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Exploring Science Teachers' Perspectives on STEAM Learning

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ABSTRACT

STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning has proven to be effective for 21st century education. However, there is a lack of knowledge regarding how teachers understand and implement STEAM in schools, particularly in science education. This study aims to explore science teachers' perspectives on STEAM learning. This case study focused on four dimensions: teachers' understanding, experience, state of mind, and expectations. The study involved 448 Indonesian science teachers from 24 provinces. Data were collected through an online questionnaire using Google Forms. The analysis employed inductive content analysis, extracting themes, sub-themes, categories, and codes from participants' responses. Indonesian science teachers acknowledged their limited understanding of STEAM. They found the existing STEAM frameworks and seminars insufficient in providing clear guidance. They expressed a need for a more explicit STEAM framework that is easy to implement. Additionally, they requested comprehensive examples of lesson plans that demonstrate the application of STEAM in their classrooms. Thus, this study highlights the need for improved understanding and implementation of STEAM learning among science teachers. Clear guidance, comprehensive frameworks, and practical examples are necessary to support educators in effectively integrating STEAM into various educational contexts.

Keywords:
Science education; STEAM learning; teachers' perspectives

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1. Introduction

It has been around 30 years since Education for Sustainable Development (ESD) has been put forward. Anchored by sustainable development values, now education must be a collection of purposeful activities that develops students' abilities to contribute to future sustainable environment via collaboration and interdisciplinary learning [1]. STEAM (Science, Technology, Engineering, Arts, and Mathematics) is viewed as an integrative learning that meets the values of ESD [2]. Besides collaboration, STEAM is projected to improve students' problem solving and creativity [3] and other 21st century skills [4]. Those skills can be gained through STEAM education because students establish links among various disciplines via integrated learning.

In 2019, the United Nation (UN) released "ESD for 2030" policy. Since then, many schools around the globe have included the UN Sustainable Development Goals (SDGs) in ESD [1]. Consequently, there

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has been increasing interest for STEAM education due to the global awareness to prepare students for a more complex world. Many countries hope that integrative STEAM learning can become the manifestation of ESD. However, expert noticed that there are serious challenges that teachers face to implement STEAM in their classrooms [5]. Therefore, it is important to address teachers' perspectives on STEAM education.

In developed countries, for example South Korea, STEAM education has become a national program. Since 2011, the South Korean Ministry of Education has started the effort to implement STEAM education in elementary and secondary schools throughout the country [6]. Every school in South Korea must include 20% of STEAM related topics in their syllabi. During the five years of the mandatory practice, Park *et al*., [6] pointed out that little was known about the implementation of STEAM in South Korean schools. Therefore, Park *et al*., [6] suggested that knowing how teachers understand, value, and implement STEAM education is crucial.

In Indonesian context, the notion STEAM education is relatively new among educational stakeholders (e.g., teachers, students, and administrators). The latest national regulation, known as Merdeka Belajar (Emancipated Learning), STEAM teaching is not explicitly mandatory to be implemented in schools [7]. However, the policy recommends subject integration in schools. For example, at the high school level, it is possible that teachers integrate the content of natural science subjects with that of social sciences [7]. Implicitly, the Indonesian Ministry of Education has invited all teachers to create more integrative learning in schools [7]. In this regard, Indonesian educational experts, including many teachers, should translate that STEAM, due to its nature of integration, can be a response to that policy. The concept of 'Emancipated Learning' emphasizes self-directed and self-paced education, empowering students to take control of their learning journey. STEAM education aligns perfectly with this philosophy by providing students with opportunities to explore their interests, make choices, and engage in project-based learning [8,9]. This approach fosters independence and encourages students to take ownership of their education.

Until recently, there has been increasing research interest on STE(A)M education that can be found in the literatures, see for example [10-12]. An international study was reported by Harris *et al*., [13] who investigated how creativity and teacher practice of STEAM education are discussed and valued by interviewing secondary school teachers in Singapore, Canada, USA, and Australia. The findings suggested that more research is needed to determine how STEAM education initiatives based on communication and collaboration can successfully transfer knowledge and skills to prepare the 21st century learners [13]. In the local context, we have reported several results on STE(A)M education focusing on Malaysian students' perspective [14] and Indonesian students' creativity [15]. With the recent numbers of practitioners in STEAM among Indonesian teachers, the obvious question remains; how these teachers perceive STEAM in their teaching? Learning from the experience of well-developed countries, we foresee to investigate how Indonesian teachers understand and value STEAM education early on. This paper aims to examine corresponding perspectives among Indonesian teachers' as they adopted STEAM in daily teaching practices.

