The Effect of STEAM in Mathematics Learning on 21st Century Skills: A Systematic Literature Reviews

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ABSTRAK

Perkembangan pendekatan pembelajaran berbasis Science, Technology, Engineering, Art, dan Mathematics (STEAM) yang dilaksanakan dengan interdisiplin pengetahuan saat ini telah banyak digunakan dalam pembelajaran dan penelitian pendidikan matematika. Namun demikian, penggunaan metode pembelajaran dan pengaruhnya terhadap keterampilan abad 21 belum dideskripsikan secara utuuh. Untuk menjawab permasalahan tersebut, penelitian untuk menyelidiki dan dan menginterpretasikan data tentang perkembangan dan penggunaan metode yang tepat dalam implementasi STEAM, khususnya dampaknya pada pembelajaran matematika dan keterampilan abad ke-21. Penulis melakukan tinjauan pustaka sistematis terhadap article yang diterbitkan untuk menghasilkan tinjauan bibliometrik yang menggabungkan deskripsi kuantitatif isi literatur dan analisis kualitatif proses, hasil, dan kondisi pembelajaran matematika menggunakan pendekatan STEAM dari database terpilih antara tahun 2012 sampai 2021. Hasil studi yang digunakan sebanyak 35 article dari literatur yang relevan dengan tujuan penelitian. Setelah melakukan analisis, dapat disimpulkan bahwa penelitian terkait STEAM khususnya dalam kajian matematika mengalami peningkatan yang signifikan dalam 5 tahun terakhir sejak tahun 2016. Dari aspek keterampilan abad 21, STEAM memiliki pengaruh yang dominan dalam meningkatkan keterampilan pemecahan masalah dan kreativitas. Namun demikian, dampaknya keterampilan kolaboratif dan komunikasi masih rendah. Dari sisi penggunaan metode pembelajaran, STEAM memiliki hubungan yang signifikan dengan metode project-based learning (PjBL). Hasil dari kajian ini dapat dijadikan sebagai bahan konfirmasi yang menunjukkan bahwa STEAM dan metode PjBL merupakan kombinasi yang ideal dalam pembelajaran dan juga dapat dijadikan alternative pendekatan dan metode pembelajaran untuk meningkatkan kemampuan pemecahan masalah serta kreatif.

Kata Kunci : keterampilan abad 21; matematika; PjBL; STEAM.

ABSTRACT

The development of a Science, Technology, Engineering, Art, and Mathematics (STEAM)-based learning approach that is implemented with interdisciplinary knowledge has now been widely used in learning and research in mathematics education. However, the use of learning methods and their influence on 21st century skills has not been fully described. To answer these problems, research is to investigate and interpret data on the development and use of appropriate methods in the implementation of STEAM, in particular its impact on mathematics learning and 21st century skills. The author conducted a systematic literature review of published articles to produce a bibliometric review that combines quantitative descriptions of literature content and qualitative analysis of processes, outcomes, and conditions of mathematics learning using the STEAM approach from selected databases between 2012 and 2021. The results of the study used 35 articles from literature relevant to the research objectives. After conducting the analysis, it can be concluded that research related to STEAM, especially in the study of mathematics, has increased significantly in the last 5

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years since 2016. From the aspect of 21st century skills, STEAM has a dominant influence in improving problem solving skills and creativity. However, the impact of collaborative and communication skills is still low. In terms of the use of learning methods, STEAM has a significant relationship with the project-based learning (PjBL) method. The results of this study can be used as confirmation material showing that STEAM and PjBL methods are an ideal combination in learning and can also be used as alternative approaches and learning methods to improve problem solving and creative abilities.

