Concepts and Practices of STEM Education in Asia pp 237–252 | Cite as

Towards Integrating STEM Education into Science Teacher Preparation Programmes in Indonesia: A Challenging Journey

Nurul F. Sulaeman, Pramudya D. A. Putra & Yoshisuke Kumano

Chapter | First Online: 21 October 2022

Abstract

The science teacher preparation programme is vital as the early stage of developing science teacher competency. While the needs of STEM education are identified, it is challenging to adopt this movement to the programme. The complexity of the science teacher preparation program is intertwined with the context of each country. In this chapter, the context of Indonesia as one of the most populated countries in Asia with around 184 science teacher education programmes is introduced. The discussions start with the organization of science teacher education programmes, how STEM education is integrated, challenges and strategies that observable in Indonesia. The data was collected from university websites, programme curricula, observations of classes, interviews with key informants, and personal reflections. While the programmes require students to choose one specialty from the beginning, the challenge of integrating that subject with other STEM subjects was identified. We found several strategies to address this challenge, such as designing a new compulsory course in STEM education, integrating STEM into other pedagogical courses, elective courses, and

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Springer

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ISBN 978-981-19-2595-5 ISBN 978-981-19-2596-2 (eBook)
https://doi.org/10.1007/978-981-19-2596-2

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

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Chapter 13
Towards Integrating STEM Education into Science Teacher Preparation Programmes in Indonesia: A Challenging Journey

Nurul F. Sulaeman, Pramudya D. A. Putra, and Yoshisuke Kumano

Abstract The science teacher preparation programme is vital as the early stage of developing science teacher competency. While the needs of STEM education are identified, it is challenging to adopt this movement to the programme. The complexity of the science teacher preparation program is intertwined with the context of each country. In this chapter, the context of Indonesia as one of the most populated countries in Asia with around 184 science teacher education programmes is introduced. The discussions start with the organization of science teacher education programmes, how STEM education is integrated, challenges and strategies that observable in Indonesia. The data was collected from university websites, programme curricula, observations of classes, interviews with key informants, and personal reflections. While the programmes require students to choose one specialty from the beginning, the challenge of integrating that subject with other STEM subjects was identified. We found several strategies to address this challenge, such as designing a new compulsory course in STEM education, integrating STEM into other pedagogical courses, elective courses, and extra-curricular activities. However, more significant efforts are needed to develop STEM PCK in Indonesia's science teacher preparation programmes. Integrating STEM education in pre-service science teacher programmes should be seen as aligned with the national goal of science education at the school system level and the needs of common goals of educational policy regarding STEM education among the programmes.

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M. M. H. Cheng et al. (eds.), *Concepts and Practices of STEM Education in Asia*,
https://doi.org/10.1007/978-981-19-2596-2_13

Keywords Indonesia · Pre-service science teacher program · STEM education

Introduction

This chapter provides a description of the current science teacher preparation programmes in Indonesia, and the challenges of integrating STEM education into these programmes. While science education in Indonesia requires school students to engage in problem-solving and to explore integrated STEM issues, the science teacher preparation programmes face challenges in adapting to these goals. At present, no programme explicitly prepares pre-service science teachers to be STEM teachers. This chapter begins with a brief overview of Indonesia's context, goals of K-12 science education, the science teacher preparation programmes, and challenges of integrating STEM education into these programmes. Although all programmes follow the Indonesian national qualification framework implemented in 2012, some aspects of the programmes have developed differently in various universities. In this chapter, we discuss some of these variations. Our analysis focuses on general trends identified from a variety of sources. These include university websites, programme curricula, observations of classes, interviews with key informants, and personal reflections. The findings indicate that science teacher education in Indonesia generally follows the national standard. A pre-service science teacher should choose one specialty in integrated science, biology, physics, or chemistry. Pre-service teachers must attain a minimum of 144 credits during the 4-year curriculum, equal to around 216 in the European Credit Transfer and Accumulation System (ECTS), to build their pedagogical content knowledge (PCK) in science. The programmes prepare science teachers to teach at junior and senior high school levels. Various additional courses are offered, influenced by local needs and international trends. While the programmes require students to choose one specific subject (for example, biology education) from the beginning, the challenge of integrating that subject with other STEM subjects was identified. We found several strategies to address this challenge, such as designing a new compulsory course in STEM education and integrating STEM into other pedagogical courses, elective courses, and extra-curricular activities. However, more significant efforts are needed to develop STEM PCK in Indonesia's science teacher preparation programmes. Integrating STEM education in pre-service science teacher programmes should be seen as being aligned with the national goal of science education at the school system level and the needs of common goals of educational policy regarding STEM education among the programmes.

