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STEM Implementation Issues in Indonesia: Identifying the Problems Source and Its Implications

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STEM Implementation Issues in Indonesia: Identifying the Problems Source and Its Implications

Abstract

The last few years, STEM education received more attention in the world, including Indonesia. There are many teachers who have participated in socialization and applied STEM in their schools. Therefore, this study aims to describe the various obstacles faced by teachers implementing STEM learning. This qualitative study uses a phenomenological methodology. Data is collected from in-depth interviews with nine teachers who have information and knowledge related to STEM as an integrative learning framework and have participated in socialization, workshops, or seminars. The stages of data analysis are doing data reduction, determining themes, making links between themes, and concluding findings. The conclusions of the study are three broad categories of things that challenge schools in implementing STEM learning in Indonesia, namely policy support and limited learning facilities, complex learning management, and the ability of teachers to manage students that are very diverse.

Keywords

implementation, Indonesian curriculum, issues, schools, phenomenological methodology, STEM education

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STEM Implementation Issues in Indonesia: Identifying the Problems Source and Its Implications

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The last few years, STEM education received more attention in the world, including Indonesia. There are many teachers who have participated in socialization and applied STEM in their schools. Therefore, this study aims to describe the various obstacles faced by teachers implementing STEM learning. This qualitative study uses a phenomenological methodology. Data is collected from in-depth interviews with nine teachers who have information and knowledge related to STEM as an integrative learning framework and have participated in socialization, workshops, or seminars. The stages of data analysis are doing data reduction, determining themes, making links between themes, and concluding findings. The conclusions of the study are three broad categories of things that challenge schools in implementing STEM learning in Indonesia, namely policy support and limited learning facilities, complex learning management, and the ability of teachers to manage students that are very diverse.

Keywords: implementation, Indonesian curriculum, issues, schools, phenomenological methodology, STEM education

Introduction

In recent years, STEM (Science, Technology, Engineering, and Mathematics) has received more attention in education (Arlinwibowo et al., 2020, 2021b; Honey et al., 2014; Peterman et al., 2017). Initially, the United States had poor results in the international PISA (The Programme for International Student Assessment) survey. On the other hand, fact shows that the American population has difficulty competing in the world of work (Bicer et al., 2017). The solution taken by the American government is to give special emphasis in strengthening STEM to its people (Bicer et al., 2017; Chesky & Wolfmeyer, 2015). Strengthening STEM is included in the realm of education with the aim of increasing the quality of graduates so that they are able to compete globally. Ntemngwa and Oliver (2018) state that STEM education is a process of giving and receiving structured and systematic instruction in the disciplines of Science, Technology, Engineering, and Mathematics. STEM education is carried out through integrative practices involving two or more STEM domains. The purpose of the process is to provide authentic contexts and relationships between domains on subject themes (Arlinwibowo et al., 2021a; Arlinwibowo, Retnawati, & Kartowagiran, 2020a; Kelley & Knowles, 2016). The expected result is an increase in the quality of learning compared to the results of previous learning.

STEM education aims to form competitive students in the 21st century (Hallström & Schönborn, 2019). STEM learning based on integrated projects and investigations can improve 21st century skills such as independence, creativity, critical thinking, communication, and collaboration (Bybee, 2010). Related to 21st century competency needs, the STEM framework is able to align the educational process with the demands of the times. Many problems require the integration of various STEM concepts (Roehrig et al., 2012) such as make proportional engineering designs, develop ergonomic tools, plan economical infrastructure development, and so on. Substantially the STEM learning aims to find the relationship between the STEM domain and the relevant context (Kelley & Knowles, 2016). The benefits for students learning with the STEM approach are (a) understanding the concept of contextualization in the STEM field; (b) understanding the STEM context that is socially and culturally relevant; and (c) increasing interest in STEM disciplines.

STEM is a new learning concept in Indonesia (Suprapto, 2016). But among academics and researchers, STEM has been widely known. Many simulations and studies have been carried out related to the implementation of STEM learning conducted by researchers, lecturers, and education practitioners in Indonesia. Some data shows that the implementation of STEM learning in Indonesia has a positive impact on learning outcomes (Khaeroningtyas et al., 2016; Putra, 2017; Wisudawati, 2018). Findings show that STEM provides an increase in the quality of education both in and outside Indonesia (Çevik, 2018; Ong et al., 2016; Wan Husin et al., 2016).

Universities and governments today have sought to popularize STEM learning. The aim is that the quality of education increases, and graduates are formed in accordance with the demands of the times. The government of Indonesia through the Directorate of Secondary Education, the Center for Development and Empowerment of Educators and Education Personnel (P4TK), SEAMEO (Organization of the Ministry of Education in Southeast Asia), and QITEP (Quality Improvement of Teachers and Education Personnel) in science, mathematics and languages carry out various STEM socialization to teachers and principals. The socialization was carried out in various formats ranging from disseminating news to workshops and training. Another strategy implemented by the Ministry of Education and Culture in publicizing STEM in 2018 is inaugurating STEM to villages in Padukuhan Joho, Condongcatur, Depok, Sleman Regency, and the D. I. Yogyakarta Province (Nurmalia, 2018).

The socialization of STEM learning made many teachers attempt to implement STEM learning in their schools. STEM is the adoption of a system from outside Indonesia (Bybee, 2010). A new concept in education must refer to the applicable curriculum; thus, the implementation of STEM learning should not be carried out in a hurry. There must be various adjustments so that STEM implementation remains in line with the education curriculum in Indonesia.