Keywords: mathematics; PjBL; STEAM; 21st century skill; systematic literature review

INTRODUCTION

The rapid development of science and technology today cannot be avoided, but needs to be approached and mastered to support and promote life activities, including learning practices (Kim, 2017). The problem of globalization today is very complex in many ways. Even many problems are not enough to be solved in one area, but problem solving requires the convergence of several areas and creative problem solving skills (Kim, 2017). The impact of the Fourth Industrial Revolution has brought new changes, especially in the field of artificial intelligence and intelligent robots, which can now change the social situation of society. On the other hand, in the field of education, several questions arise, whether today's students are really ready to face the changes of present and future life. It is certainly difficult to predict how and what life will be like in the future, what is certain is that the needs for complex skills and abilities (Lee et al., 2019), with creative convergent thinking (Wandari et al., 2018) become basic needs in the future.

Today's schools need to focus specifically on future math topics such as big data, information and communication technology (ICT), in order to cope with the inevitable turbulence impacted by the Industrial Revolution 4.0 (Braña, 2019; Harini & Taufiq, 2021; Septian & Monariska, 2021) and society 5.0. The implication of this new paradigm in education is the need to adopt a different learning approach, placing students at the center of curriculum development, education and evaluation that helps students engage in learning and develop analytical, collaborative, and communication skills (Friedlaender et al., 2014; Maskur et al., 2020). Within the scope of this approach, the importance of interdisciplinary education and its contribution to effective and meaningful learning (MacLeod & van der Veen, 2019) thus enabling students to study and examine the subject being studied from the point of view of various disciplines (Howlett et al., 2016).

There is no denying that science, technology, engineering, and mathematics today are used as basic disciplines that can be integrated into almost all disciplines. However, students' perceptions of mathematics remain unchanged even in the 2019 OECD report showing that 15 year old students are not able to master the minimum mathematical skills (Lasisi et al., 2020), mathematics is one of the subjects that is considered difficult and even becomes an obstacle to developing an academic career related to engineering (Li et al., 2019) there are even science students who have low basic math skills, especially in the first years of study (Coupland et al., 2013). This should be an important consideration how to develop innovative mathematics learning and be able to provide new views that are better and can be accepted by students (Sanusi et al., 2020; Septian, 2022; Suryawan & Permana, 2020). At least in the last decade, along with the rapid development of information technology and the

internet, it is known that the process of transferring knowledge to students is expected to be more student-centered (SCL) so that students' involvement in all learning is expected. process is the main focus of this educational innovation. However, the process of implementing SCL certainly requires the right approach and method so that it can optimize student involvement in learning.

One of the approaches developed for student-centered learning is STEAM. Several studies to date have shown that STEAM is a fun approach to learn in the classroom, arouses curiosity and motivates people to participate in learning activities (Taljaard, 2016) of course this is one of the very good points for making student engagement in the classroom. In addition, STEAM educational activities are believed to be able to improve formal education teaching by providing fun activities with content-rich education (Kney et al., 2016) and also allows students to express and be creative to make students show their abilities more (Ozkan & Umdu Topsakal, 2021).

Some researchers state that the importance of cross-disciplinary learning (Quinnell, 2019) as well as the STEAM approach which is able to improve 21st century skills such as: critical thinking, problem solving, creative thinking, collaborative and communicative and has a positive effect on students' career choices and job perceptions in science and technology (Hong, 2017). This certainly requires further study to what extent STEAM is able to improve these skills, how STEAM is applied both in terms of the use of content, methods and teacher motivation in its application. Currently, studies related to the implementation of STEAM with learning methods are still dominated by a combination using the project based learning (PjBL) method, this is mostly based on the fact that STEAM is a development of STEM, in which STEM is mostly implemented using the PjBL method (Han et al., 2014). The use of PjBL does not fully guarantee that it will have effectiveness in improving high-level skills (Juandi, 2021) even in the literature review from this research, there are still many implementations of STEAM using other methods and proven to have a positive impact on the development of achievement, interest, self-confidence (Dejarnette, 2018) or 21st century skills of students.

