Analysis of teachers’ difficulties in implementing STEM approach in learning: a study literature

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Abstract. STEM approach in learning is applicable in the 21st century in which it promotes 4C skills: communication, collaboration, creativity, and critical thinking. The implementation of STEM increases the productivity of the learning process in responding to the challenges of the industrial revolution 4.0. Because it is relatively new in Indonesia, the application of the STEM approach in learning has certain difficulties for teachers. This study aims to determine the difficulties faced by Indonesian mathematics and science teachers in implementing STEM in recent five years. Based on seven main articles compared in this study, the difficulties faced by teachers in implementing STEM or STEAM are varied depending on its main focus (mathematics or science). The most common obstacle faced by mathematics teachers are finding real-life contexts of abstract topic in mathematics. While, the main difficulty experienced by science teachers are insufficient comprehension toward STEM and the limitation of time. Moreover, both mathematics and science teachers shared common difficulties as follows: low understanding about STEM, the lack of facilities and limited time provided in learning schedule. Therefore, to overcome teachers’ difficulties mentioned before, several solutions are offered depends on the needs such as increasing teachers’ comprehension toward STEM, completing school facilities and adjusting curriculum targets under the implementation of STEM.

1. Introduction
The learning approach continues to change with particular innovation, including in learning and teaching of mathematics. One approach in learning mathematics that is available nowadays is STEM approach. An approach that integrates four disciplines, namely Science, Technology, Engineering, and Mathematics (STEM) that was introduced in the United States through educational policy by the National Science Foundation in the 1990s. Besides comprising four scientific disciplines, STEM is also combined with Medicine which is called as STEMM or it can also be varied with Art and abbreviated as STEAM. The presence of Art in STEAM can increase creativity and rationality [1] so that the learning that takes place will be more meaningful and memorable for a long period of time. The use of STEM as a form of integration of the four knowledge is considered the right solution at this time because the fragmented learning of Science, Technology, Engineering, and Mathematics turns learning to be meaningless and boring[2]. Students who study under the STEM approach can also create interactions and form experiences in conducting authentic investigations [3].
The 21st Century skills that include communication, collaboration, critical thinking, and creativity, or abbreviated as 4C skills are the essential skills to be developed today. Teachers are required to facilitate education that is able to equip students with 4C skills in order to help them face the challenges of globalization [4]. STEM has a positive relationship with the 21st century skills [5]. These skills are increased through research-based learning [6]. One of them is STEM learning [3]. The interconnection between STEM and 21st century skills shows that they are inseparable and interrelated with each other [7].

Meanwhile, the 4.0 revolution caused alteration in term of innovation in education such as the development of artificial intelligence and digital physical frameworks, which make humans interface with technology on routine basis [8]. Other challenges that arise are the internet of things, big data, and cyber-physical systems [9]. These challenges require the teacher to prepare students to have knowledge and skill to deal with these problems [10]. This is because the industrial revolution 4.0 strongly encourages all parties to grow new knowledge and competencies so that the education system can respond quickly to developments and changes that exist [11]. Implementation of STEM as one of the approaches in learning is very appropriate in the era of the industrial revolution 4.0 [12]. Due to STEM Education integrates several field of subjects to solve problems creatively to be used to develop innovations in the future [13]. One of the initial STEM implementations in Indonesia has been done in class VII, junior high school through learning about balloon-powered cars [14]. Based on this research, the motivation and experience of student to design and create something increased through STEM-based learning.

The urgency of applying STEM in Indonesia is strengthened by the existence of several advantages gained through learning with the STEM approach, including (1) increasing students' mathematical correlatives abilities [14], (2) increasing students' critical thinking skills [12][15], (3) increasing creative thinking skills [16], (4) increase students to think systematically and logically according to the demands of 21st century skills [17] and (5) enhance students' ability in problem-solving [18]. These findings reinforce that STEM is a potential approach to be applied in the 21st century and the era of the industrial revolution 4.0. Although it has a very positive potential for the current challenges, the implementation of STEM learning has many obstacles [19][20][21][22][23][24]. Therefore, this study was conducted to explore the difficulties of Indonesian mathematics and science teachers during the implementation of STEM in the latest five years in order to find the right solution to minimize their difficulties in the future. Active student involvement in learning with the STEM approach requires several support programs such as a clear curriculum, instructions and assessment instruments, integration of Engineering and Technology knowledge into the Science and Mathematics curriculum, and improving the ability of scientific inquiry [25].

At present time, the STEM approach in Indonesia is not written explicitly in national curriculum, but it is implicitly stated in the curriculum's goals because it requires students to be faithful, creative, innovative, productive, and able to contribute to the life of society, nation, state and civilization worldwide. Furthermore, knowledge patterns that can be developed in the curriculum consist of single knowledge (monodiscipline) and plural knowledge (multidiscipline). The statement can be assumed that the application of STEM in learning in Indonesia is an expansion of the 2013 curriculum concept. However, preparing curriculum that covers the framework of implementing STEM will takes time [26] and can be anticipated by implementing STEM that supports the 2013 curriculum by substituting the local wisdom characteristics that exist in Indonesia [27].

