The Types of STEM Education Implementation in Indonesia

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Abstract - The purpose of this study is to define variations in the implementation of STEM in Indonesia as a result of socialization. This research is qualitative research with a phenomenological approach to defining the STEM implementation processes in education. The informants in this study were 9 teachers who had received the STEM education integration socialization in learning. Data collection in this study used in-depth interview and documentation techniques. The stages of analysis in this research are managing data, reading data and memoing, translating data, classifying data, describing data, and making visualizations and representations. The research findings are that STEM implementation in Indonesia is divided into 3 types, namely integrating STEM at school scale, building STEM subjects, and integrating STEM in a subject. Each type of implementation in a school has its history, namely from the commitment of the principal, school facilities, student characteristics, and peer support. But one of the most influential is the commitment of the principal. Thus, it will be very good if the socialization first targets the school principal to have a more massive impact.

Keywords – STEM, Integration, Curriculum, Project Based Learning, Education in Indonesia.

I. INTRODUCTION

There are changes in needs that occur as a result of improvement in various fields. This change was felt in the last few times so that some scientists thought that someone must have a different provision compared to some time before. The Center of Curriculum Redesign states that current knowledge is not enough to equip a person to be able to compete [1]. People must have the expertise to be able to solve various problems in life. Not surprisingly, the Report of the Center for Public Education in America, the 21st century education defined by Craig D. Jerald in [2], is one aspect of learning that becomes important for students to succeed in work and life is the application of knowledge.

There are 4 major categories that must change in the 21st century, namely ways of thinking, ways of working, tools for work, and provision of life [3]. Categories of thinking that must be had in the 21st century are creativeness, innovation, critical thinking, problem solving, decision making, and metacognition. This way of thinking must be followed by communicative and collaborative ways of working. Categories of work aids are information literacy, ICT literacy. While the last category is the provision of one's life which consists of citizenship (local and global), life and career, as well as personal and social responsibilities including awareness and cultural competence [1], [3], [4].

Indonesia as a country also responds to the needs of the 21st century in managing education. The Ministry of Education and Culture of the Republic of Indonesia established a standard for implementing 21st century education which was formulated as the Indonesian Partnership for 21 Century Skill Standard (IP-21CSS). The standard directs
the implementation of education to be oriented to 21st century skills (creativity and innovation, critical thinking and problem solving, communication, and collaboration) coupled with the use of ICT, character education development, and emphasis on spiritual values [5].

Learning with the framework of Science, Technology, Engineering, and Mathematics (STEM) has received increasing attention over the past decade [6]. The STEM Framework is considered to be able to harmonize the educational process with the demands of the times. The rapid technological evolution in the 21st century is also changing the needs of the workforce and the problems faced are increasingly multidisciplinary which requires the integration of various STEM concepts [7]. Unfragmented real world problems require skills that cross disciplines [8], [9]. The use of an integrated STEM curriculum provides opportunities for more relevant experiences [10].

Suprapto (2016) states that STEM is still a new thing in Indonesia, however, STEM has at least been known by academicians and stakeholders. Academic began to conduct various studies and test the usefulness of STEM. Preliminary facts show that STEM-based learning in Indonesia can have a positive effect on improving the ability of students in a subject [12]–[14]. While other findings overseas also showed the same fact [15]–[17]. In addition to theoretical, the empirical facts of the research results show that there is great potential for STEM-based learning to improve the quality of Indonesian education.

In the realm of practice, the government and universities began to popularize STEM to improve the quality of learning according to the demands of the times. The Government through the Center for Development and Empowerment of Educators and Education Personnel (PPPTK), directorate of secondary education, and SEAMEO (South East Asia Ministry of Education Organization) QITEP (Quality Improvement of Teachers and Education Personnel) in Science, Mathematics and Language provide various socialization and training related to STEM education. In addition to socialization in the form of workshops and teacher training, the Ministry of Education and Culture in 2018 also inaugurated the STEM (Science, Technology, Engineering, and Mathematics) in Padukuhan Joho, Condongcatur, Depok, Sleman, D.I. Yogyakarta.

The result of this socialization effort is the increasing popularity of STEM. Many teachers try to implement STEM education in their schools. However, the implementation phase is strongly influenced by various things such as teacher competency, school support, education system, environmental conditions, and various other complex variables. Thus, in STEM which is the adoption of a system from abroad [18], of the subject it is very possible teachers make adjustments that produce a variety of implementation processes. Therefore this study aims to define variations in the implementation of STEM in education in Indonesia.