The combination of cross-subject or interdisciplinary learning so far has been widely studied and developed in at least the last 10 years (2012 – 2021), but several research results show differences in the application or use of methods and their effects on learning outcomes. In previous studies it was found that using various methods such as: PBL, PJBL, STAD, Cooperatives, RME and others, all of which have an influence on learning outcomes such as; 21st century mathematical skills and skills. Based on the results of these different studies, it certainly creates confusion for readers about how STEAM should be used, the use of learning methods and what mathematical abilities are its strengths. To answer these problems, this research will focus on a systematic literature review (SLR) to summarize and synthesize research results related to the implementation of STEAM in mathematics learning in order to obtain comprehensive information and to avoid bias for readers that may occur in the research and publication process. (Suparman et al., 2021).

METHOD

Systematic Literature Review

The research method used in determining how the results and implementation of STEAM on mathematical abilities is carried out using a Systematic Literature Review (SLR), which is a review of clearly formulated questions that use systematic and explicit methods to identify, select, and critically assess relevant research and to collect and analyze data from the research discussed in the research (Grande et al., 2015). The stages used in the SLR process include three main stages, namely: planning, conducting reviews, and reporting the results of the reviews (Booth et al, 2021; Kitchenham et al, 2009).

Planning

In the planning stage, it is divided into three steps, namely determining research questions, inclusion criteria and exclusion criteria. Research Questions, In the planning phase, it is carried out by observing the structure based on the research context, defining the review protocol and formulating questions. In this stage, it generally produces three question formulations, namely:

1   How is the description of the development of STEAM research in learning?
2   Wow is the description of STEAM research in 21st Century skills-based learning?
3   How is the description of STEAM research in learning based on the use of learning methods?.

Inclusion Criteria, in this stage consists of determining the strategy and scope of research results included in the Inclusion Criteria. The search strategy helps to define suitable search strings and identify relevant databases to collect relevant documentation (Mengist et al., 2020). The application used to search the initial article is Publish or Perish 7 with search data on Scopus and CrossRef. The screening of published articles was adapted to the early development of STEAM 2006 and began to be published in 2010 by Yakman (2010). So that the selection of these articles takes the range from 2010 to October 2021 in the form of books, proceedings and journals. The criteria for the study results used are limited to published journals/proceedings indexed by Sinta (Indonesian journal indexing), International Scopus and non-scopus (CrossRef).

Exclusion Criteria, At this stage, it is determined that the limitations related to the references used in this study are parts that are not related to the inclusion criteria. The limitations are: Research results that are not identified as "articles" and are not included in the selected journal (eg, books, chapters, colloquiums, etc.); Studies that do not provide sufficient data or do not have a clear summary of the population or sample of qualitative and/or quantitative data; Articles that do not present evidence obtained by well-structured research methods and evaluation processes (e.g.: case studies, empirical, etc.).

Conducting the review

In the article search process, to limit the search results for articles that are in accordance with this study plan, a search string is compiled, namely STEAM; Maths; Education. At the initial search stage using this string, we found articles related to more than 1108 articles consisting of the Scopus database of 108 articles and CrossRef of more than 1000 articles. In the process of filtering article search results using strings in the Scopus and CrossRef databases, it is carried out through four stages, namely: citation filtering, title

suitability filtering, abstract conformity filtering and article content suitability filtering. The distribution of the data found is as follows (Table 1):

Table 1. STEAM article search and filter results data

String (scopus dan CrossRef)	Filtering by Citation	Filtering by Title	Filtering by Abstract	Filtering by Contents
> 1108 article	445 article	278 article	61 article	35 article