STEM is considered as a very important learning approach to support future success. Thus it attracts both teachers and students to learn about it despite the challenges faced by them [28][29]. The application of STEM in learning is significantly influenced by teacher competence, one of which is related to teacher perception [30]. Furthermore, teachers are also required to have adequate knowledge in order to be able to guide students to have abilities in accordance with the needs of the 21st century [13]. Other findings indicate the readiness of teachers in implementing STEM based on behaviour and affective and cognitive aspects is already high, but not yet optimal in preparing STEM-based learning [7]. Teachers’ understanding of STEM is also very low and students do not have the motivation to take
part in STEM learning [23]. Based on the obstacles that have been revealed, it is necessary to explore other difficulties faced by teachers in implementing STEM so that the learning process with the STEM approach becomes more effective.

2. Methods
This article is a literature study based on previous researches that explores the difficulties faced by Indonesian mathematics and science teachers in applying the STEM approach in learning based on the latest five years studies. The purpose of this paper is to explore the difficulties experienced by teachers in implementing STEM in order to find the right solution to overcome the difficulties. The selected literature is the research that reveals the Indonesian teachers’ difficulties based on their perspective, knowledge and experience in implementing STEM in teaching mathematics and science. The teachers involving in the selected articles consist of high school and vocational school teachers from several province in Indonesia. This literature study compared seven main articles obtaining from Google Scholar. That main articles are researches conducted by: Milaturrahmah, Mardiana and Pramudya [31], Rosikhoh et al. [15], Winangun and Kurniawan [32], Nugroho, Permanasari and Firman [26], Wahono and Chang [19], Parmin, Saregar, Deta and El Islami [33] and, Susilo and Sudrajat [23].

Furthermore, this study literature conducted by using these following steps, which include: (1) identified STEM education articles that revealed teachers’ difficulties, (2) analysed teachers’ difficulties in implementing STEM from each article, (3) classified teachers’ difficulties in implementing STEM based on main focus (mathematics or science), (4) grouped teachers’ difficulties with similar category and (5) discovered appropriate solution to overcome its difficulties.

3. Result and Discussion
3.1 Teachers’ difficulties in implementing STEM approach
Referring to the first literature used in this study [31], the difficulties faced by Indonesian mathematics teachers based on their experiences in the process of STEM learning are (1) finding the real life problem related to mathematics topics, and, (2) preparing learning tools and materials. Based on the first difficulties, implementing STEM in mathematics are challenging because some topics in mathematics are quite abstract and teachers could not find the appropriate contextual example or applications of that topic in the real life. The second difficulties reveal an inadequate learning tools and materials that reducing teachers’ desire to conduct mathematics learning using STEM approach.

Meanwhile, based on the second literature [15], the difficulties faced by mathematics teachers in implementing STEAM were not effective even though the government are willingly to support because of these conditions: (1) the limitation of time providing in teaching mathematics in the class to carry out STEAM project, (2) teachers’ lack of competence to implement STEAM due to the inadequate training and supporting references about STEAM project, and, (3) only several topics in mathematics can be implemented in STEAM project.

Referring to third literature [32] that explicitly mentioned the difficulties faced by science teachers in implementing STEM, there are nine difficulties encountered from that research including: (1) the limitation of time, (2) the restriction to cooperate with other professionals and experts that related to STEM, (3) not regulated teamwork, (4) less of support from students’ parent, (5) teachers’ lack of competence to prepare tools and materials needed in STEM, (6) less of sponsor to fund STEM learning, (7) the unsupported school management in providing adequate time and funding, (8) the limitation of school facilities and (9) teachers are not familiar to compose STEM-based lesson plan. Based on this article, the most difficulties faced by teachers are the limitation of time particularly in planning STEM, support from students’ parents and preparing learning with STEM integration.

The fourth literature [26] conducted to explore science teachers’ perspective in implementing STEM. Based on that research, the fact that obtained toward teachers’ difficulties in implementing STEM are: (1) teachers’ insufficient comprehension toward STEM, (2) teachers’ training providing by government is very general and unconnected to the teachers’ current needs in teaching, (3) inadequate school facilities, (4) several teachers are not involve actively in school subject teachers’ working group
(MGMP) as a teachers discussing forum on certain subject and transferring information about latest teaching approach, including STEM.

Referring to the fifth literature used in this study [19], the implementation of STEM in the class, science teachers face the obstacles that are classified as rational, neutral, and irrational. Rational constraints include: limited knowledge about STEM, the difficulty of combining topics in science with mathematics, and not all topics can be taught using the STEM approach. Neutral constraints consist of students' different abilities, low skills in mathematics, teacher education background, limitation of time, and limitations in using technology. While the irrational obstacles that occur include the location of the school is far from urban areas, limited facilities and infrastructure, students are not familiar with STEM learning, students' motivation is low in learning, there are no applications in the device, and frequent blackouts.

Furthermore, based on the sixth literature [33] toward science teachers, there are several difficulties faced by teachers, namely: (1) teachers are assure for having insufficient information about STEM, (2) science teachers are hesitate to teach integrated science because not their expertise, (3) lack of teachers’ believe that integrated STEM is appropriate approach in teaching science.