II. RESEARCH METHODOLOGY

2.1 General information
This research is qualitative research with a phenomenological approach. Phenomenology is a study that reveals the life experiences of several people in the concept of a phenomenon. The focus of research is to describe the habits of participants in dealing with a phenomenon [19]. The research was carried out to define the processes of implementing STEM in education in Indonesia. The study was conducted in September 2019 - December 2019. To collect data, this study used in-depth interview and documentation techniques. In-depth interviews were carried out to explore various relevant information in depth and documentation was carried out to trace traces of facts related to schools, teachers, and students.

2.2. Participants and Research Data
The informants in this study were 9 teachers who had received information on the integration of STEM education in learning conducted by the ministry of education and culture, SEAMEO QITEP, universities, or schools in collaboration with others. This study collected opinion data from participants in the form of oral opinions through interviews and written opinions through essay questions. The researcher tried to collect data through interviews, but there was one participant who did not want his voice recorded so that the researcher could only handle opinion data in written form.

2.3. Data Analysis
The results of interviews and documentation are collected into one big data set and analyzed using the analytical model developed by Creswell (2007). The stages of analysis in this research are managing data, reading data and memoing, translating data, classifying data, describing data, and making visualizations and representations.

III. RESEARCH RESULT
The entry of a new approach to education is a natural thing in the development of science and technology. Various experts always try to align learning strategies with achievement goals that are relevant to the conditions of the time.
Likewise, STEM which is a learning approach was formulated by various experts as an effort to answer the challenges of the changing times. Figure 1 is a flowchart of the entry of STEM approaches in Indonesia.

3.1. STEM Information Source

Implementation of STEM education in schools begins with socialization from the government through the Center for Development and Empowerment of Educators and Education Personnel (PPPTK), directorate of secondary education, and SEAMEO QITEP. The dissemination of STEM implementation to teachers began to be felt widely by teachers in 2017. After that year, the socialization was carried out continuously by involving more organizers and participants, including many schools that organized socialization independently by inviting experts.

The socialization model is implemented in various formats. The first format is a workshop that begins with the presentation of material related to STEM and then the practice of making learning designs. In general, the workshop will be held for several days with the final product being applied. The products of the workshops are adjusted to the teacher's work at school, the characteristics of students, availability of facilities, and various other aspects that are thought to influence the learning process. Thus it is expected that after the workshop, the product can be put into practice in each teacher as the participant. The second format is the seminar. The format was carried out shortly with a focus on socialization on the theoretical understanding of participants. The third format is the STEM implementation research grant. The format was implemented to encourage teachers to implement STEM in their classrooms. Joseph received a grant of Rp. 3,000,000 to implement STEM in his school. The following are some of the informant's explanations which clearly show a description of the source of initial insight into STEM education.

"I have known STEM since 2017 from training and then I tried to implement it in my school" (Stefanny)
"I know STEM from the training" (Charles)
"I got a grant (Rp. 3,000,000) to implement STEM in class. Yes, that one (taking one small electric car as a learning product) costs Rp 500,000.00. So that 6 groups require funds of Rp 3,000,000.00." (Joseph)

3.2. The Relevance of STEM Education

After the training, the teacher continued with the implementation in each school. The teacher adopts the material that has been presented in the socialization or implements the products of the workshop. STEM is a relatively new approach in Indonesia. The habit of fragmentation of subjects makes integrative learning models STEM seem complex. Thus the informant agreed that learning designs should refer to existing references. At present, there are many examples of STEM learning designs that can be adopted. Many examples have been implemented by the teacher. Some of them are spring dolls, skydiving, solar cell applications and wind turbines, housing miniature designs, clinometers, bungie jumping, heavy helicopters, innovative food processes, and various other projects. Thus, beginners can more easily implement STEM. If a beginner directly tries to be creative without being based on an example, it is feared that the implementation of learning will face more constrained. Then after having experience in implementation, the teacher can make modifications from the examples. When they already have a deep understanding of STEM, they can design the project independently.

The implementation of the socialization for the last 3 years received a good response by the teachers as alumni of the socialization participants. Teachers who already understand STEM have more interest in the approach. The reason is that STEM is considered to be able to make learning that was originally difficult to be more contextual and easily understood. According to the experience of the teacher who has implemented it, STEM learning makes students more exploratory towards a case so that learning material becomes more meaningful. Furthermore, there is a compatibility of the STEM approach with the development of science. In the current era, memorization is no longer able to be used as a foundation for learning models. Learning must be able to support the development of the required skills. The technological age makes things more complex and the fragmentation of subjects no longer relevant.

