Implementation of STEM education in Indonesia: teachers’ perception of STEM integration into curriculum

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Abstract. Recently in America, Europe and Asia, STEM education has been viewed as an educational reform that answers 21st-century demands in an era of productive technology and information that trigger economic, political and demographic changes around the world. As a developing country, Indonesia is called upon to deal with these demands by developing qualified human resources through educational reform. STEM education is one of the strategies for achieving this goal. Finding possibilities for the integration of STEM in the science and math curriculum through teacher training programs is the first step in this implementation, whether or not STEM education can actually be included. This study took place in a school that uses two curricula (KTSP and the 2013 national curriculum). Results of an investigation of teachers’ perceptions showed that the 2013 national curriculum was more appropriate for the inclusion of STEM education than the KTSP curriculum. The impact of training on teachers’ perceptions was shown by significant differences before and after training.

1. Introduction
Education is essential for economic and social development. A child who has received a good education tends to be a better parent, make informed decisions, earn a better living, adopt new technology, cope with crises, and be a responsible citizen [1]. Education is an important component that should be considered by the government to develop the nation through qualified human resources. These resources are developed by an appropriate educational system that includes teachers, policymakers and students. Indonesia is a developing country that still needs qualified human resources to contribute to its development.

The Indonesian government has published a new curriculum, called the 2013 national curriculum. This is a revision of the previous curriculum because of the lack of competence of graduates, the excessively broad and irrelevant content, and the fact that it was teacher centered, textbook oriented, and used cognitively focused assessment. This revision was also triggered by the new challenges of the 21st century, an era of rich technology and information that impact on modernization, globalization, science and technological development. The McKinsey Global Institute [2] stated in regard to unleashing Indonesia’s potential that the country has 55 million skilled workers, and it is predicted that Indonesia will need 113 million skilled workers in 2030. Thus, the country needs to improve the quality and relevance of education because it is critical for economic and social development [3].
This newly released curriculum is one strategy developed by the government to enhance educational quality in order to create qualified students to compete in an international world. The main purpose of this new curriculum is to build productive, innovative, creative, and good affective human resources through a reinforcement of attitudes, skills and knowledge in order to face the challenges of the 21st century. The government has not implemented this reform in all regions; it has been carried out in specific areas and responses are being collected from educational practitioners. Teachers criticize this curriculum because of the thematic content, which forces them to think holistically in order to teach lessons. In other words, teachers need to integrate all subjects into a lesson to achieve the core competencies in students. In fact, the answer to what is the best methodology to achieve the purpose of the curriculum has not been studied yet. However, the integration of science and technology plays an important role in creating the citizenry needed in this century [4]. Thus, implementation of STEM education has been chosen as a methodology to achieve these purposes. The first step in its implementation is teacher training to develop teachers’ perceptions of STEM education. This study investigated teacher perceptions and their differences before and after training.

2. Methods

2.1. Theoretical framework

2.1.1. Differences between KTSP and national curriculum 2013. Education in Indonesia is regulated by the government based on the Constitution of 1945, which set the goal of educating the nation. The Indonesian government has changed the curriculum periodically since 1947. Curriculum reform has been carried out continuously in an effort to adapt to scientific and technological development, as well as societal demands. This was done to achieve a perfect balance between learning goals, student potential, and local conditions and facilities. Therefore, science education has a great role in enhancing the curriculum, especially in increasing the number of qualified students who are creative, critical, logical and able to take the initiative regarding issues in society that result from scientific and technological development [5].

The development of the curricular framework in Indonesia refers to the Constitution and follows several phases. The phases of curriculum development from 2004–2013 are presented in Figure 1. In 2004, curriculum development began with the design of the framework, followed by structure and content standards (development of thematic content for grades I and II) that delivered standards for processes, graduate competencies, government has changed the curriculum periodically since 1947. Curriculum reform has been carried out continuously in an effort to adapt to scientific and technological development, as well as societal demands. This was done to achieve a perfect balance between learning goals, student potential, and local conditions and assessment. After developing these three sets of standards, the government developed guidelines, syllabi, and sample lesson plans. The next step was textbook, learning and assessment development, which were conducted by educational units (local governance). In 2006, the government established a new policy that the development of syllabi, lesson plans, textbook development, learning and assessment would be conducted by educational units (local governance) and developed thematic content for grades I–III. This was called the Kurikulum Tingkat Satuan Pendidikan (KTSP). In 2013, the government changed the framework of the curriculum development process. In the first phase, they analyzed student profiles and needs in relation to national educational goals, and then improved graduate competency standards, from which were derived process, framework and assessment standards. Content standards were developed from the curriculum structure that followed the curricular framework. Thematic content is designed for grades I–VI.
Since the school sample were using two kinds curriculum (KTSP (2006), and 2013 national curriculum), then teachers were asked to analyze the content’s coherency to STEM education implementation based on the different curriculum framework in Figure 1. Thus, their perception of STEM Position in curriculum became a first step before implementation.