One of the keywords of STEM learning is integration. Related to this, the curriculum in Indonesia is divided into two, namely, thematic learning for elementary school and non-thematic learning (fragmentation between subjects) for junior high, senior high school, and vocational school (Retnawati, Munadi, et al., 2017). Thus, for the junior high, senior high, and vocational school level, the implementation of STEM needs several adjustments. Adjustment of non-integrative learning into integrative learning is not easy. Various implementation constraints must be found in the efforts to implement STEM learning. Therefore, this study aims to describe the various obstacles faced by Indonesian teachers in organizing STEM learning. The results of the study are expected to be material for joint reflection so that the implementation of education can be more developed.

Indonesia is a developing country with a growing variety of educational facilities. This heterogeneity allows this research to produce an overview representing a broader portrait of STEM education. The investigation results will be detailed so readers can sort and choose situations following the conditions around them. Thus, the results of this study can provide more comprehensive benefits (domestic or foreign).

This research is significant for researchers and readers. For researchers, this article is an investment of knowledge that can be used as a basis for further study. This is because the first and second researchers are lecturers engaged in the field of assessment and learning in mathematics, the third researcher is a physics teacher, and the fourth researcher is an engineering student. Knowing the situation of implementing STEM learning can be an initial insight to find other problems and innovate to find alternative solutions. Various potential future projects will impact the author's scientific side, skill improvement, and career. For the general public, an overview of this issue will provide helpful information to anticipate various obstacles in the implementation of STEM learning.

Literature Review

STEM education is an interdisciplinary teaching method that integrates content and context (Barak, 2012) of science, technology, engineering, and mathematics that consist of knowledge and skills (Barak, 2012; Koul et al., 2018; Leung, 2020). STEM learning refers to the four disciplines combined with creativity at all levels of education, formal and informal (Kanematsu & Barry, 2016), and taught collectively to improve problem-solving and critical thinking skills (Rosicka, 2016). The goal of STEM learning is to increase students' understanding of each discipline, broaden understanding through relevant contexts, and make learning more interesting (Wang et al., 2011)

The integration of the four sciences can be explained as a technique of applying science (and mathematics) for the optimal conversion of natural resources so that they can be utilized by humanity (Barak, 2012). Engineering design can provide an ideal STEM content integrator (Katehi et al., 2009). In addition, engineering design incorporates engineering practice into the curriculum so that it becomes a catalyst for the four disciplines in alignment. The nature of engineering design provides students with a systematic approach to solving problems that often occur naturally in all STEM fields (Kelley & Knowles, 2016). Design techniques in learning can be carried out by asking questions, imagining, designing, creating, and improving, which, when translated, become asking, imagining, planning, creating, and improving (Lachapelle & Cunningham, 2007; Syukri et al., 2017).

However, implementing STEM learning is certainly not immediately implemented in schools. There are many other aspects that must be considered, such as the curriculum and school facilities (Arlinwibowo, Retnawati, & Kartowagiran, 2020b). The adoption of a new learning model in a country always requires adjustments (Arlinwibowo et al., 2020). This is because the curriculum in Indonesia has character (Kartowagiran et al., 2017; Retnawati et al., 2016), as does STEM learning (Arlinwibowo et al., 2021b). Currently, the curriculum that applies in Indonesia is the 2013 Curriculum, in which the concept of learning in elementary is semi-thematic (for some thematic subjects) while high school uses the idea of fragmentation between subjects (Indriani & Atiaturrahmaniah, 2019; Kartowagiran et al., 2017; Retnawati, Munadi, et al., 2017). Along with the various conditions of educational facilities, the problems and implementation of STEM in schools can vary greatly (Arlinwibowo, Retnawati, & Kartowagiran, 2020b).

Method

Research related to the issues of implementing STEM-based learning is a qualitative study using a phenomenological approach. Qualitative research using a phenomenological approach is a study that focuses on the life experience of resource persons in a phenomenon concept. A person's experiences and habits (participants or research subjects) are the focus of phenomenological research. This study was conducted to explore and describe various constraints and problems for a teacher in implementing STEM learning in Indonesia. The study was conducted from September of 2019 to June of 2020. Data collection methods used in this study were documentation and in-depth interviews. In this study, interviews were conducted to explore the depth of the teacher's experience and documentation was carried out to identify other things not found in the in-depth interview process.

Participants in this study were nine teachers who have information and knowledge related to STEM as an integrative learning framework. To guarantee the privacy of each respondent, in this research report the name of the respondent has been disguised. The criteria for the informants were to have participated in socialization, workshops, or seminars conducted by SEAMEO QITEP, the Ministry of Education and Culture, universities, schools, or other related institutions. Currently, the population of teachers who have graduated from STEM learning socialization/seminar/workshop programs that implement STEM learning in schools is still limited. Thus, the data from the interviews with the nine teachers can be an initial representation of an implementation picture that can be used as a reference for anticipating the implementation process in other schools. This judgment is reinforced by the heterogeneous conditions of the nine teachers. The results of the study are interview data. However, for informants who did not want the interview process to be recorded, the researcher archived the data in written form.

This qualitative research produced descriptive response data from the informants and document data from the documentation process at the schools. Research data were analyzed using a research data analysis model developed by Bogdan and Biklen that showed in Retnawati et al. (2018). The process of analyzing interview data and documents is done starting with data reduction, determining themes, making links between themes, and drawing conclusions.

Results

Various stakeholders began publishing STEM learning in Indonesia. New learning models always come in with various problems before they can be implemented well in a country (Arlinwibowo et al., 2020; Retnawati, Munadi, et al., 2017). Table 1 displays data on learning facilities and various policies in Indonesia related to the relevance of STEM learning implementation.

