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ENHANCING INDONESIAN SCIENCE TEACHERS' PERSPECTIVE OF AND BELIEF IN STEM THROUGH PROFESSIONAL DEVELOPMENT

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ABSTRACT

STEM is an approach to teaching science that integrates technology, engineering, and mathematics, but studies have found that teachers still need help implementing STEM education in their classrooms. This current paper investigated how Teacher Professional Development for STEM Education (TPD-STEM) influenced the perspective of science teachers and their beliefs about STEM education. Results suggested that TPD-STEM shifted the teachers' perspectives on STEM education. The program also encourages most teachers to believe that STEM education can be implemented in their classrooms. A few teachers still have concerns about STEM education, and their concerns about implementing STEM education due to several educational constraints or challenges are discussed.

ABSTRAK

STEM adalah pendekatan pengajaran sains yang mengintegrasikan teknologi, teknik, dan matematika, namun penelitian menemukan bahwa guru masih memerlukan bantuan dalam menerapkan pendidikan STEM di kelas mereka. Makalah ini menyelidiki bagaimana Pengembangan Profesi Guru untuk Pendidikan STEM (TPD-STEM) memengaruhi perspektif guru sains dan keyakinan mereka tentang pendidikan STEM. Hasil penelitian menunjukkan bahwa TPD-STEM mengubah perspektif guru terhadap pendidikan STEM. Program ini juga mendorong sebagian besar guru untuk percaya bahwa pendidikan STEM dapat diterapkan di kelas mereka. Beberapa guru masih memiliki kekhawatiran mengenai pendidikan STEM, dan kekhawatiran mereka mengenai penerapan pendidikan STEM karena beberapa kendala atau tantangan pendidikan juga dibahas.

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INTRODUCTION

STEM is an approach to teaching science that integrates technology, engineering, and mathematics (STEM) which Kelley and Knowles (2016) illustrate the conceptual framework of STEM education as a situated learning connecting engineering design, scientific inquiry, technological literacy, and mathematical thinking in an integrated system. Dare et al. (2018) study uncovers science teachers' implementation of STEM in their classroom, and their findings indicate that there are differing degrees of STEM approach implementation in the classroom. The degree of integration may be related to the teacher's awareness of making connections between the disciplines meaningful and explicit. If teachers believe discipline integration is valuable, they will be more willing to help students connect disciplines (see Dare et al., 2018). Kloser et al. (2018) further supported the varying degrees of teachers' conceptions of STEM teaching in which engineering and technology are commonly underplayed, with technology usually perceived as subservient to other disciplines. Aside from how science teachers view the role of each STEM education component and discipline, their view of their ability to teach is also a concern. Firat (2020) study of Turkey's Science Teachers found that 60% of in-service science teachers perceived their ability to integrate STEM in their classrooms as inadequate. Shernoff et al. (2017) found that teachers' lack of understanding of effectively integrating STEM into their classroom practices was the common challenge in teaching STEM. DeCoito and Myszkal's (2018) study found that although 82% of science teachers in their study were highly confident in teaching STEM, further analysis of how they conducted lessons showed that they felt confident in teaching stand-alone STEM subjects and not in an integrated inquiry-based approach. Margot and Kettler (2019) meta-analysis found that teachers experiencing pedagogical barriers in teaching STEM were concerned about their ability to plan lessons and guide their students in learning STEM. In mentioning support for teaching STEM effectively, teachers believe that well-organized and frequently available professional development programs would facilitate successful STEM initiatives (Margot & Kettler, 2019).

Professional development is an essential program through which a teacher improves skills and knowledge related to their ability to teach in the classroom. The knowledge can include pedagogical knowledge, assessment knowledge, knowledge of students, knowledge of curriculum, and knowledge of content (Gess-Newsome et al., 2019). Professional development can be effective if the teachers' attitudes change after following the professional development program, and this transformation will then also alter their practice and improve students' performance and achivement in science (Whitworth & Chiu, 2015). Johnson (2006) findings suggested that professional development efforts for science teachers sometimes do not address and reveal all teachers' existing beliefs about teaching, which becomes a barrier to instructional practice transformation. Lumpe et al. (2012) corroborated the findings that aside from improving teachers' beliefs about teaching science, the number of hours of teachers professsional development participation significantly predicted students' achievement. Glackin (2016) study similarly supported the notion that teachers' beliefs correlated with the actual success of a learning program, and Kleickmann et al. (2016) findings further suggested that scaffolded professsional development can significantly modify science teachers' beliefs and motivation toward science teaching.