2. Literature Review

Over the past 20 years, there has been a significant push for STEM education to prepare young people for a better society in the 21st century. STEM education, as defined by Sanders [16], emphasizes the need for integrated teaching and learning, and it can only be effectively achieved by addressing real-world problems. STEM goes beyond being an acronym for science, technology, engineering, and mathematics. It involves integrating these disciplines in the teaching and learning process, using real-world problems as the basis. Thus, "integration" is the key concept in STEM education [16], which can be achieved through both context and content integration [17]. Content integration involves incorporating at least two of the STEM disciplines within a single lesson that focuses on real-world problems. It is not necessary to integrate all four disciplines simultaneously, as suggested by Kloser *et al*., [18]. Content integration aims to merge STEM disciplines to solve real-world issues. On the other hand, Stohlmann *et al*., [19] argues that context integration makes STEM content more meaningful and applicable to specific situations. For example, one way to achieve STEM integration is by using mathematical modeling within a science context [19].

Recently, the integration of arts into STEM (STEM + Arts, known as STEAM) has become a new variant for the 21st century educational approach [10]. According to Guyotte *et al*., [20], the inclusion of the arts in STEAM is not solely responsible for fostering creativity. Quigley *et al*., [8] argued that integrating the arts into STEM education expands its scope and provides a more comprehensive approach to solving real-world problems, both in the present and the future. Guyotte *et al*., [20] emphasized that STEAM education breaks down traditional disciplinary boundaries, allowing students to acquire new knowledge and skills. Therefore, STEAM, which encompasses the arts, goes beyond enhancing science lessons and making them more engaging. STEAM education is about preparing students to solve real-world problems [8] through integrative learning approach [21]. It has the potential to address pressing global issues such as deforestation, climate change, and ecological disasters that are prevalent worldwide.

While there has been a growing emphasis on integrating arts into STEM education to form STEAM, there is a lack of research focusing specifically on science teachers' perspectives on STEAM learning [22]. Most of the existing literature in the field of STEAM education has predominantly focused on general aspects such as the benefits of integrating arts [8], the impact on student interest and engagement [23], and the development of student creativity [10]. Understanding science teachers' perspectives on STEAM learning is crucial for several reasons. Firstly, science teachers play a pivotal role in delivering STEAM education and shaping students' understanding of scientific concepts [24]. Their attitudes, beliefs, and perceptions can greatly influence the implementation and effectiveness of STEAM programs in science classrooms [6]. Secondly, Park *et al*., [6] added that exploring science teachers' perspectives on STEAM learning provides valuable insights into the challenges and barriers they encounter while implementing STEAM approaches. By identifying these challenges, educational stakeholders can provide necessary support to science teachers, ultimately enhancing the implementation of STEAM education [25]. To bridge this gap, this study captures the Indonesian science teachers' perspectives on STEAM learning, investigating their understanding, experience, state of mind, and expectations regarding the STEAM education practices in science classrooms.

3. Methodology

This research adopted a case study design to understand and interpret a phenomenon in the natural setting. The aim is to evaluate the phenomenon of interest, Indonesian teachers' perception on STEAM education, in a holistic perspective. Thus, the participants were regarded as a case. We framed this study in a qualitative approach because the focus of this research is on the "what" and "how" the teachers' perspectives towards STEAM learning. The respondents included 448 Indonesian science education teachers from 24 (out of 37) provinces. The survey was conducted online via Google Form. The questions were designed in the form of open ended.

Cheung [26] suggests that teachers serve as role models for their students, highlighting the importance of teachers' perspectives and understanding in educating their students [22]. According to Ferguson *et al*., [22], teachers' skills in teaching, particularly in STEAM education, are influenced by their perspectives and actions. Thus, it is crucial to understand teachers' thoughts and expectations regarding STEAM education. To gather this information, a set of questionnaires was constructed, with significant modifications, based on previous studies conducted by Aykan *et al.*, [27]. In this study, the participants' experience, state of mind, and expectations regarding STEAM education are expected to be revealed through their engagement with the questionnaires. To collect that crucial information, the following questions were addressed in the survey:

1. What do you know about STEAM?
2. Have you implemented STEAM in a classroom? If yes, please elaborate on how STEAM learning is done.
3. How do you feel about doing STEAM in teaching? Please provide an explanation.
4. Have you attended any STEAM seminar/workshop? What is your opinion after joining the seminar?
5. What is your expectation on STEAM education for your own professional development?