Table 1
Learning Facilities and Policy Support in STEM Implementation

<table>
<tr><th>Data</th><th>Themes</th><th>Link Between Themes</th></tr>
<tr><td>Not all teachers understand STEM learning</td><td rowspan="2">Not all teachers are ready to implement STEM learning</td><td rowspan="5">The policy and learning facilities aspects are still not ideal to support the implementation of STEM learning</td></tr>
<tr><td>Teacher responses to STEM learning vary</td></tr>
<tr><td>Lack of infrastructures</td><td rowspan="2">Many schools are not ready to be associated with policies and fulfillment of facilities</td></tr>
<tr><td>Limited funding</td></tr>
<tr><td>Some schools do not provide supporting policies</td><td></td></tr>
</table>

Government policies have not fully supported STEM learning	Some policies have not fully supported the implementation of STEM learning	

The concept of integrated STEM learning is relatively new in Indonesia. Most of the teachers are familiar with the word "STEM" but many of them do not understand the philosophy and technical learning of STEM. STEM has an image among teachers who do not understand as a complex learning concept. Many teachers imagine that learning STEM is difficult because it is complicated. Misunderstandings often occur in the definition of technology and engineering. Many teachers understand the technology and engineering in STEM to be sophisticated and therefore, difficult to implement. Truly, STEM can involve simple technology and engineering. In fact, many teachers make use of simple implements and materials. Negative stigma may prevent teachers from wanting to learn about STEM (Arlinwibowo et al., 2020).

Facts show that there is a polarization of attitudes towards STEM learning. Some teachers who are generally young teachers and have received STEM training have the view that STEM is a very good approach. They are of the opinion that STEM is relevant and urgent because it can improve the quality of education. On the other hand, teachers who do not understand STEM and who are consumed by stigma do not respond well to STEM learning information. The polarization causes obstacles in the implementation of STEM because the STEM implementation process requires collaboration between teachers. Besides the two parties, there is one group of teachers who are still neutral, namely, teachers who have no knowledge of STEM. The group must be given good socialization so as not to be consumed by stigma. The following are the participant statements related to teacher readiness in implementing STEM learning.

> Many teachers still do not understand STEM learning. What is STEM and how? Teacher responses are not all positive. There are teachers interested when I tell STEM, some are not”. On the other hand, Ham said that “The technology actually does not have to be sophisticated technology. The ruler is also technology. Many understand STEM rigidly (Nur).

STEM learning is based on projects that produce products. The learning process is exploratory and varied. Thus, the learning process requires different infrastructure compared to classical learning. Some of the facilities needed are a study room and supporting tools and materials. The learning process of the project cannot be carried out in a neat and quiet seating format. Often students must leave the classroom to conduct experiments which leads to disturbing the concentration of students in other classes.

Tools and materials are another problem in STEM learning. Tools and materials for STEM learning are more complex than classical learning. For example, in STEM learning with a miniature ship theme. Learning requires tools such as glue gun, small drill, and cutter. The materials needed are bottles, glue, rubber, ice cream sticks, and various other supporting materials. For example, in STEM learning with a simple oven theme, learning requires tools such as a glue gun, cutter, scissors, and thermometer. The materials needed are cardboard, aluminum foil, glue, and mica. The complexity of the learning facilities becomes a problem in implementing STEM learning.

Problems with providing locations, tools, and learning materials are related to the school funding post. STEM is an option in organizing learning so providing a special budget that adjusts STEM learning needs is not an urgent matter. In general, such a situation makes schools compromise, teachers are allowed to conduct STEM learning but do not drain school funds. Consequently, STEM learning must adjust to the availability of school facilities. However, there is schools that make STEM as the basis for learning approaches in schools. STEM has been implemented in every subject using integration concept. Thus, the school always tries to provide learning support facilities. The following are the participant's statements related to the readiness of facilities and infrastructure in conducting STEM learning.

> Perhaps many of the schools have not budgeted for the procurement of materials for STEM learning. Our school still does not have supporting facilities (Hud).

> The first problem with STEM learning is infrastructure (Rob).

One of the sectors that most influences the implementation of STEM is policymakers, ranging from local schools to national. At the school level, the principal has the power to make policy. If the principal has a commitment to implement STEM and considers STEM-based learning to have a strong urgency to implement, then local policies will be very supportive. If there is a principal who has the idea to integrate all fields of science, the new school year begins with a curriculum review so that integration can be carried out properly. In other schools, there are principals who make policies by making STEM learning a subject of local content. However, this condition is only found in a few schools.

Not all schools have policies that allow teachers to be able to implement STEM learning freely and conveniently. Many schools still do not have the commitment to implement STEM learning so teachers must work independently. Such an atmosphere makes a variety of situations that are less supportive such as limited facilities, difficulty in arranging lesson schedules, irregular arrangement of material, and difficulty in collaboration between teachers. One example occurs in the boarding school where laptops, cellphones, and the internet are restricted. The situation makes students unable to explore and find various ideas in solving STEM challenges.

Furthermore, national-level policies do not fully support the implementation of STEM learning, especially in secondary schools. In primary schools, learning is thematic, so it is suitable for STEM implementation. However, in secondary schools, the learning process is still fragmented between subjects. Thus, the implementation of STEM learning is relatively difficult because of the partial order and material scheduling. In addition to the learning process, the assessment policy is also a problem in STEM-based learning. STEM learning is project-based so students conduct investigations and explorations. Evaluation of learning outcomes is by cognitive assessment through a system of drill questions. These two things are contradictory, so the teacher is very worried that students who study on the STEM basis have difficulty completing the final evaluation problem. The following are the participant's statements related to policy support in organizing STEM learning.

> STEM is something that is very urgent, but learning will still refer to the applicable curriculum. The principal has a very strong power to carry out STEM activities (Nur).

> Weaknesses in schools that implement STEM can be seen when presented with questions from the service. Students often have difficulties (Hud).