RESULTS AND DISCUSSION (REPORTING)
Description of Data by Demographics

The results of the study that were collected through a search string were obtained as many as 241 articles discussing STEAM at various levels, but after filtering based on the Inclusion Criteria, 35 results were determined according to the research focus. The following is the distribution of the sample data from the STEAM study based on demographics:
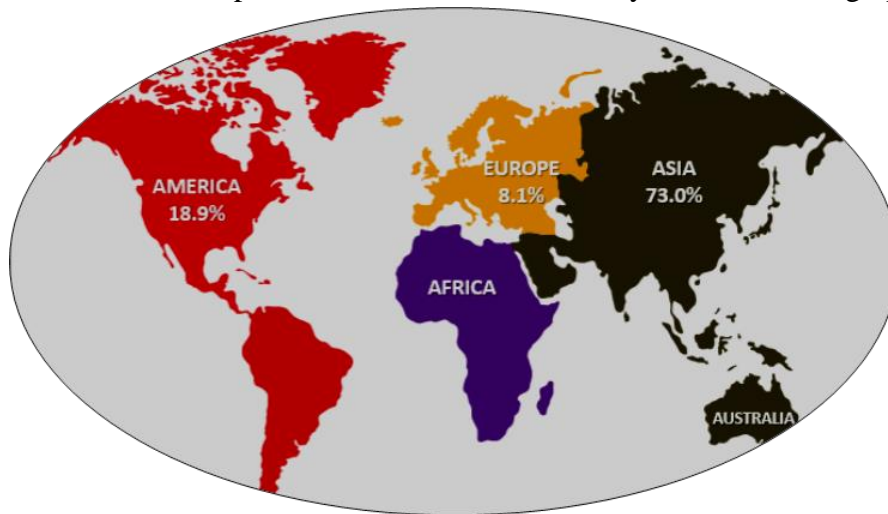

Figure 1. Demographics of Research Result Samples

From Figure 1, it can be seen that the distribution of research collected from various countries in the world, this shows that at least STEAM research has been quite developed even though some teachers or students are still not familiar with STEAM in learning (Anisimova et al., 2020). In this study, the samples used were spread from several countries in the Americas, Asia and Europe, this can be seen from the distribution of 73% from the Asian continent, 18% from the Americas and 8.1% from the European continent. On the Asian continent itself, the most samples came from Korea, namely 11 samples, followed by Indonesia 9 samples, Taiwan 4 samples and China 2 samples, this shows that the research theme related to STEAM has become a concern for academics and researchers in Asia. Especially in Korea itself has implemented STEAM in the national curriculum since 2012 (Chu, 2021).

STEAM has actually been developed since 2006 but began to be published in 2010 by Yakman (2010) until now it has become one of the focuses of interdisciplinary research in accordance with technological developments in the era of the industrial revolution 4.0. Figure 2 is a graph of the development of research related to STEAM, mathematics, interdisciplinary and skills in the 21st century. The figure shows that the development of STEAM since 2012 has increased significantly with an average increase of 42.08% annually, this is certainly due to the fact that STEAM has become a serious study of developed

countries in the last decade (Quigley et al., 2017) in the context of sustainable development (Wang et al., 2018) and can be implemented in different disciplines even in cross-cultural studies (Meuleman & Billiet, 2018).
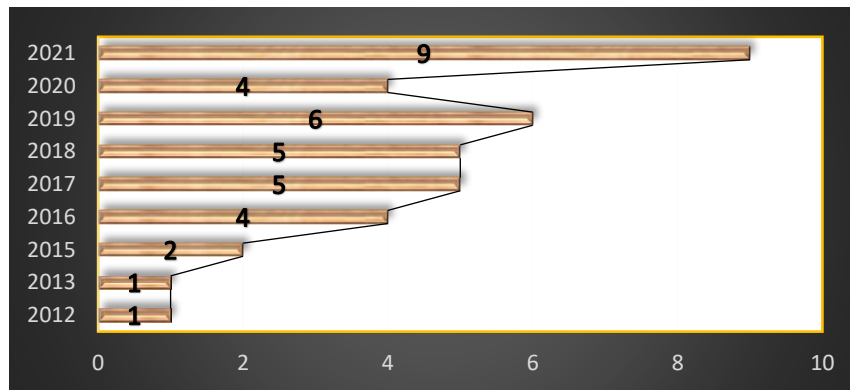

Figure 2. Research Developments by Year

From the whole research in Figure 2, most of the authors discuss the implementation of STEAM in classroom learning which is divided into several learning subjects, namely mathematics 75.6%, interdisciplinary 18.9% and other subjects 10.8%. In addition to the implementation of STEAM in the classroom, several studies have also found that STEAM has a significant influence on future students, especially the ability to think critically (Zharylgassova et al., 2021) creativity, social empowerment (Allina, 2017), digital literacy (Wilks, 2019) and collaborative abilities which are quite influential on students' future careers (Hong, 2017).