The data were then analyzed by means of content analysis to identify, describe, and evaluate patterns within the data of teachers' responses [28]. We started from reading multiple times the teachers' answers and becoming familiar with the data. Next, we started to extract the codes that reflect key ideas of teachers' answers followed by categorizing the codes. We then examined the themes by organizing the codes. We reviewed the themes, categories, and codes and correlated them back to the research questions. On presenting the data, we included direct quotations to give a coherent picture of teachers' perspectives.

4. Results and Discussion

Demographic data in terms of teachers' age, teachers' teaching time, and distribution of provinces where teachers work are presented in Fig. 1. The teacher participants were 76% female and 24% male. The two big pie charts illustrate the proportion of teachers' age and teaching time. In general, we distributed teachers' age and teaching time in five-year intervals. The survey revealed that young teachers (below 26 years old), old teachers (over 56 years old) and senior teachers (over 31 years of teaching experience) were the least respondents. Teachers with teaching experiences less than 6 years, in the intervals of 6 – 10, 11 – 15, 16 – 20, and 21 – 25 years contributed almost equally, with ~18% on average. Teachers with ages of 26 – 30 years old contributed, i.e., 15%, as many as those at 51 – 55 years. 12%, 14%, and 17% of teachers with respectively ages of 31 – 35, 41 – 45, and 46 – 50 years old consented to participate. Meanwhile, 20% of teachers with ages of 36 – 40 years old filled the questionnaire. Fig. 1 also includes the distribution of the participants' working area, presented in province. It is seen that the survey was followed by numerous of teachers in almost all over Indonesia with most of the participants, around 75%, were from Jawa Timur. Although other teachers from other province were not so many as from Jawa Timur, their answers were equally important.

Table 1 displays the analysis of teachers' understanding of STEAM learning. Looking at the trend from the graph by excluding 'no answers responses', it can be said this question does not lead to multiple answers. This is because, most of the responses either referring STEAM by its acronym or simply stating its purpose. These simplistic responses although not much can be accounted for understanding yet described their earliest encounter for STEAM. To this question, around 45% of the respondents stated either the definition of STEAM in terms of its acronym (science, technology, engineering, arts, and mathematics) or the needs of integration/collaboration in the STEAM learning process. In this survey, 6.5% of the respondents stated that STEAM is about facilitating students to achieve various learning outcomes like creativity, problem solving, and critical thinking. At the same time, over 20% of the respondents viewed STEAM as a learning approach. They mentioned about problem-based and project-based learning. A few teachers defined STEAM as science-based or arts-based learning. On top of that, nearly 28% of the total respondents did respond to STEAM Those who failed to respond can be assumed to either not have any idea about STEAM or more familiar with term like STEM apart for technicality issues. Either way, both possible interpretations lead us to believe that teachers do not recognize art (A) within STEM.