The implementation of STEM learning during a curriculum that is not yet fully supported results in a challenge. Management and learning plan are a challenge that must be resolved by teachers and schools to bridge the STEM learning in accordance with the curriculum. The problems of management and learning planning in implementing STEM in the 2013 curriculum are summarized in Table 2.

Table 2
Management and Learning Plan in STEM Implementations

Data	Themes	Link Between Themes
Lack STEM learning references	Difficult to do learning management	Learning management problems and lack of references are the source of obstacles in implementing STEM learning
It's hard to schedule STEM learning		
It takes more time than usual		
Curriculum demands often hamper	Curriculum management and learning materials often become obstacles in implementing STEM learning	
Difficult to map appropriate material		
The order of material in the curriculum is often not supportive		
The teacher must adjust basic competencies (KD) in the curriculum		
Not all grades are compatible with STEM learning		
Rating standards not yet available	There is no reference to the STEM learning assessment system in the Curriculum 2013	
It's hard to make a rubric assessment		
Assessment not integrative		

Theoretical and practical references are always needed in the implementation of a new system, including learning. In recent years, STEM has been widely publicized in Indonesia. The problem found that is complaints from schools, teachers, and practicians is literatures in online and offline to STEM implementation is still relatively rare. If references are found, most references are in foreign languages. References in foreign languages not only make some teachers constrained in language but also setting the situation. There are often situations that are not possible in Indonesia. Thus, the teacher often has difficulty in finding examples of application.

The consequence of applying STEM-based learning is implementing integrative and project-based learning. This learning model requires a lot of time and collaboration between several subjects. Practical learning requires more preparation and closure. Learning starts with students preparing various tools and ends with tidying up the tools. According to the teacher's experience, each preparation and closing takes about 15 minutes. The lost time for preparation and closing is 30 minutes. In general, learning in Indonesia is carried out from two to three classes (40 minutes per class for junior high school and 45 minutes per class for high school) per subject in a day. The 30 minutes lost are very valuable in carrying out the learning process.

Combining two related subjects will provide flexibility in the implementation of STEM. For example, mathematics (three hours) and science (three hours) are carried out in sequence so students will be more conducive to implementing STEM learning. However, this strategy results in a more complicated scheduling process. Schools in Indonesia rarely have the availability of classrooms for exactly the number of hours of study required. With these attributes in mind, schedulers have had difficulty locating teachers, especially if the scheduler must consider the type of STEM subjects. The following are the participant statements related to the elaboration of the facts above.

> The obstacles of learning in school are not in accordance with the learning needs of STEM. It does not seem to make the collaboration of some teachers still difficult (Ham).
>
> Must really manage that time very well (Iko).
>
> Controlling children is relatively difficult so it takes more time (Fer).
>
> Learning preparation takes time and must be completed at least 20 minutes before the next lesson starts because I have to clean up (Ham).
>
> I'm having trouble because STEM is still rare so the references are lacking, external references are difficult to implement (Rob).

The curriculum is a reference that must be held in the administration of education. The Curriculum 2013 has demanded learning outcomes. The learning process must refer to the basic competencies abbreviated as KD that exist in the curriculum. KD is arranged in detail for each subject. Although the curriculum suggests the learning process is carried out using the method of problem-based learning, discovery learning, and project-based learning, the teacher considers that the KD is very dense, so it fits with classical learning (the teacher explains and students understand).

STEM learning is carried out in a project format that requires more time and has extensive exploration. The teacher feels that the demands of the Curriculum 2013 are very dense to be implemented with a project-based learning format. Students often explore so learning cannot focus on achieving targets. As such, teachers are often faced with two choices: carrying out learning projects ideally or focusing on curriculum targets. That choice makes teachers inclined to prefer focusing on KD because STEM implementation is only optional and completing the material is mandatory.

Related to material demands, the curriculum provides targets every semester. Thus, the competencies that must be mastered during school are very clear. There are several types of assessment of learning achievements in cognitive aspects, namely the end of the semester exams, year-end exams, national standard school exams, and national exams. Related to the various exams, they are carried out uniformly in all districts, provinces, and for uniform national examinations throughout Indonesia. This type of uniform exam often makes teachers rethink implementation of STEM learning. The teacher states that STEM learning is explorative so students can have a deep and broad understanding, but students will have difficulty carrying out a uniform examination. The teacher even stated that students with STEM learning would find it difficult to compete in examinations with students who study conventionally (drill systems).

This fact makes almost all teachers agree not to hold STEM learning in the final grade (in elementary, junior, and senior high school, or vocational school). The case is based because at the end of each final grade in school level students will be faced with a graduation process. The final grade in the school level of graduation has a very high meaning and benefit for judging learning outcomes and registering at the next level.

The next problem related to the curriculum is the map of the suitability of the material with the project. The teacher must be able to design a project that matches the character of the material. Thus, a material map and suitable project will be obtained. The process requires high creativity and good analytical power. Not that the level of creativity and analytical power of teachers is low but to be able to plan a STEM project requires above-average capabilities. One source of the problem is the availability of reference: STEM implementation has not been found in Indonesia. Some STEM books in circulation are references to foreign contexts.

Integration is the concept of combining several subjects to solve a particular theme. Thus, the order of material between subjects involved in the project must be good. This means that material in subjects related to the project must be available in the same semester so that the project can be implemented. However, field facts show that the order of material is still one of the obstacles in STEM learning. The junior high and senior high school curriculum in Indonesia, which were built in 2013, are not yet oriented towards integrative education. Therefore, there is no emphasis on relationships for each subject so that they stand individually. As a result, the order of material between subjects is often not ideal for STEM learning. Teachers often complain about that. The following are the participant statements related to curriculum and material management concerns.