Background

Since 2012, the education system in Indonesia has been reformed to clarify the national qualification framework from elementary school up to post-graduate programmes (Directorate General of Higher Education, 2012). This framework clarifies the set of qualifications that should be achieved at each education level. Within the nine levels of qualification, Teacher Education Institutions (TEIs) are categorized as being at levels 6 and 7. The science teacher education programme involves a 4-year course-based programme (Level 6) plus a 1-year teaching practice-based programme (Level 7) followed by a national qualification framework. From the outset, pre-service teachers need to choose one subject as their major: physics, biology, chemistry, or integrated science. A teacher with a specialty in integrated science is qualified to be a science teacher at the junior high school level. A teacher with a specialty in specific science subjects (such as biology, physics, and chemistry) is qualified for senior high school level.

Discussions on the preparation of science teachers need to be understood in the context of the science learning goals in the schooling context of Indonesia. Globally, more attention is being paid to integrated STEM education, and the Indonesian science curriculum has adopted this approach as one of the goals of science education. However, this change has not been readily implemented by science teachers in schools (Nugroho et al., 2019; Permanasari et al., 2021). Although science teachers have stated that STEM education is in line with the science curriculum (Suwarma & Kumano, 2019), parents and teachers in Indonesia have reported a lack of effort to educate the youth about 21st-century skills (Nambiar et al., 2019). Understanding of integrated STEM approaches has also been found to be low among pre-service science teachers in Indonesia (Putra & Kumano, 2018). The discrepancy between the science curriculum and science teachers' implementation of STEM education could be understood by exploring the science teacher preparation programmes in more detail. This chapter introduces the pre-service science teacher preparation programmes in Indonesia, the relation between teacher preparation and the high school science curriculum, and analysis of STEM education in the teacher preparation programmes. Building from this discussion, this chapter addresses the challenges, complexities, and opportunities for enhancing pre-service science teacher programmes by including integrated STEM education.

The Indonesian Context: Education as a National Government Responsibility

Indonesia is an archipelagic nation located in Southeast Asia. Currently, 13,466 islands interconnected by straits and seas have been registered with valid coordinates. The five largest islands are Sumatra, Kalimantan, Sulawesi, Jawa, and Papua. A population of around 270 million is spread across the archipelago (Statistics Indonesia, 2021). When discussing Indonesia as a context, it is important to realize that it is a highly diverse country. Most Indonesians are Muslim, while others are Christian, Buddhist, or Hindu, among others. Moreover, there are more than 1,000 ethnic groups speaking nearly 500 different languages (Steinhauer, 1994). The founding fathers of

Indonesia recognized the need for a spirit of unity. The country's motto is *Bhinneka Tunggal Ika,* or Unity in Diversity, which is a reminder of the unity of all Indonesians. In every official meeting, including in schools, the language that should be used is the national language *Bahasa Indonesia.*

Indonesia's education system reflects the country's diverse religious heritage, its struggle for a national identity, and the challenges of resource allocation (Frederick & Worden, 2011). The problem of providing access to basic schooling across this huge archipelago remains the main challenge (Heyward & Sopantini, 2013). Students in rural areas experience a less supportive learning environment (Wahyudi & Treagust, 2006), including inadequate teacher quality (Sari, 2019) and teacher mismatches, especially in mathematics and science (Hendayana et al., 2011). To ensure equality and equity for all Indonesians, the education system in Indonesia is the responsibility of the national government. This centralized system has received some criticism, especially regarding the balance of authority between central and local authorities (Haridza & Irving, 2017). The slogan for education in 2020 was *Merdeka Belajar* or The Freedom of Learning. Despite the challenges presented by the archipelagic structure of Indonesia and its large population, schools are expected to be the acculturation place for young Indonesians and to nurture the spirit of innovation and problem-solving. This slogan strongly empowers the education system to be more humanist and to appreciate the uniqueness of children. There is massive open recruitment of schools, teachers, lecturers, and researchers who are willing to be part of this policy. In 2021, there are 2500 schools from 34 provinces participating in this programme. The main goal is to enhance student literacy (reading, numeric, and science) to improve teachers' and schools' quality.