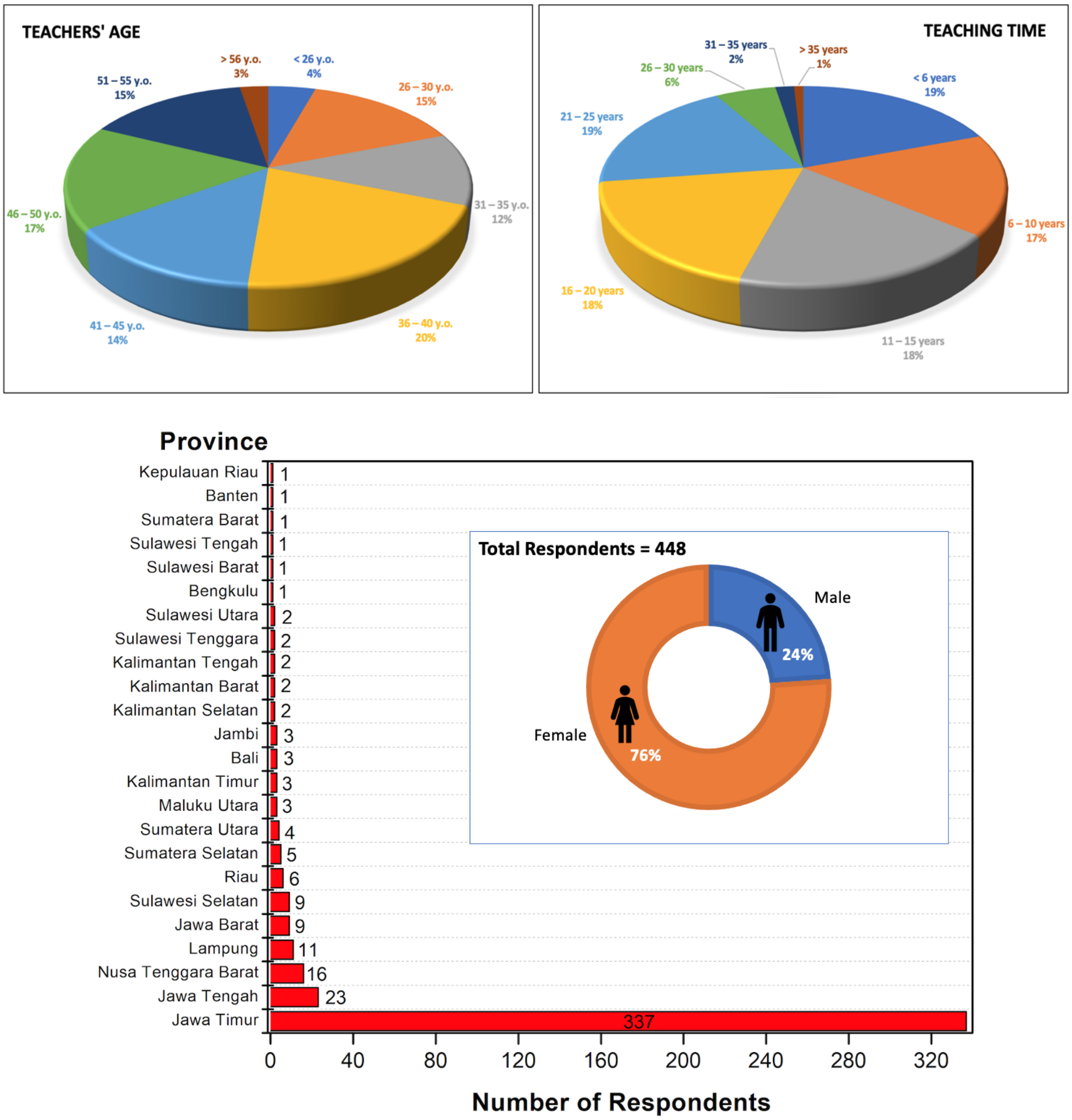

Fig. 1. Demographic data of the respondents

Table 1
Teachers' understanding of STEAM learning

Themes	Categories	Codes	Quotes
Teachers' Understanding of STEAM Learning	Definition	Acronym (n = 79, p = 17.6%)	Science, Technology, Engineering, Arts, and Mathematics. (#322)
		Integration (n = 120, p = 26.8%)	It is an integration of science, technology, engineering, arts, and mathematics. (#45)
		Collaboration	It is a collaborative learning. (#451)

	(*n* = 4, *p* = 0.9%)	
Learning approach	Learning strategy (*n* = 60, *p* = 13.4%)	It is a learning strategy. (#256)
	Problem-based learning (*n* = 15, *p* = 3.3%)	It is good for students to solve real-world problem. It is a problem-based learning. (#172)
	Project-based learning (*n* = 5, *p* = 1.1%)	It is a project-based learning that makes students learn how to create a product as a solution to a given problem. (#98)
	Science-based learning (*n* = 4, *p* = 0.9%)	A learning approach that is based on science. (#257)
	Arts-based learning (*n* = 8, *p* = 1.8%)	It is an arts-based learning approach. (#54)
Learning outcome	Creativity (*n* = 16, *p* = 3.6%)	An integrated learning to develop students' creativity. (#341)
	Problem solving (*n* = 5, *p* = 1.1%)	It is used to train students solve problems more comprehensively. (#275)
	Critical thinking (*n* = 8, *p* = 1.8%)	A learning that is best for students' critical thinking. (#262)
No answer	(*n* = 124, *p* = 27.7%)	-

n, *p*, and # respectively represent number of respondents, percentage of respondents, and respondent number

Fig. 2 shows a diagram of teachers' understanding by age. 31 to 40-year-old teachers managed to know only the STEAM definition. From the figure, it is implied that teachers over 50 years old tended to have little idea about STEAM. Some young teachers (under 30 years) also had no understanding on STEAM. The second question concerned about teachers' experience in STEAM learning. As shown in Table 2, more than 80% of the respondents had not implemented STEAM learning in their classrooms.