> I still have difficulty fulfilling KD with project-based learning because the project makes students very exploratory and difficult to direct in one particular point of knowledge, sometimes even a lot of knowledge but outside KD (Fer).
>
> STEM has many activities while the national curriculum is focused on the delivery of material (Rob).
>
> So I have implemented STEM in grades 7 and 8, but in class 9 I have never been because I was afraid because I was close to the final exam (Ham).
>
> Not all material can be taught with STEM learning such as trigonometric limits, trigonometric derivatives, binomial Newton. I asked my friends in the community and on YouTube regarding STEM implementation for the material but found none (Nur).

The last obstacle in learning management and curriculum is the assessment system. The concept of integration which involves several subjects in one theme makes it difficult for teachers to organize an assessment process. The difficulty of the assessment begins with the absence of STEM assessment process standards that are in accordance with the curriculum in Indonesia. Basically, teachers are allowed to carry out an assessment system as needed with fixed provisions referring to the basic assessment available in the curriculum. Thus, there must be a formula that combines the STEM learning concept and the learning assessment system in the curriculum 2013. Combining the two things is not an easy job; the teacher needs a basic reference to guide the assessment process which currently does not exist. The impact is that teachers experience confusion in assessing so that aspects of STEM learning can be portrayed, and curriculum demands can be met. Facts on the ground show that many teachers are still confused in determining the STEM assessment format. What techniques and instruments are used in the assessment process are the main difficulties in carrying out the assessment process. Every assessment process is always accompanied by an assessment rubric. The assessment rubric contains what will be assessed, the assessment criteria, and how the assessment process will progress. The most difficult part in making an assessment rubric is to create an objective guide that contains all the things you want to measure. Many teachers stated that they had not been able to make an assessment rubric that could be used easily and objectively. The level of difficulty in making STEM learning assessment rubrics is more difficult due to the complexity of the material and learning activities. The teacher still has difficulty in mapping what should be assessed, assessment criteria, and how to grade them. Basically, the teacher wants all activities in STEM learning can be recorded and then concluded as a learning outcome.

However, the inability of teachers to make good assessment rubric in STEM (objective and accurate) yet makes teachers only focus on one subject (simplification) and many aspects are not well documented as learning outcomes. Following are the participant's statements related to the difficulty of STEM assessment.

> I'm still confused in making an assessment. For example, if the test must have a written test and then an oral test, or just one of them (Fer).
>
> Assessment is based on each teacher. What are the assessment standards? What is the formula for evaluating? Not available (Hud).
>
> The assessment that I did was not guided by the rubric because I had difficulty in making the assessment rubric of STEM learning (Nur).
>
> The assessment process we carried out has not yet maximally measured the ability of students in STEM-based learning (Rob).

The last issue found in the STEM-based learning process comes from students. The current education paradigm does not recognize student profiles as an obstacle in the learning process. However, knowing teacher perceptions related to the relationship of student profiles with the learning process is important. By knowing these perceptions, the learning process can be better planned so that various potential problems can be minimized. Table 3 is the reduction of student profile data and constraints in STEM implementation.

Table 3
Student Profiles and Constraints on STEM Implementation

<table>
<tr><th>Data</th><th>Themes</th><th>Link Between Themes</th></tr>
<tr><td>Students are very heterogeneous</td><td rowspan="3">The student population is very diverse</td><td rowspan="5">Teachers often find it difficult to manage students with diverse profiles</td></tr>
<tr><td>Student insights are very diverse</td></tr>
<tr><td>Student collaboration ability is lacking</td></tr>
<tr><td>Choosing material that suits students is difficult</td><td rowspan="2">Difficult to determine the material and the appropriate learning process for the students</td></tr>
<tr><td>Difficult to manage the students’ focus</td></tr>
</table>

The first difficulty experienced by teachers related to students is heterogeneity. The student population in a class varies greatly for the profile of cognition and life background. Students' insights are very diverse. For example, students who live in coastal locations will be different compared to students who live in mountainous areas. Students who are raised by academic parents will be different from students who are raised by business parents. Students' knowledge about technology and its applications also varies greatly. Thus, the STEM project must not only be in accordance with the subject matter but must also be following the conditions of the students. It is very possible that project A can be implemented well in class A, but it cannot be done well in class B.

Related to student profiles, not every student has felt comfortable in a team, even though STEM learning is a learning concept based on teamwork. The need for teamwork among students often creates obstacles in the learning process. This problem is very complex because there are students who are cognitively good but unable to cooperate in a team. There are students who are only able to work with certain friends. There are also students who are apathetic in the team.

The final problem is the management of student focus. Learning projects make students very busy with their activities. Students can carry out extensive exploration. The teacher often finds situations where students lose focus. Things that cause loss of focus are (1) students are too absorbed in the project that they forget the project objectives; and (2) students do activities outside the scenario with various project tools and materials. Loss of focus makes it difficult for students to complete and summarize project findings. The following are the participant statements related to the constraints due to student profiles in STEM implementation.

> Sometimes there are students who don't like other students because of causes.
>
> That is the first obstacle of many (Ham).
>
> Student knowledge related to technology varies greatly (Rob).
>
> My experience while teaching in school A is different from when teaching in school B. I feel teaching in school A is smoother and easier (Ham).

Discussion

In general, there are three issues in implementing STEM learning: teachers, facilities, and education policies. The success or failure of integrated STEM learning is determined by the teacher who plans, implements, and assesses student learning outcomes. Teachers must have a strong understanding of integrated STEM learning (Bowers et al., 2020). Teachers need more creativity and insight in teaching through STEM learning than conventional learning models (Billiar et al., 2014; Chen et al., 2016). Teachers need more effort to be able to understand domains outside their scientific specifications (Billiar et al., 2014; Thibaut et al., 2018). Creativity is not only related to the suitability of the material with the project but involves other variables such as student background, student thinking level, student interest, and various other attributes attached to students (Plonczak et al., 2014). However, teachers must dare to try to implement STEM learning in their classes because teacher experience is the key to the successful implementation of STEM learning (Sias et al., 2017). In addition, the government should encourage socialization, training, and workshop efforts because it is very important (Retnawati, Munadi, et al., 2017) for new initiatives such as STEM (Al Murshidi, 2019).