Studies have previously been conducted to explore science teachers' professional development in STEM education. For instance, Ring et al. (2017) reported that science teachers' conception of STEM integration shifted over the professional development model in which their models of integration evolved from a simple conception into a more complex one. Dare et al. (2019) further explored how professional development programs develop science teachers' conceptions of STEM education as an integrated education in which they reject models that did not include explicit connections between disciplines. Professional development programs for STEM education are also experiencing challenges. Lo (2021) TPD analysis uncovered that even after participating in TPD programs, some teachers lacked the necessary knowledge of STEM, or although they do have the knowledge of STEM, they were not contented in teaching it.

Teachers' belief influenced how teachers implemented STEM in their classroom in which Wang et al. (2020) study found that even when after TPD teachers believe in an interdisciplinary and integrated STEM education, if the teachers did not feel that a particular content knowledge would be educationally beneficial, they lost interest in teaching STEM interdisciplinary. Studies exploring how teachers' professional development affects Indonesian science teachers' perspectives and beliefs in STEM are currently scarce. However, Suwarma and Kumano's (2019) study also found that teachers' perceptions of STEM education are connected to how they implement STEM education in the classroom. In their study, Indonesian science teachers' perception of STEM integration in the curriculum after TPD has improved into STEM education as an integrated system. Unfortunately, they still find challenges in integrating engineering and technology and perceived efforts for such integration to be time-consuming. To offer renewed insight into the perspective of science teachers and their beliefs of STEM education after following TPD, this current paper investigated how TPD-STEM influenced the perspective of science teachers and their beliefs of STEM education.

METHOD

A 20-hour Teacher Professional Development Program in STEM Education (TPD-STEM) was conducted for two weeks. Two STEM education specialists, a full professor from University of Minnesota and Shizuoka University, were invited as counsel on integrating the STEM approach in the Indonesian classroom. The professsional development program is described in Table 1.

Table 1. The Professional Development Program in STEM Education

Activity	Topic	Goals	Time (hours)
Seminar in STEM Education: The American and Japanese contexts	STEM in the USA and STEM in Japan	Teacher increases understanding of STEM education based on the Indonesian context	8 hours
STEM Education in Elementary School	Balloon Rocket	Teachers understand how STEM education can be implemented in elementary school	4 hours
STEM Education in Junior High School	Wind Power	Teacher understands how STEM education can be implemented in junior high school	4 hours
STEM Education in Senior high School	Laser Security Power	Teacher understands how STEM education can be implemented in senior high school	4 hours

Table 2. Questions for Probing Teachers' Perspective and Belief

No	Questions in pre-interview	Questions in post-test
1	What do you know about STEM education?	After you observed the STEM lesson by the experts, what did you think about STEM education?
2	How long have been aware of STEM education?	Based on your opinion, what is the core subject of STEM education?
3	If you teach with STEM education, what kind of best teaching model will you use in your classroom?	Since joining this program, do you think that it is possible to apply STEM education in science learning in class?
4	What kind of appropriate assessment will you use in implementation of your STEM education-based lesson?	What lesson in the national curriculum will you develop for STEM-based learning?

Our objectives were to evaluate whether TPD-STEM affects science teachers' perspectives and beliefs about STEM education. Therefore, several criteria were used to select eligible science teachers as the study sample. We selected participants who were (1) novice or minimally experienced with STEM education, (2) were currently teaching science in their school based on the Indonesian National Curriculum, and (3) had previously never attended or taken part in a STEM professional development program. Based on the criteria, twenty-one science teachers were eligible as the study sample. The sample consisted of five (5) elementary science teachers, ten (10) junior high school science teachers, and six (6) senior high school science teachers. Their ages ranged between twenty-five and forty-seven years old; ten teachers were male, and eleven were female.