The main reasons were because of no understanding and feeling unsure for STEAM implementation. For those who have experiences teaching STEAM at schools, they acknowledged the use of subject integration, the use of problem- or project-based learning. As STEAM learning results, the students could create 2D or 3D products.

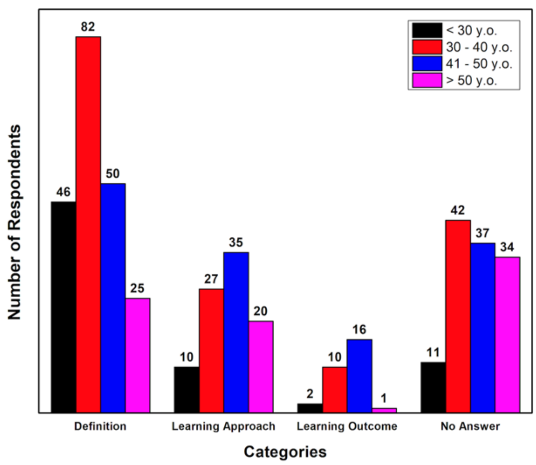

Fig. 2. Teachers' understanding of STEAM by Age

Table 2
Teachers' experience in STEAM learning

Themes	Sub-Themes	Categories	Codes	Quotes

Teachers' Experience in STEAM Learning	Experienced	Integration type	Subject integration (n = 3, p = 0.7%)	In case of teaching "Quantities and Units", physics and mathematics were used for conceptual understanding, and it was applied in measuring technological instruments. (#16)
			Science topic integration (n = 76, p = 16.9%)	I combined physics with biology topics that connected the concepts of pressure and capillarity with plantation. (#55)
		Learning method	Real-world problems (n = 14, p = 3.1 %)	Taking thermodynamics as the example. Students were presented with a real problem, for example the aircraft cabin problem. Then they learn the concept by connecting with engineering and technology fields. (#79)
			Project-based learning (n = 28, p = 6.2%)	In the topic of static fluids, students were taught with STEAM learning and as a result students created tools that apply Pascal's law, in the form of simple machines. (#70)
		Learning product	2D design product (n = 7, p = 1.6%)	In electrical energy topic, students created house designs to save the energy. (#35)
			3D design product (n = 23, p = 5.1%)	Students designed bridges using ice cream sticks and tested their strength. Topic: force. (#258).
	Inexperienced		No understanding (n = 345, p = 77.0%)	I have not understood. (#51)
			Unsure (n = 4, p = 0.9%)	Not sure. (#358)
			No reason (n = 12, p = 2.7%)	-

n, *p*, and # respectively represent number of respondents, percentage of respondents, and respondent number.

Fig. 3 displays the teachers' experience in STEAM learning by work time. Teachers with 10 – 20 years of teaching experience became the most inexperienced in STEAM learning. Also, it happened to teachers with less than 10 years or over 20 years of teaching experience. Given the number of experienced teachers with STEAM learning is small, it is implied that even the teachers have known about STEAM, as from the analysis of Table 1, did not guarantee them to implement it to their classrooms.