In the process of implementing STEM learning, schools must be able to manage learning management properly. However, the limited reference for holding STEM is a problem in Indonesia. A similar case occurred in the UAE. Al Murshidi (2019) said that some of the literature came from foreign and foreign languages. The same problem occurs as in Indonesia, namely the ability of teachers to understand English literature is still lacking and many foreign contexts that are difficult to implement in the country. Another substantial problem in the process of organizing STEM learning is forming learning structures. STEM is an import learning model so it will likely require curriculum restructuring and significant shifts in the teaching process (Nadelson & Seifert, 2017).

STEM learning requires collaboration between teachers and subjects. Ortiga et al. (2020) found that teachers mentioned this was one of the biggest challenges. Each teacher has difficulty choosing the time to work together. Ejiwale (2013) states that the problem is very often found. The problem is more complicated because project-based learning makes the learning process require more time (Thibaut et al., 2018). Thus, the STEM implementation must be supported by good system support.

Learning outcomes are identified through an assessment system that is able to see student development in an objective and standardized manner. Without STEM assessment standards, it is difficult for teachers to make an assessment process because each teacher has their own perceptions (Billiar et al., 2014). Inconsistencies often occur between the learning process and assessment (Gao, 2020). Although labeled as STEM, in the assessment it is often the STEM element that is not measured properly. Al Murshidi (2019) states that STEM learning will not run well until there is a standardization of implementation in accordance with the curriculum.

Another thing that influences the implementation of learning is facilities. The facility is one of the most important aspects in the administration of education (Arlinwibowo & Retnawati, 2015; Marsigit et al., 2020; Retnawati, Hadi, et al., 2017). Learning support facilities are very important to obtain STEM knowledge so students are able to learn relevant content (Auld & Morris, 2019). Ejiwale (2013) and Ramli et al. (2017) states that the limited material for learning and laboratory facilities is a condition commonly found in the implementation of STEM learning. The situation can be understood because STEM learning does require complex learning materials and greater funding (Al Murshidi, 2019; Leung, 2020; Thibaut et al., 2018). Students will have many opportunities to explore and investigate if the school has good facilities, especially laboratories (Iqbal & Clayton, 2020).

Complexity makes not all policy makers choose to implement STEM (Leung, 2020). Everything that is done in the education process always has rules that result from a policy. The government is the center of education management policies including curriculum publishing (Chiu, 2016; Retnawati et al., 2018) and funding (Kharisma & Pirmana, 2013). Government policy is final; if it can change, it requires a relatively long time. The principal is a policymaker at the school level so that it has a very strong influence (Tran et al., 2020). The principal has a role in determining the character and characteristics of the school being led (Ng, 2019). Thus if the principal has a commitment to organizing STEM learning, then the principal can take quick and strategic steps so that learning can proceed well (Ejiwale, 2013).

Conclusions

There are problems in implementing STEM-based learning which is divided into three broad categories: learning policies and facilities, learning management, and the ability of teachers to manage students. (1) Policy and facility issues include teachers that are not ready competently (pedagogical or professional) to implement STEM-based learning. The policy aspects and learning facilities are still not ideal to support the implementation of STEM learning. Schools do not yet have adequate facilities and infrastructure, and policies in some schools show sub-optimal support. (2) STEM-based learning management is very complex, especially related to material mapping, scheduling, learning planning, and the absence of reference assessment standards that are in accordance with the curriculum. (3) Student profiles are so diverse that teachers find it difficult to manage students. Thus, the teacher must try harder in identifying the appropriate project.

References

Al Murshidi, G. (2019). STEM education in the United Arab Emirates: Challenges and possibilities. *International Journal of Learning, Teaching and Educational Research, 18*(12), 316–332. https://doi.org/10.26803/ijlter.18.12.18

Arlinwibowo, J., & Retnawati, H. (2015). Developing audio tactile for visually impaired students. *International on New Trends in Education and Their Implications (IJONTE)*, *6*(4), 18–30.

Arlinwibowo, J., Retnawati, H., & Kartowagiran, B. (2020a). *Model penilaian capaian belajar matematika dengan framework STEM*. UNY Press.

Arlinwibowo, J., Retnawati, H., & Kartowagiran, B. (2020b). The types of STEM education implementation in Indonesia. *Journal of Xi'an University of Architecture & Technology*, *XII*(VIII), 606–613.

Arlinwibowo, J., Retnawati, H., & Kartowagiran, B. (2021a). Item response theory utilization for developing the student collaboration ability assessment scale in STEM classes. *Ingenierie Des Systemes d'Information*, *26*(4), 409–415. https://doi.org/10.18280/ISI.260409

Arlinwibowo, J., Retnawati, H., & Kartowagiran, B. (2021b). How to integrate STEM education in the Indonesian curriculum? A systematic review. *Materials of International Practical Internet Conference "Challenges of Science," Iv*, 18–25. https://doi.org/https://doi.org/10.31643/2021.03

Arlinwibowo, J., Retnawati, H., Kartowagiran, B., & Kassymova, G. K. (2020). Distance learning policy in Indonesia for facing pandemic COVID-19: School reaction and lesson plans. *Journal of Theoretical and Applied Information Technology*, *98*(14), 2828–2838.