The last, from the seventh literature [23], it is known that the difficulties of biology teachers in Indonesia in implementing STEM include: (1) teachers do not comprehend the meaning of STEM in detail, but only know what it stands for, (2) lack of time in the STEM learning process, (3) students’ interest in STEM integrated learning is still low and they do not yet understand the essential essence of STEM learning, and (4) teachers' experience in teaching STEM is still low and requires further training to be more skilful during implementation [23].

Based on seven main articles compared in this study, the difficulties faced by teachers in implementing STEM or STEAM are varied depending on its main focus (mathematics or science). However, in the several mentioned studies, the Indonesian mathematics and science teachers experienced the same difficulties in implementing STEM. After analysing seven main articles, it could be inferred that (1) the most difficulties faced by mathematics teachers are executing mathematics in STEM for several abstract topics due to its characteristics which not related to real-life implementation [31][15], while science teachers do not reveal the same difficulties, (2) the most difficulties experienced by science teachers in implementing STEM are teachers insufficient comprehension toward STEM [26][33][19][23] and the limitation of time to conduct STEM approach in learning [32][19][23], and (3) both mathematics and science teachers suffering common difficulties namely the low understanding about STEM and its implementation, the lack of facilities, limited time providing in the school schedule to conduct STEM approach in learning.

### 3.2 Solutions to overcome teacher difficulties in implementing STEM

The STEM approach has a positive impact in learning [34]. STEM approach is a form of learning that combines four disciplines, science, technology, engineering, and mathematics in learning so that it can be connected with real problems in daily life [12]. Other reasons for choosing STEM than another learning approach are: (1) availability of subjects adjustment needed in STEM, (2) the application of STEM are easy, simple, useful and does not require big amount of expenses and too long period of time, (3) STEM learning process is effective, maximizing students’ potential, easy to understand and creating long life or permanent learning, and (4) generating diverse knowledge and has added value [20].

Solutions that can be applied to overcome teachers’ difficulties when implementing STEM, include: (1) Educational authorities are responsible for building teachers’ awareness about the importance of STEM so that teachers become motivated and able to guide students to be actively involved in learning with the STEM approach, (2) Educational authorities need to provide adequate training so that teachers have the skills in implementing STEM and (3) provide the facilities needed when implementing STEM projects [22]. Teachers must be assisted by organizing training to develop professionalism, pedagogical support, and understanding of the curriculum so that they are ready to apply the STEM approach in learning [35][36].
To overcome teachers’ difficulties in facing inadequate learning tools and material, teachers can search information from multiple sources including from Indonesia and other countries in order to adopt the STEM implementation. After finding the appropriate application, teachers are encouraged to modify and adopt STEM application adjusting to the current facilities condition in their school [31]. The efforts for providing STEM training to teachers are very important and beneficial recently [37]. Because teachers must be given the opportunity to develop their professionalism to be ready in guiding students with the STEM approach [25]. The significant role of teachers in learning influences the implementation of STEM [29]. Teachers are also interested in implementing STEM but confuse whether they can do it without equipped with adequate preparation through workshops or training [38]. The enthusiasm of Indonesian educators in implementing STEM in learning has been seen from the development of learning instruments, for example, STEM-based student books [39], STEM-based modules [40] and STEM-based Science Worksheets [41].

The discovery and development of STEM learning tools show that the interest of educators in Indonesia in implementing STEM in learning has emerged and has great potential to be developed. In addition, increasing teachers and government awareness toward STEM education is essential to create opportunities and enhancement of its implementation [26]. Another solution that will greatly help teachers in implementing STEM is support from school management and other teachers besides mathematics and science teacher [22]. This is due to the fact that STEM is only understood by the majority of mathematics and science teachers, so other teachers cannot help them in implementing STEM. Furthermore, the successful implementation of STEM will also be achieved if there is a clear and supportive curriculum [36]. This is because teachers will obtain greater opportunities in implementing STEM learning without ignoring the desired targets in the national curriculum.

4. Conclusion
The STEM learning approach is an appropriate solution to master the 21st century skills and responding to changes in the educational innovation due to the industrial revolution 4.0. Because it is relatively new in Indonesia, the application of the STEM approach in learning has certain difficulties for teachers. Based on literature review, the difficulties faced by teachers in implementing STEM or STEAM are varied depending on its main focus (mathematics or science). However, in the several mentioned studies, both Indonesian mathematics and science teachers shared common difficulties in implementing STEM as follows: low understanding about STEM, the lack of facilities and limited time provided in learning schedule. Therefore, to overcome teachers’ difficulties mentioned before, several solutions are offered depends on the needs such as increasing teachers’ comprehension toward STEM, completing school facilities and adjusting curriculum targets under the implementation of STEM. Regarding to the limitation of this study that only comparing mathematics and science teachers’ difficulties in implementing STEM in Indonesia, the authors suggest the following researchers can investigate teachers’ difficulties in implementing STEM which focusing on engineering and technology and also finding other solutions to overcome teachers’ difficulties in implementing STEM.

5. References
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