Related to the education system, teachers have an opinion that STEM education is suitable to be implemented in Indonesia. The reason is that STEM has conformity with the curriculum 2013 as an applicable curriculum in Indonesia. The teacher considers that the two have in common namely the mandate of conducting contextual, problem-based learning, and oriented to high order thinking skills. Technically, one of the learning models mandated by the curriculum 2013 is project-based learning and STEM is also project-based learning. The following are the participant statements related to the description above.

"Our children are no longer in the era when I was at school. The era was different. The millennial era makes everything completely digital. Thus the mindset must be able to follow the change”. (Stefanny)
“One of the characteristics of STEM is integrating science, technology, engineering, and mathematics. With this integration, students become more understanding of seeing problems. When there are problems they can find more adequate solutions.” (Lucas)
3.3. The Types of STEM Implementation

Implementation of STEM in schools which is a continuation of the socialization process is a very interesting phenomenon. Socialization material is very likely to be interpreted differently because it is influenced by participants’ understanding, school conditions, and student characteristics. Thus, it is very difficult to do to make uniform forms of STEM implementation. The variety of STEM implementation techniques is a natural thing. The case is not wrong, because the implementation of an approach cannot be separated from the attributes that are inherent in the daily learning process.

The types of implementation are divided into two big categories namely school scale implementation and class scale implementation. School scale implementation is integrating various subjects in the form of projects with the STEM approach. Class scale implementation is divided into two, namely building a STEM subject and implementing a particular subject using the STEM approach. All three have their respective characters. About concerning choosing the type of implementation, each school has its reasons. Following is a description of each type of STEM implementation.

3.3.1. School Scale STEM Integration

Integrating STEM in school scale means linking many subjects. For schools, implementation in this way requires enormous energy because it requires the strength of policy and commitment of personnel (teachers and principals). Schools that can implement are schools that have a principal with a strong commitment to STEM. That is because the principal can build a school through its policies. There is one school in Central Java Province that is very well able to take a school-scale STEM implementation strategy. The school succeeded in linking one subject with another subject through the STEM approach which was supplemented by the art aspect. The background to this success is the commitment of the principal. In 2017, the Principal attended training related to STEM and felt that the approach had a very strong urge to be implemented so that graduates from the school were competitive. As a result, the Principal received an appreciation as Champion 2 Best Principal in Central Java Province and the school became a reference for other schools that wanted to implement STEM. The principal said, "... because it might be considered successful. I was asked by other schools to share about it, from schools in Java to outside Java. Here is an invitation from the Habibie festival to take part in the Expo as a representative of the Ministry of Education and Culture. At Habibie festival, our school is with STEM communities."

The process of preparing for the implementation of STEM involves all teachers in the school. All teachers are invited to one forum to conduct curriculum studies. Each teacher analyzes the subject in the curriculum then discusses what projects can be implemented. One teacher with other teachers discusses with each other to agree on what projects can be implemented together between subjects. Another thing to note is the order of material in the subjects. Often the order of subjects becomes a barrier to integration between students. Thus the flexibility is given to change the sequential the material so that according to the project can be done. Furthermore, each teacher will make a learning design with an agreed project. Finally, they have a grouping map of subjects and projects. The keyword for this preparation is the quality of teamwork and communication between teachers must go well so that each teacher knows what their peers are doing.

The final preparation is structuring lesson schedules that support the project in the learning process. One of the constraints of project-based learning is time. Thus, the making of the schedule will be arranged based on the project implemented so that the project can run conducive. For example, mathematics, physics, and electronics are implemented in one project then the three subjects are carried out sequentially. Thus, the project working time becomes more flexible and conducive.

The most fundamental challenge in implementing this learning model is teacher communication and collaboration in managing learning. Unifying learning and assessment processes makes communication between teachers must be very intensive. The teacher must be able to record every moment of the student. In an integration class, where there is collaboration, it is not easy for a teacher to do a repetition of moments in learning as he manages independently.

Learning assessment uses a project-based learning assessment model. Thus the assessment is based on process and product. In addition, cognitive assessments that are oriented towards achieving the basic competencies of each subject are also carried out. Related to the Indonesian education system which separates between subjects and requires that there be scores per subject, the advantage of this STEM integration type process is that the results of the assessment can be utilized for various related subjects. Some of the informants’ submissions related to the above description are as follows.