Pre- and post-TPD-STEM interviews were utilized to extract the conceptualization of STEM education from the participants. The open-ended questions were developed in the interview protocols so that the participants could give an opinion based on their perspectives and experience (see Table 2 for the questions). The data were collected by a one-on-one interview method. Participants' responses were coded based on Ring et al. (2017) with modification. Ring et al. (2017) study previously categorized teachers' perspective of STEM into eleven models, but for this study, only four categorizations were used: (1) STEM is defined as integration between science, technology, engineering, and mathematics or *Integrated STEM*; (2) STEM learning which focus on engineering design to learn science concepts or Engineering design process as context; (3) STEM was integrated as relevant to students' situation or real-world problem solving as context; and (4) STEM stands for Science, Technology, Engineering, and Mathematics or STEM as acronym. Several categorizations, for example, STEM as a science discipline and STEM as a single discipline, were not included to comply with the Indonesian National Curriculum definition of STEM as learning science using interdisciplinary subjects. Aside from omission, another categorization (5) STEM as an approach to support the students with 21st-century skills or STEM supporting 21st-century skills, was eventually added with consideration to the teachers' interview results.

RESULTS AND DISCUSSION

Teachers' perspective of STEM Education

In the initial interview (pre-TPD), four (19%) science teachers viewed STEM education as an integrated learning. Two teachers touched on the importance of proportional consideration of each discipline in STEM learning. It is also noteworthy that another teacher mentions that STEM learning should also grounded on actual everyday problems (Teacher 4). Teacher 4 elaborates that each discipline is interconnected and cannot be taught separately when asked how the teacher describes the relationship among the four disciplines. As opposed to STEM education as integrated learning, four or 19% of the teachers emphasize the engineering design process as context when learning STEM.

In contrast to using interconnection among STEM disciplines or emphasizing a particular discipline, three teachers (14,3%) had the perspective on STEM education, which foregrounds problem-solving as a context. Five teachers (24%) presented a more straightforward perspective, by defining STEM as the acronym for science, technology, engineering, and mathematics. Three teachers explained STEM as only an acronym for the four subjects without giving a more profound explanation (Teachers 12, 13, and 14). In comparison, two teachers offered additional definitions of STEM, such as theoretical learning (see Teacher 15 answer) or as teaching method of science, technology, engineering, and mathematics (Teacher 16). Teachers' perspectives actually can be categorized into four categories, but surprisingly, there were five teachers (24%) believed that STEM education is a learning method that supports 21st-century skills. They expressed that by using STEM, students can be creative, critical, or innovative in the learning process. Due to this distinctive perspective, science teachers' perspectives were eventually categorized into five categories. After completing the TPD-STEM program, the view of STEM as learning supporting the demand for building 21st-century skills remained. Nevertheless, overall results suggested a shift in teachers' perspectives on STEM education (Table 3).

After TPD-STEM, 33% of the teachers understand STEM Education as an interrelated and interconnected learning. The number of teachers who describe STEM only as its acronym without giving sufficient explanation was reduced to only 10%. One teacher (Teacher 14) successfully improved the understanding in which if, in the pretest, the teacher describes "*STEM is science, technology, engineering, and mathematics*," in the posttest, the perspective is shifted into a complete description of "*STEM is overlapping between science, technology, engineering, and mathematics*". Teacher 14 also provides a relationship diagram describing STEM education (Figure 1). In the diagram, Teacher 14 put engineering and technology in one circle. The teacher did not distinguish between engineering and technology in STEM learning because the teacher believes that "*Engineering and technology are quite similar. Engineering is a way for solving a problem, and technology is a tool for solving a problem*"