Skills Description by Year and Level of Study

Entering the era of the industrial revolution 4.0 regarding the development of digitalization and intelligence (Vaidya et al., 2018) which has been known since 2011 has had a significant impact on people's lives. The revolution was then followed by the introduction of the term society 5.0 in 2016 by the Japanese government, the term society 5.0 (Onday, 2019) is the impact of the revolution which resulted in the transformation of people's habits by utilizing scientific and technological innovations in life. This era shows a fairly rapid change in the entire life of the world community at the beginning of the 21st century.

To adjust to these conditions, researchers and academics have designed skills that can support society in the future in facing the rapid development of information technology. The Partnership for 21st Century Skills (P21) compiles several learning and innovation skills needed in the 21st century which consist of: Critical thinking and problem solving; Creativity and innovation; and Communication and Collaboration.

Table 2. Data Based on 21st Century Skills

	Criteria	Number of STEAM Research	Skills			
			Critical Thinking and Problem Solving	Collab-oration	Commu-nication	Creativity and Innovation
Year	2012 - 2015	4	40%	-	20%	40%
	2016 - 2018	16	35%	13%	13%	39%
	2019 - 2021	19	42%	5%	11%	42%

	Elementary school		14	41%	6%	12%	41%
Level Study	Junior high school		16	29%	12%	12%	47%
	Senior High School		7	50%	-	13%	38%

The development of the results of the study in this study began to experience a significant increase since 2016 (Table 2), this shows that learning mathematics, interdisciplinary using STEAM in learning has received attention from researchers and academics at least in the last 6 years. Based on the distribution of research results, it appears that STEAM is more widely used in elementary and junior high school students, some researchers argue that the introduction of STEAM is very suitable to be used to increase student activity and confidence (Hsu et al., 2021) especially at the elementary and junior high levels who often have a fear of mathematics.

The integration of STEAM in mathematics learning has been widely studied both at the elementary, junior high and high school levels which from the overall results of the research show that the integration of STEAM has a significant impact on the development of 21st century skills of students (Smith, 2015). From the data collected, 38% of the total research shows developments in critical thinking-problem solving skills, 39% creativity-innovation skills and 23% other skills.
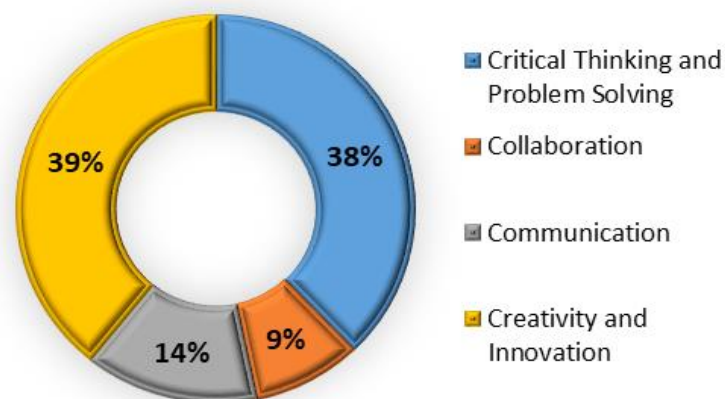

Figure 3. Data Based on Skill Aspect

In line with the findings of Perignat & Katz-Buonincontro (2019), in Figure 3 it is clear that critical thinking skills-problem-solving and creative-innovative are skills that are quite often found from the entire sample of research results, they differ quite a bit. significant with other skills, this finding is not only in the focus of closed research on the theme, but is also found in open-ended research that examines the effect of STEAM on students' overall skills. The use of technology as a source and learning media can provide space for students to access extensive sources of knowledge (Kirkwood & Price, 2014) so that they can give birth to alternatives (creative-innovative) in problem solving (critical thinking and problem solving) (Siegle, 2017).