"... the observation is to assess activeness and other things, students peer assessments can also be used, very well in line with the curriculum 2013. The results of the contents of student worksheets are assessed according to the rubric of assessment. (Joseph)"
"So the point is collaboration, and that's what I built from the start. All the team teachers who already know, (Mathematics is this, Science is this, Sports is this) so that anyone who enters the class, just needs to continue."

(Stefanny)

3.3.2. Building STEM Subjects

The first type of STEM class scale implementation is building STEM subjects. Facts in the field show that there is one school that makes STEM subjects fill the local content subject. Taking the policy refers to the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 79 of 2014 concerning Local Content of the Curriculum 2013. In the Ministerial Regulation, schools are given freedom in determining local content subjects related to cultural arts, crafts, physical education, sports, and health, language, or technology. STEM learning is related to crafts and technology.

Some schools choose STEM implementation by building STEM subjects as local content subjects. Implementation in this way requires the strength of policy from the leadership. Schools that choose this implementation model are generally led by principals who have insight on STEM. Schools encountered in the research process, the school was led by the school principal who graduated from the STEM implementation workshop.

At the beginning of the semester, mathematics, science, and IT teachers conduct studies in developing STEM subject curricula. By following the Minister of Education and Culture Regulation number 79 of 2019, local content is developed starting from the formulation of basic competencies to developing syllabi and textbooks. The curriculum development process and the provision of teaching materials refer to various general references and references obtained from STEM socialization. Finding references is not easy because most of them are foreign references. The obstacle to adopting foreign references is the difference between the situation and conditions with education in Indonesia. Examples of the implementation of STEM in abroad show the majority of projects with high levels of funding, materials that are not always easy to find, and different case backgrounds within Indonesia. Thus, personnel must make various modifications to produce a curriculum that is per under the conditions of the school.

This implementation of the STEM model has high flexibility because schools build curricula independently. The standard of goal learning outcomes makes schools flexible in choosing projects and integration between subjects. Thus, project learning can be purely based on themes. The teacher can let students explore in depth the theme without worrying about the based competence achievement of each related subject.

Although developing the STEM learning curriculum independently, these subjects remain bound to the national curriculum that mandates authentic assessment. Assessment is carried out using a project-based learning assessment model that focuses on processes and products. In both focus, the teacher evaluates attitudes, knowledge, and skills in accordance with the learning achievement targets that have been compiled by the STEM subject curriculum.

The following is an example of a direct statement from the school principal who conducts STEM lessons in his school. "In Indonesia, there have not to STEM subject curriculum. We try to develop the curriculum and build STEM subjects. Our teacher makes a kind of learning goals or syllabus that refers to modules or experiences that we have gained during training while attending camps about STEM. The obstacles, I difficult to find reference STEM. I look for references from abroad, there are many things that are difficult to implement, so we have to be smart to choose the project." (Ali)

3.3.3. Implement STEM in a Subject

Not all school principals and teachers have positive responses to STEM learning. Facts show that there are still many teachers and principals who consider STEM difficult to implement in schools, and even tend to provide obstacles to the achievement of learning targets. Generally, schools focus on national exams so that the drill method is chosen more than project learning. Thus, the implementation model most often found is implementing STEM in a subject. Implementation of STEM in a subject is considered the easiest way because it does not require a policy of principals like the other two models. Teachers who already have STEM insights can implement in their classrooms.

The teachers start the implementation process by selecting the material and class in which to implement it. Learning refers to the national curriculum. Teachers have their respective strategies, for example, the teacher chooses easy material so students can implement STEM smoothly, others choose abstract material in the hope that STEM can make the material contextual and easy to understand. Next, the teacher must find out about students’ capacity in various subjects related to the project. The teacher must ensure that the students' abilities are sufficient so that the project can be done well.

The project is a learning model that requires a lot of preparation and a lot of activity. The rules in the Indonesian curriculum according to Minister of Education and Culture Regulation number 22 in 2016, one hour study for primary schools is 35 minutes, the junior high school is 40 minutes, and senior high school is 45 minutes. The case
in the field that often occurs is that special time is needed for learning preparation and closing. The time required is relatively long, which is about 10 to 20 minutes for preparation and 20 minutes for closing and packaging project equipment. Time for practice is very minimal. Thus the teacher must be clever in anticipating project implementation so that it can run smoothly and the learning objectives are achieved.

