels including at the elementary school level. The form of STEAM application itself is the creation of dynamic online learning applications that adapt to the habits of students who are starting to depend on gadget technology.

Leaderman 2019 also mentioned that there are six characteristics of science and scientific knowledge in the STEAM concept. These six characteristics include encouraging students' awareness of the important difference between observation and inference. Students during the STEAM learning process can argue unsure of the conclusion as a distinction between scientific laws and theories. This is because scientific knowledge is not only derived from observations of nature (empirical) but also involves human imagination and creativity. Scientific knowledge is subjective or theory-laden but also a human endeavour practised in a larger cultural context. STEAM or Science, Technology, Engineering and Mathematics is a term first described by Judith Ramaley in 2001 as Assistant Director of the Directorate of Education and Human Resources at the National Science Foundation (NSF). STEAM is an educational system that can integrate two or more similar STEAM subjects in the disciplines of science, technology, engineering and math.

STEM research in Indonesia is conducted to improve 21st-century skills in students using various methods. Based on the literature, it is stated that the uptake of STEM in learning in Indonesia is relatively high, this can be seen from several STEM studies over several decades (Ardwiyanti et al., 2021). With the application of several STEM approaches, learning becomes more qualified and directed. This is because the STEM approach is an approach that combines science, technology, engineering, and mathematics in its learning so that it can help students acquire knowledge independently and skillfully overcome problems, knowledge independently and skillfully overcome problems in real life (Basu et al., 2021; Lestari et al., 2018)). Implementing STEM methodology from the elementary level up to practical use can motivate students to learn and improve their skills and view Science as a way of life (Imbachi-Diaz et al., 2023; Stonier & Adarkwah, 2023). For example, STEM-based enrichment books can support STEM education in Indonesia to further develop STEM in Indonesia (Sinta et al., 2020; Triayuni et al., 2023). With STEM learning, the class will become more active (Burke et al., 2020).

1.2.3 STEM or STEAM Analysis on Junior High School

There are three main concepts in integrated STEAM education. The first concept is integrated STEM education that involves multidisciplinary knowledge. There are at least two fields that must be involved in STEM learning. The second concept, in terms of teaching, integrated STEAM can be a learning approach, especially an integrated learning approach. The third concept, integrated STEM education is expected to master students' conceptual understanding, problem-solving skills, critical thinking, creative thinking, collaborative abilities, and design thinking skills in achieving the goals to be achieved. In order to achieve better results in implementing integrated STEAM education, the STEAM model can be collaborated with the 6E Learning byDeSIGN™ model. 6E stands for: engage, explore, explain, engineer, enrich and deploy (Lederman & Lederman, 2019).

Based on studies, STEAM is widely implemented in and integrated into several learning models such as PjBL. However, there is also something specific about implementing STEM without being integrated with other learning models, meaning that it does not follow the syntax of the PBL or PjBL models. Based on the studies analyzed, STEM-PjBL is more often implemented in Mathematics learning than STEM-PBL, indicating that some material in Mathematics learning can be integrated with a STEM approach through providing project-based assignments to train creative and collaborative thinking skills as well as train students' critical thinking skills in solve project-based problems. Apart from integrating STEM with learning models, according to Piaget's stages of cognitive development, junior high school students are at the formal operational stage which requires the ability to think critically in solving abstract problems (Rahmawati et al., 2022).

STEAM is a superior learning method because it tries to integrate two related subjects which can be implemented at one time. This aims to ensure that students, especially at junior high school level, can think critically in solving problems based on experience and also to build a sense of empathy and awareness of events that occur in the surrounding environment. This is in line with previous research which explains that the application of the STEAM approach provides students with the opportunity to expand their knowledge in science and humanities and at the same time develop their skills in critical thinking, leadership, working in teams, creativity and resilience (Priantari et al., 2020).