Auld, E., & Morris, P. (2019). Science by streetlight and the OECD's measure of global competence: A new yardstick for internationalisation? *Policy Futures in Education*, *17*(6), 677–698. https://doi.org/10.1177/1478210318819246

Barak, M. (2012). Teaching engineering and technology: Cognitive, knowledge and problem-solving taxonomies. *Journal of Engineering, Design, and Technology*, *11*(3), 316–333. https://doi.org/10.1108/JEDT-04-2012-0020

Bicer, A., Capraro, R. M., & Capraro, M. M. (2017). Integrated STEM assessment model. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3959–3968. https://doi.org/10.12973/eurasia.2017.00766a

Billiar, K., Hubelbank, J., Oliva, T., & Camesano, T. (2014). Teaching STEM by design. *Advances in Engineering Education*, *4*(1), 1–21.

Bowers, S. W., Williams Jr., T. O., & Ernst, J. V. (2020). Profile of an elementary STEM educator. *Journal of STEM Education: Innovations & Research*, *21*(1), 51–57. http://libproxy.boisestate.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=143695506&site=ehost-live

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology & Engineering Teacher*, *70*(1), 30–35.

Çevik, M. (2018). Impacts of the Project Based (PBL) Science, technology, engineering and mathematics (STEM) education on academic achievement and career interests of vocational high school students. *Pegem Egitim ve Ogretim Dergisi*, *8*(2), 281–306. https://doi.org/10.14527/pegegog.2018.012

Chen, C., Schneps, M. H., & Sonnert, G. (2016). Order matters: sequencing scale-realistic versus simplified models to improve science learning. *Journal of Science Education and Technology*, *25*(5), 806–823. https://doi.org/10.1007/s10956-016-9642-4

Chesky, N. Z., & Wolfmeyer, M. R. (2015). *Philosophy of STEM education*. Palgrave Macmillan.

Chiu, M. S. (2016). The challenge of learning physics before mathematics: A case study of curriculum change in Taiwan. *Research in Science Education*, *46*(6), 767–786. https://doi.org/10.1007/s11165-015-9479-5

Ejiwale, J. A. (2013). Barriers to successful implementation of STEM education. *Journal of Education and Learning (EduLearn)*, *7*(2), 63.

https://doi.org/10.11591/edulearn.v7i2.220
Gao, F. (2020). Features and inspirations of performance framework for regional universities in Australia. *International Journal of Emerging Technologies in Learning*, *15*(18), 139–150. https://doi.org/10.3991/ijet.v15i18.16743
Hallström, J., & Schönborn, K. J. (2019). Models and modelling for authentic STEM education: Reinforcing the argument. *International Journal of STEM Education*, *6*(1), 6–22. https://doi.org/10.1186/s40594-019-0178-z
Honey, M. A., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K-12 education: status, prospects, and an agenda for research*. The National Academies Press. https://doi.org/10.17226/18612
Indriani, F., & Atiaturrahmaniah. (2019). Evaluation of the implementation of integrative thematic learning: A qualitative research approach phenomenology. *Jurnal Penelitian Dan Evaluasi Pendidikan*, *23*(2), 184–192. https://doi.org/10.21831/pep.v23i2.27431
Iqbal, M. Z., & Clayton, M. E. (2020). Designing an interdisciplinary field and lab methods course in hydrology to integrate STEM into undergraduate water curriculum. *Journal of STEM Education: Innovations & Research*, *21*(1), 41–50. https://ezproxy2.library.colostate.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,url,cpid&custid=s4640792&db=aph&AN=143695505&site=ehost-live
Kanematsu, H., & Barry, D. M. (2016). *STEM and ICT education in intelligent environments*. Springer.
Kartowagiran, B., Retnawati, H., Sutopo, & Musyadad, F. (2017). Evaluation of the implementation of curriculum 2013 vocational. *International Conference on Education, Research and Innovation (ICERI 2017), May 2018,* 814–819.
Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. The National Academic Press. https://doi.org/10.17226/12635
Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(11), 1–11. https://doi.org/10.1186/s40594-016-0046-z
Khaeroningtyas, N., Permanasari, A., & Hamidah, I. (2016). Stem learning in material of temperature and its change to improve scientific literacy of junior high school students. *Jurnal Pendidikan IPA Indonesia*, *5*(1), 94–100. https://doi.org/10.15294/jpii.v5i1.5797
Kharisma, B., & Pirmana, V. (2013). The role of government and its provision on the quality of education: The case of public junior high school among province in Indonesia period 2000-2004. *European Journal of Social Sciences*, *37*(2), 259–270.
Koul, R. B., Fraser, B. J., Maynard, N., & Tade, M. (2018). Evaluation of engineering and technology activities in primary schools in terms of learning environment, attitudes and understanding. *Learning Environments Research*, *21*(2), 285–300. https://doi.org/10.1007/s10984-017-9255-8
Lachapelle, C. P., & Cunningham, C. M. (2007). Engineering is elementary: children's changing understandings of science and engineering. *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition Copyright*, 1–33.
Leung, A. (2020). Boundary crossing pedagogy in STEM education. *International Journal of STEM Education*, *7*(1). https://doi.org/10.1186/s40594-020-00212-9
Marsigit, M., Retnawati, H., Apino, E., Santoso, R. H., Arlinwibowo, J., Santoso, A., & Rasmuin, R. (2020). Constructing mathematical concepts through external representations utilizing technology: An implementation in IRT course. *TEM Journal*,

9(1), 317–326. https://doi.org/10.18421/TEM91

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *Journal of Educational Research*, *110*(3), 221–223. https://doi.org/10.1080/00220671.2017.1289775

Ng, F. S. D. (2019). Instructional leadership. In B. Wong, S. Hairon, & P. T. Ng (Eds.), *School leadership and educational change in Singapore* (pp. 7–30). Springer. https://doi.org/10.1007/978-3-319-74746-0_1