Schooling in Indonesia is administered through two parallel systems: The Ministry of Education and Culture administers non-religion-based schools, and the Ministry for Religious Affairs administers religion-based-schools. All Indonesians have to complete 9 years of compulsory education, including primary school and junior high school. They can then continue to senior high school (3 years) and an undergraduate degree (4 or 5 years). The schools are also divided into two main categories: public and private schools. Some of the private schools are based on a specific religion, such as Islamic or Christian schools or specific approach such as Montessori school or international school. All schools follow the national curriculum standards, and all schools provide equivalent certifications that are valid to be used as an application to a higher level of education.

Goals of K-12 Science Education in Indonesia

As Indonesia is the fourth most populous country in the world, the educational movement towards STEM education is both crucial and challenging. Based on PISA results, Indonesian students show unsatisfactory reading, science, and mathematics skills compared to other countries (Organisation for Economic Co-operation and Development [OECD], 2019). The Indonesian government is tasked with effectively educating diverse student groups to meet the country's changing needs, internally and internationally. Science education is expected to play an essential role in preparing students to be leaders in STEM fields and in improving citizens' scientific literacy (Faisal & Martin, 2019).

Science is a compulsory subject for students from grades 4 to 12. Students in grades 1 to 3 study science as a thematic topic in their reading, writing, and mathematics subjects. Primary school science is taught by class teachers who graduated from primary teacher preparation programmes. Science in junior high school is taught as integrated science, while in senior high school, it is taught as single specific subjects (physics, chemistry, and biology). Earth science is treated as part of Physics. Science teacher preparation programmes are aimed at those who wish to teach science at the high school level. The goals of science education have been translated into English and are presented in Table 13.1.

These goals are achieved through the topics covered in science learning. The topics are scientific activities and safety, living things, energy, matters and its transformation, earth and space, science-environment-technology-society. Each topic clarifies the minimum understanding and skills that students should achieve after the science learning. The goals show an awareness of balance in science learning between content knowledge, procedural knowledge, and epistemic knowledge, as in the PISA framework (OECD, 2019). Moreover, the last goal emphasizes the importance of integrating science concepts with technology, environment, and society. As a subject at the K-12 level, science is a tool with which students can develop their problem-solving skills based on scientific considerations.

Table 13.1 Goals of science education in Indonesia

No	Specific goals
1	Students live life with a positive attitude, critical thinking, creativity, innovation, and honest collaboration based on the scientific process and product
2	Students understand the natural phenomena around them based on the result of science learning through specific science subjects such as physics, chemistry, and biology
3	Students distinguish science and technology products through scientific thinking
4	Students make choices based on scientific considerations
5	Students solve real-life problems based on scientific considerations
6	Students recognize the roles of science in solving the general problems of humanity, such as food supply, health, and environmental issues
7	Students understand that the development of science leads to technology in the past and future of society and the environment

(Indonesia Ministry of Education and Culture, 2020)

The Science Teacher Preparation Programmes in Indonesia

In the following, we describe the pathways for the science teacher preparation programmes and discuss the challenges of preparing science teachers to teach effectively. The science teacher preparation programmes prepare pre-service teachers for teaching at the high school level. Science teachers are prepared to teach in junior high school (grades 7 to 9) or senior high school (grades 10 to 12). Before the senior high school level, all elementary and junior high school students learn basic science as an integrated and thematic subject with no distinct separation between physics, chemistry, and biology content. At the senior high school level, each science subject is taught separately as compulsory courses. In most schools, engineering and technology education are additional subjects for students. Engineering and technology subjects are generally taught as elective classes that students choose.

Structuring a science teacher education programme requires consideration of what teachers need to know to promote the goals of education (Olson, 2017). In Indonesia, pre-service science teachers are prepared to achieve the goals of K-12 science education (Table 13.1). National and private universities provide teacher education programmes. In 2019, 184 programmes (mathematics, science, physics, biology, and chemistry education) were available. On average, these programmes accept around 20–60 students each year (Indonesia Ministry of Education & Culture, 2021). The demography of universities that conduct these programmes on major Indonesian islands is shown in Fig. 13.1. The majority of the science teacher preparation programmes are conducted in universities on Jawa island. This island is also the most populated island in Indonesia and is where the capital city, Jakarta, is located. Around 5,000 graduates per year are shaped through these programmes, highlighting the urgency of maintaining and enhancing the programmes' quality and ensuring that they are aligned with global challenges.