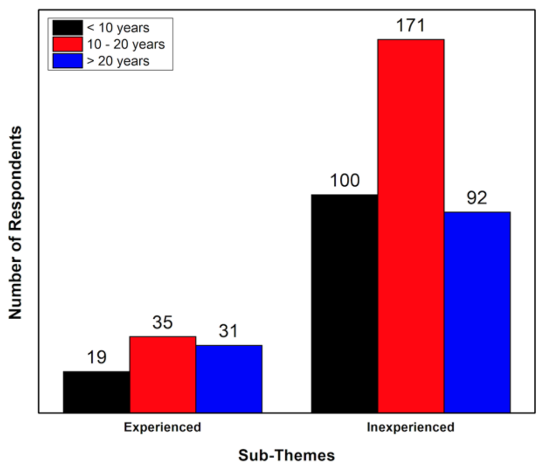

Fig. 3. Teachers' experience in STEAM learning by teaching Time

The third question was about teachers' state of mind to implement STEAM. The content analysis is summarized in Table 3. We divided teachers' feeling into two categories, it can be either difficult or easy to implement STEAM. A majority of the teachers, 86% of the respondents, felt STEAM implementation is not feasible for their environment. Some reasons included less understanding regarding core-concept of STEAM learning, the lack of learning facility, and time constraint. As for the minority, 14% of the respondents viewed that STEAM is 'easy'. They believed that STEAM guarantees student-centered learning (7.1%), STEAM is about contextual learning (4.9%), and STEAM improves students' thinking skills (2.0%). The results depicted from Table 3 is in line with teachers' response on their STEAM understanding and experience in STEAM learning.

Table 3
Teachers' State of Mind to Implement STEAM

Themes	Categories	Codes	Sample Responses
Teachers' state of mind to implement STEAM	Difficult	Core-concept of STEAM (n = 287, p = 57.9%)	It is new for me, so I need to study the concept of STEAM before implementing it. (#25)
		Learning facility (n = 42, p = 8.5%)	It is hard to implement integrated learning, like STEAM, in my school due to the lack of facilities. (#31)
		Time management (n = 20, p =4.0%)	I wonder that I will have enough time to teach STEAM. I am afraid that all topics will not be covered in the school timetable. (#57)
		No reason (n = 77, p = 15.6%)	-
	Easy	Student-centered learning (n = 35, p = 7.1%)	Student-centered learning is easier with STEAM. (#138)
		Contextual learning (n = 24, p = 4.9%)	Hands-on activities in STEAM are contextual. (#187)
		Students' thinking skills (n = 10, p = 2.0%)	Students' thinking skills can be triggered with STEAM activities and projects. (#55)

n, *p*, and # respectively represent number of respondents, percentage of respondents, and respondent number.

The fourth question dealt with teachers' source of knowledge on STEAM by attending related seminars or workshops, as shown in Table 4. More than 61% of the participants did not attend any seminar or workshop on STEAM education. A majority of them did not get any information on the available seminar/webinar. The rest who attended the seminar/webinar on STEAM exhibit different responses to this question. Nearly 16% of the respondents obtain STEAM knowledge and regard this as something new. Others show implication from attending the seminar to their personal development as teacher such as motivated. However, the analysis soon finds that, 102 teachers who joined STEAM seminar remain demotivated after seminar because teaching STEAM is an overreaching aim.

Table 4
Teachers' Experience Attending STEAM Seminar or Workshop

Themes	Categories	Codes	Sample Responses
Teachers' experience attending STEAM	Not Attended	Missing information (n = 235, p = 52.5%)	I have not heard any information about STEAM workshop. (#72)
		No reason (n = 77, p = 15.6%)	-

seminar or workshop	Attended	Building knowledge (n = 36, p = 8.0%)	I was happy because I could get new knowledge. (71)
		Getting motivated (n = 35, p = 7.8%)	I was motivated to implement STEAM in my school. (#127)
		Difficult to implement (n = 102, p = 22.8%)	After the workshop, I felt it was still difficult to implement. (#9)

n, p, and # respectively represent number of respondents, percentage of respondents, and respondent number.

Table 5 shows findings on teachers' expectation towards STEAM education. There is well established pattern when it comes to expectation. Many of them required a workable example of STEAM teaching. For instance, 58.5% of them demand for guidance to implement that include resources like lesson plans. A big part to normalize STEAM in Indonesia also stems from lack of circulation of knowledge and practice on STEAM. Closely 60% of the respondents expected a clear and easy-to-use STEAM learning framework. Workshops to help teachers get correct understanding on STEAM and further implement it in the schools were also expected. On the other hand, 35 respondents did not provide any expectation to this matter.