Ntemngwa, C., & Oliver, J. S. (2018). The implementation of integrated science technology, engineering and mathematics (STEM) instruction using robotics in the middle school science classroom. *International Journal of Education in Mathematics, Science and Technology*, *6*(1), 12–40. https://doi.org/10.18404/ijemst.380617

Nurmalia, I. (2018). *Mendikbud Meresmikan Kampung STEM di Sleman [Minister of Education and Culture Inaugurates STEM Village in Sleman]*. Minister of Education and Culture. https://radioedukasi.kemdikbud.go.id/read/1835/mendikbud-meresmikan-kampung-stem-di- sleman.html

Ong, E. T., Ayob, A., Ibrahim, M. N., Adnan, M., Shariff, J., & Ishak, N. (2016). The effectiveness of an in-service training of early childhood teachers on stem integration through Project-Based Inquiry Learning (PIL). *Journal of Turkish Science Education*, *13*(Specialissue), 44–58. https://doi.org/10.12973/tused.10170a

Ortiga, Y. Y., Chou, M.-H., & Wang, J. (2020). Competing for academic labor: Research and recruitment outside the academic center. *Minerva*, *58*(4), 607–624. https://doi.org/10.1007/s11024-020-09412-7

Peterman, K., Daugherty, J. L., Custer, R. L., & Ross, J. M. (2017). Analysing the integration of engineering in science lessons with the engineering-infused lesson rubric. *International Journal of Science Education*, *39*(14), 1913–1931. https://doi.org/10.1080/09500693.2017.1359431

Plonczak, B. I., Brooks, J. G., Lodato, G., Elijah, R., & Caliendo, J. (2014). STEM Studio: Where innovation generates innovation. *Kappan*, *95*(5), 52–56. https://doi.org/10.1177/003172171409500512

Putra, D. P. A. (2017). Educational game for STEM education in Indonesia local wisdom. *Japan Society for Science Education*, *31*(8), 97–100.

Ramli, A. A., Ibrahim, N. H., Surif, J., Bunyamin, M. A. H., Jamaluddin, R., & Abdullah, N. (2017). Teachers' readiness in teaching stem education. *Man in India*, *97*(13), 343–350.

Retnawati, H., Arlinwibowo, J., Wulandari, N. F., & Pradani, R. G. (2018). Teachers' difficulties and strategies in physics teaching and learning that applying mathematics. *Journal of Baltic Science Education*, *17*(1), 120–135. https://doi.org/10.33225/jbse/18.17.120

Retnawati, H., Hadi, S., & Nugraha, A. C. (2016). Vocational high school teachers' difficulties in implementing the assessment in Curriculum 2013 in Yogyakarta Province of Indonesia. *International Journal of Instruction*, *9*(1), 33–48. https://doi.org/10.12973/IJI.2016.914A

Retnawati, H., Hadi, S., Nugraha, A. C., Arlinwibowo, J., Sulistyaningsih, E., Djidu, H., Apino, E., & Iryanti, H. D. (2017). Implementing the computer-based national examination in Indonesian School: The challenges and strategies. *Problems of Education in The 21st Century*, *75*(6), 612–633. https://doi.org/10.33225/pec/17.75.612

Retnawati, H., Munadi, S., Arlinwibowo, J., Wulandari, N. F., & Sulistyaningsih, E. (2017). Teachers' difficulties in implementing thematic teaching and learning in elementary schools. *The New Educational Review*, *48*(2), 201–212. https://doi.org/10.15804/tner.2017.48.2.16

Roehrig, G. H., Wang, H., Moore, T. J., & Park, M. S. (2012). Is adding the E enough?

Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, *112*(1), 31–44. https://doi.org/10.1111/j.1949-8594.2011.00112.x

Rosicka, C. (2016). *From concept to classroom Translating STEM education research into practice*. Australian Council for Educational Research.

Sias, C. M., Nadelson, L. S., Juth, S. M., & Seifert, A. L. (2017). The best laid plans: Educational innovation in elementary teacher generated integrated STEM lesson plans. *Journal of Educational Research*, *110*(3), 227–238. https://doi.org/10.1080/00220671.2016.1253539

Suprapto, N. (2016). Students' attitudes towards STEM education: Voices from Indonesian junior high schools. *Journal of Turkish Science Education*, *13*(Special issue), 75–87. https://doi.org/10.12973/tused.10172a

Syukri, M., Halim, L., & Mohtar, L. E. (2017). Engineering design process: Cultivating creativity skills through development of science technical product. *Jurnal Fizik Malaysia*, *38*(1), 55–65.

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van de Velde, D., Van Petegem, P., & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education*, *3*(1), 1–12. https://doi.org/10.20897/ejsteme/85525

Tran, T., Trinh, T.-P.-T., Le, C.-M., Hoang, L.-K., & Pham, H.-H. (2020). Research as a base for sustainable development of universities: Using the Delphi method to explore factors affecting international publishing among Vietnamese academic staff. *Sustainability (Switzerland)*, *12*(8), 3449. https://doi.org/10.3390/SU12083449

Wan Husin, W., Mohamad Arsad, N., Othman, O., Halim, L., Rasul, M., Osman, K., & Iksan, Z. (2016). Fostering students' 21st century skills through project Oriented problem based learning (POPBL) in integrated STEM education program. *Asia-Pacific Forum on Science Learning and Teaching*, *17*(1), 1–19.

Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM Integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research*, *1*(2), 1–13. https://doi.org/10.5703/1288284314636

Wisudawati, A. W. (2018). Science technology engineering and mathematics (STEM) education aproach against a misroscopic representation skill in atom and molecule concept. *International Journal of Chemistry Education Research*, *2*(1), 1–5. https://doi.org/10.20885/ijcer.v2i1.10067

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