There are two pathways to becoming a science teacher in Indonesia (see Fig. 13.2). The most common way is to join a science teacher preparation programme. Students

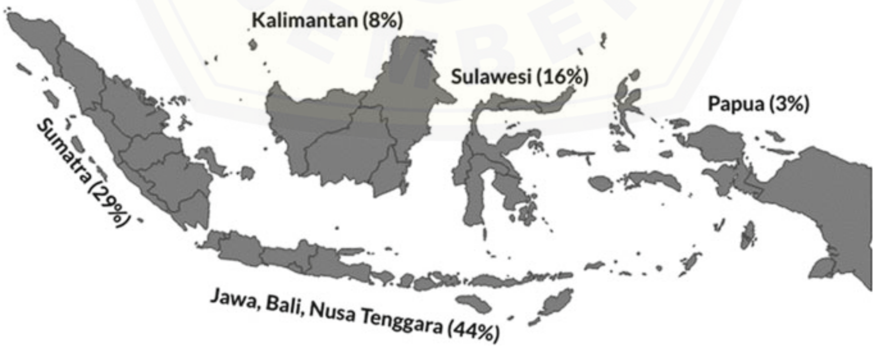

Fig. 13.1 Distribution of pre-service science teacher programmes in Indonesian universities

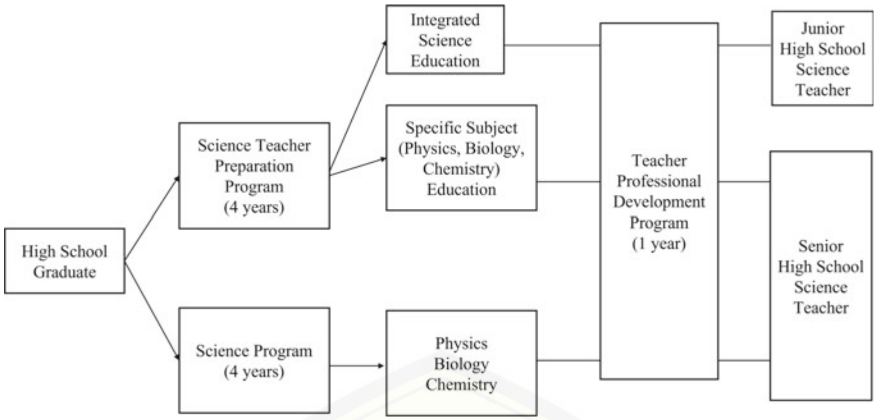

Fig. 13.2 Pathways to becoming a science teacher in Indonesia

are asked to choose one specific subject at the beginning of this programme: integrated science education, physics education, biology education, or chemistry education. After completing the programme, students are awarded a Bachelor's degree in science education. Graduates from this programme can teach at the high school level. However, they do not have a professional teaching certificate and do not qualify for certification remuneration from the Indonesian government. After finishing this programme, they can continue with a 1-year teacher professional development programme and become licensed science teachers. The second pathway to becoming a science teacher in Indonesia is completing a 4-year programme with a science major (such as physics, biology, or chemistry). After finishing this programme, students are awarded a Bachelor's degree in science. Graduates from a science major need to take the 1-year teacher professional development programme before becoming science teachers.

The Curriculum of the Science Teacher Preparation Programmes

Following national regulation (Directorate General of Higher Education, 2012), the higher education programmes (including TEIs) use the model of Outcome-Based Education (OBE). The science education programmes for teaching in Indonesia have a similar set of outcomes overall, although the details may vary across universities. The outcomes are called Programme Learning Outcomes (PLO). The outcomes consist largely of a knowledge domain and skill domain. To decide the PLOs, national regulation was discussed through the association for similar programmes. Several associations are active in Indonesia for science education, such as the Indonesian Science Teacher Association or the Physical Society of Indonesia. Moreover, insights from the international associations or accreditation boards also influence the development of PLOs. The PLOs determine the detailed outcomes for each course.

The teacher preparation programmes are divided into 4 years of coursework and 1 year of teacher professional development. The distribution of the credits across the 4 years of the science education programmes is shown in Table 13.2. Courses are divided into five main categories, with 55% related to content knowledge and 45% related to pedagogy and general courses. For the physics, biology, and chemistry education programmes, the content knowledge relates mostly to the subject that has been chosen. For an integrated science education programme, the content is integrated from each of the science domains of biology, chemistry, and physics. It is also common in Indonesia to have several elective courses that pre-service teachers choose based on their interests. Generally, the curriculum in each similar programme includes identical courses, and the Indonesian government has opened an exchange programme among these teacher preparation programmes through several programmes such as *Kampus Merdeka* or Campus Independency. These programmes allow pre-service teachers to take courses in different universities. For example, pre-service biology teachers from University A on Papua Island have opportunities to take microbiology courses at University B on Jawa island. The universities on Jawa island tend to have better facilities and quality of lecturers than others. Pre-service teachers also have opportunities to observe the uniqueness of Indonesian culture on a different island. The goal of this policy is to reduce the variation among universities in Indonesia and to nurture a sense of unity in the diversity of the country.