2.1.2. Perception of STEM position in the curriculum.

STEM is the acronym of Science, Technology, Engineering and Mathematics. In education, the goal of STEM is to provide students with STEM literacy that reflects 21st-century skills so that they can face the challenges of globalization and involvement in modern science. STEM education is a learning approach that integrates each discipline into the learning process. Bybee [6] notes that STEM has been criticized for confusion over the acronym when it occurs in an educational context. He uses the example of Keefe’s [7] survey of perceptions of STEM, which showed that most respondents linked it to cell research. He assumes that the educational community has viewed STEM as a slogan without really taking the time to understand its meaning. He further argues that the criticisms of STEM come from the ambiguity and diversity of definitions, meanings, and purposes. Thus, he defines STEM in education not only as a slogan but also as a constructive innovation in the US. STEM should be recognized as a unitary idea, not as a simple grouping of four disciplines under a convenient acronym [8]. In addition, Bybee [6] does not view STEM as an abbreviation of names of disciplines, but as having purposes. Generally, it triggers students to become literate in STEM.

Moreover, Bybee [6] noted that STEM education teaches all students to learn to apply basic content and practices from the STEM disciplines to situations they encounter in life, in other words, to be STEM literate. He suggests to consider the position and purposes we want to achieve before implementing STEM education in a state, district or school. This is revealed by analyzing the position of the four disciplines in the curriculum, instructional strategies, student achievement, strengths, weaknesses, plans, and other elements, such as alignment with Common Core Standards for Mathematics.

The first step in considering the position of STEM in the curriculum is evaluating what may occur in the system by indicating grade level and approach to conducting two integrated STEM units, courses, or programs for all six possibilities. The integrated disciplines are science and technology (ST), science
and engineering (SE), science and mathematics (SM), technology and engineering (TE), technology and mathematics (TM), and engineering and mathematics (EM). The second step is to indicate three integrated STEM programs for all four possibilities (science, technology and engineering [STE], science, technology and mathematics [STM], technology, engineering and mathematics [TEM], and science, engineering and mathematics [SEM]). The final step is to indicate the full integration of four STEM disciplines in a unit, course or program.

2.2. Method

2.2.1. Sample. In order to a more detailed comparison of curricula content at one level, this focused on elementary teacher’s perception. They were 9 female teachers and 3 male teachers, who have different education background. Two male teachers got bachelor degree in social studies, and one male teacher got bachelor degree in physics. Moreover, two female teachers took linguistic, two female teachers took social studies, and four female teachers took science for their bachelor degree. They were selected randomly, based on their interest into science learning. In the implementation, two teachers analyzed the curriculum contents of one class grade.

2.2.2. Methodology. STEM implementation was conducted once a week for 7 hours (9.00-16.00), from December 21, 2014 and January 18, 2015. It was initiated through teacher training. Teachers were introduced to STEM education and the 2013 national curriculum, and then asked to consider STEM by analyzing whether or not it was appropriate for integration into the curriculum. Second, they were given STEM based activities using engineering process approach. They asked to create balloon powered car, paper bridge and toys. At last, they asked to create a lesson plan to implement STEM in class. In order to analyze students’ learning processes, a class was observed by other teachers, and several students were interviewed.

This paper focuses on teachers’ perceptions of STEM integration based on the curricular content of science and mathematics. They were requested to read the science and math content and analyze whether or not it could be integrated with STEM. Integration of STEM is built on thinking to coordinate, complement, correlate, combine, and connect to the disciplines [6]. It consists of three steps: 2, 3 and 4 integration. First- through third-grade elementary teachers analyzed the 2013 curriculum, and fifth- through sixth-grade teachers analyzed the KTSP curriculum. To measure teachers’ perceptions before and after training, they were asked to fill out of STEM Semantic Survey (SSS), selected from Berlin and White [9] and Tyler-Wood, Knezek, and Christensen [10]. The SSS consisted of 35 semantic pairs. The last three pairs refer to feasibility of integration (simple-complicated, slow-fast, and hard-easy) and were scored differently from the other pairs. The data were analyzed separately based on area of perception. Perceptual differences before and after training were statistically analyzed using a non-parametric test for dependent samples, the Wilcoxon Rank Test. The critical value of W was ranked from 8 to 14 at p = 0.05 (two-tailed tests).

3. Results and Discussion

Teachers’ perceptions of 2 STEM discipline integration is shown in Table 1, which describes several examples of integration the 2013 curriculum for first- to fourth-grade science and mathematics by using themes or sub-themes for each grade.

Table 1. Content Analysis of 2.0 STEM Integration.

| Curriculum | Grade | STEM Disciplines | Coordinated | Complemented | Correlated | Connected | Theme/subtheme/subject matter |
|------------|-------|------------------|-------------|--------------|------------|-----------|------------------------------|
| 2013       | 1st   | ST               | ✓           | ✓            | ✓          |           | My healthy clean environment |
|            |       | SM               |             | ✓            |            |           | My healthy clean environment |

After analyzing the curriculum content and possibilities for integration with 2 STEM disciplines, teachers were asked to think of an example of full integration of STEM. Table 3 presents the results: first- and second-grade teachers presented a brief idea about full STEM integration without a clear example, while fourth-grade teachers gave an example with a short explanation of disciplinary content related to the example. In fact, third-, fifth- and sixth-grade teachers did not have any ideas for full integration.