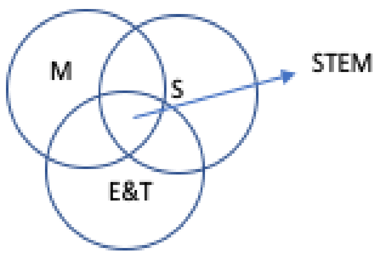

Figure 1. The relationship between STEM subjects from Teacher 14 Perspective

A refined perspective was also found in Teacher 20. In the pretest, the teacher viewed STEM as implementing technology, engineering, and calculating numbers that facilitate students in 21st-century skills. However, after TPD-STEM, the teacher refined the view that "*Science, technology, engineering, and mathematics are closely* *related. When a teacher explains a concept, it is contained in science. Also, the teacher must show the concept's application, and when a student is making a product, the process requests technology. The product must go through the engineering stage, and a test is needed to complete the product*." The perspective reflected an improved understanding of how each STEM discipline connected and supported each other.

Table 3. The Teachers' Perspective of STEM Education

Teachers' STEM Perspective	Pretest	Post test	Teacher's Statements Examples
Integrated STEM	4 (19%)	7 (33%)	STEM is an approach in the learning process which rises science, technology, engineering, and mathematics and those of subject **balance** in the learning process (Teacher 1) STEM is an approach from the four subjects, which all the subject **should use in the learning [with] same portions** each other (Teacher 2) STEM is **an integration** between science, technology, engineering, and mathematics (Teacher 3) STEM is **an integration** between science, technology, engineering, and mathematics, and those subjects should be connected in the real-world problem. [The relationship between subjects is] Science is the base of the natural knowledge, technology is a tool or material to be used, engineering is a process to make a tool or material for supporting science lesson. These subjects **could not be taught separately. Those subjects must be taught together** (Teacher 4)
Engineering design process as context	4 (19%)	4 (19%)	STEM is the learning approach **for producing a product** using science, technology, engineering, and mathematics (Teacher 5) STEM is an approach to engage students **to make a design and product** to solve the problem using science, technology, engineering, and mathematics (Teacher 6)
Real-world problem solving as context	3 (14%)	4 (19%)	An approach **to solve the real-world problem** which related with the student's experience (Teacher 10) STEM is an approach based on science subject, **in which the students give a solution that arose from a problem**. Student probably uses knowledge and skills (Teacher 11)
STEM as acronym	5 (24%)	2 (10%)	STEM is a learning approach based on **science, technology, engineering, and mathematics** to teach science (Teacher 12) STEM is an approach that brings up of **science, technology, engineering, and mathematics** (Teacher 13) Theoretical learning as **science, technology, engineering, and mathematics** (Teacher 15) STEM is one of the methods to teach science using **science, technology, engineering, and mathematics** (Teacher 16)
STEM supporting 21st skills	5 (24%)	4 (19%)	STEM as a learning model that is used to balance between knowledge and skills to support students in **creativity** (Teacher 17) The implementation of learning that guides students to be **creative and critical** on the learning process (Teacher 18) STEM is a learning that develops the **creative thinking skills** (Teacher 19) STEM is a learning to address the students for thinking in **creative, innovative, critical**, so that it can be integrated in their experience (Teacher 20)

Table 4. Teachers' belief of Implementing STEM Education in their Actual Classroom

Teachers' STEM Belief Category	Teacher's Statements Examples
I believe that it is possible to apply STEM education in my actual classroom (n = 17, 80.9%)	I believe that STEM can be used in my classroom. I will select the environment as a theme to my class because in this topic many issues should be solved. Student will design equipment to solve the environment problems (Teacher 2) I can confidently implement STEM education in the classroom. Mainly with a topic such as environment, fluids, and energy (Teacher 8) The concept of STEM as joyful learning, I believe it can be implemented in my class. Students will explore their concepts to solve the problem with their ways (Teacher 15)
I do not believe that it is possible to apply STEM education in my actual classroom (n = 4, 19.05%)	I am not sure. In my school, the number of students is in the 30s on average. Additionally, a lot of materials are still emphasized to test such as calculating in physics (Teacher 1) I do not have idea. It will need hard work to implement STEM education in Indonesia, mainly in the classroom (Teacher 11) The implementation of STEM education needs a lot of energy, mainly for preparation and needs many materials (Teacher 16) Maybe only in very small portion of Indonesia curriculum can be implemented STEM approach because a lot of material should be taught to students. The important thing that to implement STEM education need a lot of time. It will be problem for the teacher to adjust the time periods in the classroom (Teacher 19)