The content knowledge is divided into two types:

(1) Single-subject content knowledge (39 credits); for example, mathematics, fundamental physics, general biology, mechanics, astronomy
(2) Integrated subject content knowledge (42 credits); for example, biochemistry, chemical physics, basics of science, applied science, human biology.

Although the information in Table 13.2 is generally found in science education programmes, some variation can be seen in the name of courses and the number of credits awarded for each course. Moreover, each university also builds its curriculum

Table 13.2 The typical distribution of the credits in the department of science education

Group of courses	Credits	Percentage (%)
General courses (1) Religion and Indonesian nationality	6	4
(2) Language	4	3
Pedagogical knowledge	19	13
Content knowledge	81	55
Subject-specific pedagogy	26	18
Elective courses	10	7
Total	146	100

based on specific knowledge related to the university's specific knowledge expertise. Each university in Indonesia is encouraged to set up a centre of excellence based on its strengths and vision. We observed and analysed several programmes in science education at five different universities to investigate their provision of science or STEM teacher education. These programmes were chosen by considering the representation of national and private universities and the programmes in integrated science and specific science subjects.

Example A: Science Education Programme, University of Jember, National University on Jawa Island, Indonesia.

The University of Jember is located in East Jawa, the most populous island in Indonesia. It has become a centre for agriculture and medicine studies. Besides the main goals of developing science teachers' PCK, the teacher training programme also supports teachers with knowledge of agricultural issues. The curriculum of the science education programme prepares students to become science teachers in junior high school. Students must attain 144 credits (216 ECTS) through general courses, pedagogical knowledge, integrated science content knowledge, and elective courses. Additional courses that support the university's research centre are in biotechnology and agroindustry.

Example B: Physics Education Programme, Mulawarman University, National University on Kalimantan Island, Indonesia.

As the university is situated in a tropical rainforest area, this university declares itself the centre of excellence of tropical studies. A 4-year programme with a major in physics education includes 149 credits (equal to around 223 ECTS) across general courses, pedagogical knowledge, content knowledge, subject-specific pedagogy, and elective courses. After completing the minimum number of courses, students can teach physics at the high school level. The courses that support the university's centre of excellence are additional content knowledge courses in environmental physics and tropical forest environmental sciences.

Example C: Biology Education Programme, Muhamadiyah University, Private University on Jawa Island, Indonesia.

This programme is offered by a private university that is based on Islamic values. A 4-year programme with a major in biology education includes 161 credits (equal to 241 ECTS) achieved through Islamic courses, general courses, pedagogical knowledge, content knowledge, subject-specific pedagogy, and elective courses. After completing all of the required courses, students can teach biology at the high school level. The courses that support the university's Islamic values include biology and Islam, and Islam and the development of knowledge.

Teacher Professional Development Programmes

After students graduate from a 4-year science teacher preparation programme, they take the 1-year programme that prepares them to be teaching professionals. Generally, students who have graduated from teacher training faculties and those who

Table 13.3 The typical distribution of credits in the curriculum of the 1-year professional development programme

Group of courses	Credits	Percentage (%)
Content knowledge	5	42
Development of instructional design	3	25
Teacher training programme	4	33
Total	12	100

have graduated from engineering or natural science departments are able to join this programme. Students must complete two tests during the one-year programme: a comprehensive test and a performance test. The comprehensive test examines the student's mastery of content knowledge and pedagogical knowledge. The performance test examines the student's ability to teach science to an actual class of students. The typical distribution of credits in the curriculum of the 1-year teacher professional development programme is shown in Table 13.3.

Opportunities for Integration

In the earlier part of this chapter, we discussed the goals of science education at the school level (Table 13.1), the topics for science at the school level, and the curriculum for science teacher preparation programmes. While integration of science with problem-solving skills and other related subjects is emphasized at the school science level, these issues are not directly addressed in the science teacher preparation programme provision. This mismatch deserves more attention from universities. While there is a need to integrate STEM in teacher education to foster essential skills such as problem solving (Miller & Krajcik, 2019; Priemer et al., 2020), implementation in the curriculum remains a challenge. The challenge to integrating STEM education into a single subject context is a significant challenge globally (National Academy of Engineering & National Research Council, 2014), especially in the Asian context (Lee et al., 2019). It is commonly found in Asian countries, the curriculum for school level is fixed. Therefore, infusing new subject is challenging.