This-based learning has a lot of potential to increase the creativity of 21st-century students. However, in its implementation, there are still many challenges, especially at the junior high school level where teachers lack knowledge about digital resources that can be used to implement STEM-based learning, teachers who do not having the ability to create STEM-based learning tools, lack of adequate insight into STEM-based learning and lack of support or other supporting media. Therefore, in its implementation, assistance must also be needed for students or teachers themselves so that STEM education can touch all of these things (Jeanny, et.al., 2022).

1.2.4 STEM or STEAM Analysis on Senior High School

The implementation of STEAM at the senior high school in Indonesia is a strategic step in responding to the need for competent human resources in the era of globalization and industrial revolution 4.0. The use of the STEAM approach in the learning process encourages integration between science, technology, engineering, arts and mathematics to create a holistic and interdisciplinary learning environment. STEAM education includes learning experiences that increase students' motivation to learn science, mathematics, connect their interests to the real world, and help them understand how to learn and focus (Ozkan & Topsakal, 2021). The conceptualization of the STEAM approach includes (1) project-focused learning methods, (2) the application of technology combined with creativity and design aspects, (3) strategies for questioning and exploring various solutions to a problem, (4) integration between science, technology, engineering, arts/humanities, and mathematics, as important tools in problem-solving, as well as (5) strategies in solving problems collaboratively(Herro & Quigley, 2017)).

Using the STEAM approach in high school can provide new learning experiences for students. Students can learn about the connections between various scientific fields and understand how concepts from one scientific discipline can be applied in other contexts. Thus, implementing the STEAM approach in the learning process is very important in developing systematic thinking regarding creative problem-solving abilities, effective ways of collaborating and the courage to take risks (Taylor, 2018). In addition, STEAM education prepares students to be more flexible and adaptive in facing the challenges and changes that occur in the world of work, especially in an economic and industrial context that continues to develop and change. These skills are key skills in the 21st century to build a solid foundation for human development and innovation in the future.

In the process of implementing the STEAM approach at the senior secondary education level, it cannot be denied that teachers as facilitators have a significant role in the success of STEAM learning. Teachers must be able to identify explicit connections between targeted discipline content. In the STEAM approach, student-centred learning is one of the main aspects. In the learning process, the use of inquiry-based learning methods which involve direct investigations using content, context and problems appropriate to the class can be an option in the STEAM approach (Nugraha et al., 2023). However, in practice, it has been found that students do not have freedom in selecting the projects or problems to be worked on, which can reduce the ability of STEAM learning experiences to meet students' diversity of interests and life experiences (McLure et al., 2022). To overcome these problems, teachers can use approaches such as providing a variety of project options, allowing class discussions to uncover problems of interest to students, and allowing students to work on projects of their own choosing or that they design together. Such an approach can increase student engagement and motivation and provide them with opportunities to apply STEAM learning in more relevant contexts.

CONCLUSION

This study uses the Systematic Literature Review method which adopts selected reporting items to be reviewed systematically using meta-analysis (PRISMA) to obtain the influence STEM or STEAM education has on learning. In addition, this study uses the PRISMA strategy from the WATASE UAKKE software. This study shows that STEM or STEAM education has many variations in classroom application. However, this education is mostly found in the Problem-Based Learning model. STEM or STEAM has been implemented at various levels, such as in elementary, junior high, and high school. The learning results show positive results at various levels of education. At the elementary level, it shows that STEM or STEAM can motivate students to learn and improve their skills and scientific insights as a way of looking at everyday life. At the junior high school level, it shows that STEM or STEAM can think critically in solving problems based on experience and also build a sense of empathy and awareness of events that occur in the surrounding environment. At the high school level, STEM or STEAM can provide new learning experiences and learn about the connections between various scientific fields and understand how concepts from one scientific discipline can be applied in other contexts. However, at the junior and senior high school levels it is still limited to the field of natural sciences and limited to social sciences and humanities. Thus, the results of this study can be developed more broadly in non-science subjects.

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