The ability of Teacher Professional Development ability to improve teachers' perspective on STEM was also found in Ring et al. (2017) study in which in their study, throughout professional development, simplistic views such as STEM as a mere acronym were jettisoned and progressed into more comprehensive models of STEM as integrated disciplines. Similarly, Dare et al. (2019) study also evaluated STEM education conceptual models of teachers who previously participated in professional development, and they found that the teachers' consistently rejects models that did not include explicit connections between the disciplines, which reflected the goals of TPD STEM.

Teachers' belief of Implementing STEM Education in their Actual Classroom

In our professional development program, the two STEM education specialists who served as TPD-STEM counsel presented approaches to implementing STEM in the actual classroom. For example, when teaching about energy, one of the specialists guides the students by discussing wind power energy located in Sidrap, the largest wind power energy in Indonesia located on South Sulawesi Island, which is close to most students' homes. Aside from giving an example of learning using real-world examples, approaches to teaching STEM in an integrated manner or emphasizing engineering design to learn science concepts were also presented. After TPD, 80.9% of teachers believe that it is possible to apply STEM education in their actual classroom (Table 4). This finding corroborated Al Salami et al. (2017), which found that professional development programs can improve teacher attitudes in teaching STEM.

Although TPD-STEM improved teachers' perspective of STEM learning, not all teachers will implement STEM Education in their classrooms. Four teachers did not believe that STEM could be effectively implemented in their classrooms for reasons such as Indonesian curriculum requirements, time, resources, or restrictions (Table 4). Teachers' beliefs influenced how teachers implemented STEM in their classrooms (see Suwarma & Kumano, 2019; Wang, 2020), and this study's results corroborate Suwarma and Kumano (2019) study that although TPD has improved Indonesian teachers' perspective of STEM education as an integrated system, some teachers still find it challenging to integrate it in their classroom.

Lesseig et al. (2016) study analyzed middle school teachers' implementation of STEM practices in their lessons, and they categorized three challenges in STEM implementation: pedagogical, curricular, and structural. In the same vein, Hasanah and Tsukaoka (2019) categorized barriers in implementing STEM as intrinsic barriers (related to the teachers, including their beliefs and attitudes), extrinsic barriers, which are related to the supporting infrastructure for the teacher, and institutional barriers (curriculum). In our study, Teacher 1 suggested that the learning materials still emphasized one STEM branch, while Teachers 11, 16, and 19 believe that the lack of flexibility in the sequence of instructional units and the restrictions of class schedules will mainly hinder STEM implementation.

Reflecting on teacher belief (Table 4), teachers' perceived challenges in STEM implementation also suggested that there are intrinsic, extrinsic, and institutional barriers in which the perceived challenges generally fall in pedagogical, curricular (the need to adhere to grade-level content standards while holding to the components of STEM) and structural challenges (institutional features of traditional schools that make implementing STEM difficult).

Du et al. (2019) analyzed a Three-Year STEM Professional Development Program which suggested that over three years, the program has been proven to significantly improve teacher' teaching practices and approaches as well as their attitudes toward implementing STEM practices, which suggested that a continuous effort in supporting teachers to implement STEM in their classroom can alleviate challenges and setbacks that might occur in their classroom.

CONCLUSION

The Teacher Professional Development in STEM Education (TPD-STEM) was essential in improving teacher knowledge of the essence of STEM education as an integrated learning as well as how to implement it in their classroom. The TPD-STEM encourages most teachers to believe that STEM education can be implemented in their classrooms. However, some teachers still concerned about effectively delivering STEM education in the classroom. This current study was limited to evaluation within the professional development program scheme. Therefore, further study will be necessary to evaluate how the teachers eventually implement what they took from the program in their everyday classroom.

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