Description of Skills based on the number of Samples and Learning Method

The type of research from the research sample used is almost balanced between research using quantitative and qualitative methods, namely 54% and 46% respectively. If the small sample group is ≤ 30 and the large sample > 30, then on average the sample used

in the research data is included in the large sample average. However, from the total research data, it was found that 5 studies (13.5%) had less than 30 samples.

Table 3. Data Based on Sample Size

	Criteria	Skills			
		Critical Thinking and Problem Solving	Collab-oration	Commu-nication	Creativity and Innovation
Average Number of Samples	Elementary school	100,4	88	103	147,6
	Junior high school	263	-	-	158,8
	Senior High School	46	-	58	148

STEAM-PjBL (Project based learning) and STEAM-PBL (Problem Based Learning) are the most common combinations of approaches and learning methods found in the data collection process using search strings, at least 118 were found related to STEAM-PBL and 34 STEAM-PjBL. However, after the initial data collection, it turns out that the abbreviation PBL is not only used for the abbreviation for Problem Basd Learning but is also used as an abbreviation for Project based learning.

From the results of screening based on inclusion criteria related to the learning method used, it was found that several studies used the same terms between project based learning and problem based learning, namely the PBL abbreviation so that we have made a classification of the abbreviations used for project based learning using the abbreviations PjBL and PBL for problem based learning. STEAM-PjBL is the most widely used learning combination, accounting for 43% of the total sample of research results. While the PBL method is 8%, the other 13% and as much as 36% research does not mention specific learning methods.
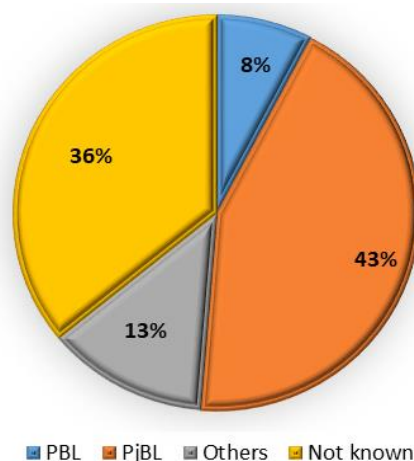

Figure 4. Data Based on Learning Method

The combination of STEAM with PjBL makes it easier for mathematics teachers to prepare lesson plans so that learning from each aspect of STEAM can run well (Quigley et al., 2017). One of the peculiarities of STEAM lies in the process of combining learning content with real-world contexts (Quigley et al., 2017), this of course will often be found in project-based learning which focuses more on contextual learning (Sirisrimangkorn, 2018). In addition to being project-based, problem-based learning is also a fairly dominant solution

in improving connection skills (Julyanasari et al., 2019) and critical thinking (Maulani et al., 2019), so it appears that success in completing projects or problems in learning is an important factor for success of STEAM based learning.

CONCLUSION

Based on the questions in this study, both in terms of development, use of methods, and the impact of the STEAM approach on skills, we have collected 35 relevant research results from 2012 to 2021. After analysis, we can summarize the research results as follows:

1. Research developments related to STEAM, especially in the study of mathematics, has increased significantly with an average increase in publications every year reaching 42.08% and has spread to various countries ranging from the continents of Asia, America and Europe.
2. From the aspect of impact on 21st century skills, STEAM is very dominant in improving problem solving skills (39%) and creativity (40%).
3. The use of technology as an aspect of STEAM learning can provide space for students to access a broad source of knowledge so that it can give birth to creativity in problem solving in learning projects. STEAM's involvement in engineering and the arts certainly cannot be evaluated only by conventional learning methods, where technical and artistic processes can only be assessed with contexts or real objects, so project work is very important to be able to measure artistic and engineering aspects of STEAM. This is the main reason that STEAM and project-based learning (PjBL) are an ideal combination in learning, where success in completing learning projects is a key factor for the success of STEAM.

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