Furthermore, teachers were asked to give opinions as to whether STEM disciplines were represented at all grade levels. Fourth-grade teachers suggested that STEM was represented in the fourth grade because of the thematic concept of the 2013 curriculum, and that it could be coordinated well with the subjects. They hoped fourth-grade students would master higher order thinking skills to solve problems and improve their communication skills in describing ideas. On the other hand, fifth- and sixth-grade...
teachers perceived that STEM was represented by some of the subject matter in the KTSP curriculum, and they believed that STEM activities in these areas would engage students in class. Moreover, they suggested that the curriculum, learning methods, teacher capacity and student discipline should be changed in order to improve STEM education.

The impact of training on teachers was assessed through the SSS questionnaire that teachers completed before and after training. The method of analyzing teacher perceptions of disciplines and STEM careers was adapted from Berlin and White [9]. It was scored 5, 4, 3, 2, and 1 for positively directed word pairs (e.g. exciting-unexciting), and 1, 2, 3, 4, and 5 for directed word pairs (e.g. mean nothing-mean a lot). Perception of feasibility was scored differently. It was re-coded to assign the number five to responses reflecting the most realistic attitude and perception related to the implementation of integration in the classroom. For the pair “simple-complicated,” the remaining recodes were distributed so as to account for slightly higher scores for attitudes and perceptions related to challenges associated with integration (1, 3, 5, 4, 2). The pair “slow-fast” was coded 2, 4, 5, 3, or 1. The pair “hard-easy” was coded 2, 4, 5, 3, or 1. Results (Table.2) showed that the perception of technology did not differ significantly (W [10] = 10, p >.05), but other areas were significantly different (W value range from 3 to 14, with a critical value range from 5 to 14 at p < .05). Regarding teachers’ perceptions of science and math changes after they had analyzed the curricular content, most of them perceived that science correlated with other disciplines. They responded that integrating science and math is not as complicated as integrating engineering and technology. Seventy-five percent of teachers thought that the integration of STEM would take a lot of time, and they suggested continuing teacher training to improve implementation. Furthermore, 58.3% of teachers responded “not very interesting” regarding engineering after the training, but 75% responded “interesting” (average score = 4.28) regarding technology. They responded that integrating technology with science and math was not as complicated as engineering.

Table 2. Wilcoxon rank test result.

| Perception      | N | Mean Post- and Pre-test rank | W critical | W value |
|-----------------|---|-----------------------------|------------|---------|
| Science         | 10| 3.54                        | 8          | 3       |
| Mathematics     | 11| 5.3                         | 11         | 8       |
| Engineering     | 11| 7.07                        | 11         | 3       |
| Technology      | 10| 3.96                        | 8          | 10      |
| STEM Career     | 12| 5.10                        | 14         | 7       |
| STEM Integration| 12| 3.57                        | 14         | 14      |

From the data above, it can be inferred that the teachers had different perspectives on STEM. Some teachers’ educational backgrounds were not in mathematics or science, but in language and social studies, so they faced difficulty in integrating STEM with curricular content. Some teachers were inexperienced in teaching science and had been working at the school for one-year teaching non-science classes. Nevertheless, most of the teachers viewed STEM as integrated disciplines through overlapping and sequencing by complementing, connecting and correlating each discipline. The unclear example that was proposed in the first- and second-grade contents illustrates an obstacle in the integration process. Thus, additional resources for STEM integration were necessary in order to provide a specific example for teachers.

The results of this study support Berlin and White’s [9] study conducted within a unique integrated teacher education program that integrated mathematics, science and technology, which showed changes in teachers’ perceptions before and after the program, and suggested integrative activities. Somehow, the processes of perception changes were took from different implementation method. However, thematic units in both curricula in the school studied were appropriate for use in class since they used single-class teaching systems where the teacher teaches all subjects in the curriculum [11].
4. Conclusions
The implementation of STEM education needs to consider the readiness of educational system support, such as the curriculum and teachers. Building unified perspectives on STEM education can make implementation easier because collaborative work among science and math teachers is needed in creating ideas for lesson plans that implement STEM education in class. The curriculum is a guideline for teachers in delivering their lessons. It helps them decide their goals regarding learning processes. Thus, before implementing STEM education in class, teachers need to analyze the coherence of curricular content. The purpose of STEM education is to create STEM-literate students by developing 21st-century skills. The curriculum as a set of guidelines for teachers also needs to have the same goals so that all goals can be reached. The 2013 curriculum was designed considering 21st-century needs. Thus, STEM education can be embedded in it because science and math content are built into one theme. On the other hand, the science and math content of the KTSP curriculum overlaps, such that STEM cannot be incorporated into all subjects. However, assuming integration into the curriculum as the appropriate approach to reform is not best [6]. It is better to consider what the educational system presently has and does not have relative to STEM education. This study showed teachers how to integrate STEM in several different ways based on the curriculum they were using. It assisted them in developing a new perception of STEM based on curricular content. However, further training in STEM content and its applications are still needed as implementation continues.

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