Lack of STEM implementation individually is a learning result that can only be used by one subject. The assessment will also only focus on one subject. Even though there are many other competencies that are related to other subjects. The second lack is that teachers have to intervene in many learning processes because of the pressure to achieve basic competencies in subjects, especially those implementing regional examinations. Thus the project implementation will be less exploratory.

A serious challenge that is generally feared by teachers is the responsibility of learning outcomes based on the curriculum 2013. Implementation independently by the teacher makes the teacher must have the courage to account for the learning process independently, including ensuring the achievement of learning targets. Thus, it is rare for teachers who dare to implement STEM in the final class in a grade level 9 (junior high school) and 12 (senior high school) because at the end of the class the students will face the UN.

"So I have implemented STEM in 7th grade, 8th grade, but in 9th grade not yet because I was afraid. Class 9 is near the national exam." (Joseph)

"Schools must take uniform tests conducted by the district. If our school is not carried out, the principal will be reprimanded." (Noor)

"It is difficult to pursue the achievement of competency standards and basic competencies in the curriculum when implementing STEM-based learning." (Nitta)

"I am different from other teachers who might choose difficult material to make a game, instead I used easy material that I made a game. I think the conditions of my students match my choice." (Joseph)

IV. DISCUSSION

STEM is a new approach that is not yet widely known by teachers in Indonesia [11]. Socialization is an important process that must be carried out by related institutions in encouraging teachers to implement a new system in education [20]. If implemented well, socialization can provide a good understanding [21] so that the probability of implementation of something new is high [22]. Thus it is very reasonable if the teacher says that the source of their knowledge comes from STEM socialization events. Therefore, increasing socialization is a strategy that can be implemented to expand the implementation of STEM in Indonesia.

Why should STEM be published in Indonesia? That sentence is a key question to answer the urgency of STEM implementation in Indonesia. Based on the urgency in preparing students to be able to compete in the 21st century [18], [23]–[25], STEM learning needs to be socialized to teachers and schools. Next, we will see the suitability of STEM with the applicable curriculum, namely the curriculum 2013. The learning character with the STEM approach is integrative [24], [26], contextual [27], [28], student-centered [29], and project-based [30].

Regarding the learning step, STEM is based on engineering design processes abbreviated as EDP [23], and the curriculum 2013 is based on a scientific approach [5] with steps 5M learning ([5], [31]). The two steps have similarities so it's very possible the two steps can be combined. Both have the essence of making students examine evidence to be concluded like an inventor or researcher. Furthermore, what can be used as a technical basis for implementation is a learning model. STEM integration is implemented in the project format [30] and one of the recommended learning models in the curriculum 2013 is project-based learning [5]. Thus, there is a similarity between the core characteristics of STEM and the Curriculum 2013. Although technically, the Curriculum 2013 has not provided specific guidelines for STEM implementation.

STEM is implemented in a project format [30] and integrative [10]. The current state of the Indonesian curriculum is still fragmented between subjects. Thus there must be a specific strategy for each school in the implementation of STEM. Honey et al., (2014) states that STEM implementation can be implemented in a variety of pedagogical strategies in accordance with local conditions. Sahlberg (2007) states that various local conditions provide wiser solutions because the decisions taken have to be in accordance with the specific conditions of a school. Thus it is logical that there are variations in the implementation of STEM in Indonesia due to differences in conditions in each school.

The variation of STEM implementation is influenced by many things. But compared to others, the principal has the most powerful and significant influence in the school (Ng & Wong, 2019; Stravakou & Lozgka, 2018). The principal has a role in developing the whole spectrum of school organizations so giving character to the school being led (Ng, 2019). As a leader, the principal has the ability to determine attitudes in the change of the world [36]. Thus it would be very good if the principal was prioritized in the STEM socialization to produce a massive impact.
IV. CONCLUSION

Implementation of STEM in Indonesia is divided into 3 types, namely STEM integration at school scale, building STEM subjects, and STEM integration in a subject. Each type of implementation in a school has its history, starting from the commitment of the principal, school facilities, student characteristics, and peer support. But one of the most influential is the commitment of the principal. The principal has authority in managing the school so that if the principal has committed to the implementation of STEM then other aspects can be conditioned. Thus, socialization should first target the school principal in order to be able to provide a more massive impact.

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