Table 5
Teachers' expectation

Themes	Codes	Quotes
Teachers' expectation	STEAM learning framework (n = 262, p = 58.5%)	I hope experts will give clearer and easier guidance for STEAM implementation. (#31)
	Correct understanding (n = 147, p = 32.8%)	I wish I can get correct understanding about STEAM. (#23)
	Workshop to train teachers (n = 4, p = 0.9%)	There must be an example of complete STEAM implementation along with the detailed lesson plan. (#443)
	No answer (n = 35, p = 7.8%)	-

n, p, and # respectively represent number of respondents, percentage of respondents, and respondent number

Analysis of the qualitative data showed that Indonesian teachers' understanding on STEAM ranging from simply the acronym to learning outcomes. Many teachers defined STEAM as a learning strategy. In this regard, experts suggested that STEAM should be viewed more than just as a learning strategy [29] and as an inspiration for innovation [30]. More teachers knew only its acronym by responding "Science, Technology, Engineering, Arts, and Mathematics." Age-wise, 30 to 40-year-old teachers provided predominantly the definition of STEAM on its acronym. Stating only the acronym of STEAM did not give a clear clue whether the teachers' view that STEAM is just an isolated or integrated subjects. Many teachers related STEAM with integration by writing "It is an integration of science, technology, engineering, arts, and mathematics." Some teachers also believed that STEAM is strongly correlated with real-world problems and project-based learning. This correlation is in line with what experts suggested [8]. However, nearly 28% of the respondents left the answer blank, indicating that they had no idea about STEAM.

Knowing and doing are different. Even though more than 72% of the respondents said some definitions about STEAM, in practice around 80% of the respondents did not have any experience in STEAM learning. This became quite contra-productive when it is revealed that 345 teachers did not know about STEAM by writing "I have not understood" to the second question. The good news is that some teachers have implemented STEAM through integration, introducing real-world problems, and using project-based learning. An experienced teacher with good understanding of STEAM wrote, "In the topic of static fluids, students were taught with STEAM learning and as a result students created tools that apply Pascal's law, in the form of simple machines." As the product, another teacher said, "Students designed bridges using ice cream sticks and tested their strength. Topic: force." Researchers have reasoned that learning STEAM by creating projects could achieve a very satisfactory performance [9].

In line with the lack experience of STEAM learning, most teachers felt that it was difficult to implement STEAM. They said, "It is new for me, so I need to study the concept of STEAM before implementing it." Besides time management and lack of learning equipment were addressed as the cause of difficulty. As a new learning paradigm, there exists too many definitions of STEAM in the literatures [21]. This may probably require teachers to deeply study the core concept of STEAM prior to implementation. Viewing integrative STEAM as a learning that required project [8] is likely to make teachers feel that they need extra time and more learning equipment for STEAM realization in classrooms.

In terms of seminar on STEAM, majority of the teachers missed the seminar information. A teacher wrote, "I have not heard any information about STEAM workshop." Meanwhile, there were three distinct codes for those who attended seminars. Teachers believed that attending STEAM seminar could improve their motivation and become more knowledgeable. But then again, many teachers felt that difficulty was unsolved with the workshop. A teacher responded, "After the workshop, I felt it was still difficult to implement." It implied that there are many challenges in STEAM instruction [31] that a workshop may not help.

Finally, the teachers' expectations were figured out. 35 teachers did not mention their expectations and only few who expect a workshop. A majority of the teachers expect a solid STEAM learning framework and correct understanding of STEAM. A teacher wrote, "I hope experts will give clearer and easier guidance for STEAM implementation." Our analysis suggested although many STEAM frameworks are available in the literatures, but Indonesian teachers need a framework that is suitable for Indonesian socio-cultural context. Chu *et al*., [32] supported that socio-cultural aspects are strongly related to students learning process [32].

It is recommended that Indonesian policymakers prioritize the development of a context-specific STEAM framework, providing clear guidance and support to address science teachers' challenges. Efforts should also focus on improving communication and awareness of STEAM workshops. By addressing these issues, Indonesia can enhance the quality of STEAM education, empowering teachers to effectively implement STEAM learning and better prepare students for the demands of the 21st century.

5. Conclusion

In conclusion, the findings of this study indicate that Indonesian teachers have varying levels of understanding and implementation of STEAM education. While few teachers demonstrate a solid understanding and successful integration of STEAM, a significant portion lack knowledge and experience in this area. Challenges such as limited time, lack of learning equipment, and the need for a clear STEAM framework tailored to the Indonesian socio-cultural context were identified. Despite some teachers attending seminars, difficulties in STEAM implementation in classrooms persisted. In addition, it is important to note that the results are specific to science teachers, and therefore, the results cannot be generalized.

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