Previous research in the United States explained that perspectives on integrating STEM are varied. The perspectives are: (1) STEM is equal to science; (2) STEM means both science and mathematics; (3) STEM means science, but incorporates technology, engineering, and mathematics; (4) STEM equals a quartet of separate disciplines, (5) STEM means that science and mathematics are connected by either technology or engineering; (6) STEM means coordination across disciplines; (7) STEM means combining two or three disciplines; (8) STEM means complementary overlapping across disciplines; (9) STEM means transdisciplinary courses (Bybee, 2013). Of the nine possible perspectives on STEM education, integrating STEM with science and incorporating technology, engineering, and mathematics seems the

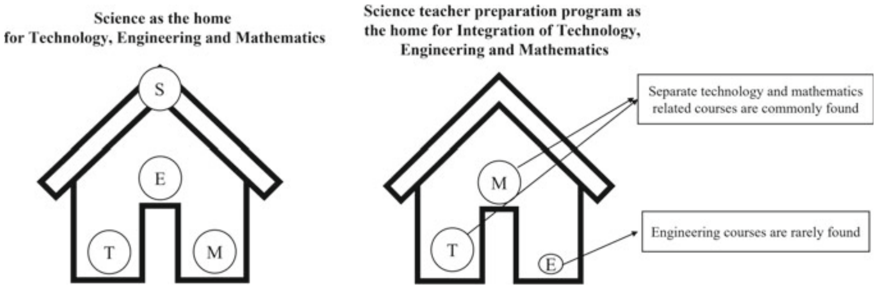

Fig. 13.3 Integration of STEM in science teacher preparation programmes in Indonesia

most feasible in the case of science teacher preparation programmes in Indonesia (Fig. 13.3). The science concepts become a 'home' that can provide a basis for the integration of technology, engineering, and mathematics elements. In the specific programmes (such as physics education, biology education, and chemistry education), the 'home' is the specific subject. The engineering component seems to be the most neglected element. This situation is also found in countries such as the United States (National Academy of Engineering & National Research Council, 2009) and Turkey (Asiroglu & Akran, 2018). The engineering element is not explicit in either the K-12 curriculum or science teacher preparation programmes in Indonesia.

Integrating STEM Education into the Science Teacher Preparation Programmes

Out of the minimum of 144 credits in the science teacher preparation programmes, mostly the integration of STEM education is considered as an additional course or additional topic in some pedagogical courses. These elements of STEM education in the current programmes should be appreciated as an initial step. However, the number of credits related to STEM education is far from sufficient. The methods of integrating STEM education vary across different universities. From our observation in five programme curricula in different universities, four approaches are currently being implemented: integrating STEM as compulsory courses, integrating STEM as part of compulsory courses, integrating STEM in elective courses, and extra-curricular activities related to STEM education.

Compulsory Courses

Some science teacher preparation programmes had STEM education courses as one of the compulsory courses. For example, at the Indonesia University of Education, STEM is a compulsory course (3 credits) that focuses on building the STEM literacy of pre-service science teachers through an integrative approach and collaborative activities. The main topics in this course are energy and new materials. This course uses inquiry- and problem-based learning in the learning process.

Part of Compulsory Courses

Although STEM education as a specific course is not part of most science teacher preparation programme curricula, our observation of several programmes revealed that STEM education topics are part of their science-specific courses. For example, at the University of Jember, there is a course called Innovative Learning Models. In this course, STEM education is discussed as an approach to learning. Another example is Mulawarman University, where STEM education is discussed in the Physics Teaching and Learning course. This course mainly examines the approaches, models, and strategies for teaching physics.

Elective Courses

As an initial process of integrating STEM education, elective courses about STEM education are offered by several universities in Indonesia. For example, in the Department of Science Education at the University of Jember, a STEM course worth two credits covers the history of the development of STEM, understanding STEM terms, perceptions of STEM learning, implementation of STEM learning, and pedagogy in STEM education. As part of this course, students develop a STEM instructional design suitable for the science curriculum in Indonesia.

STEM Education in Extra-Curricular Activities

Another approach initiated by several universities (such as Syah Kuala University) is building a research centre in STEM education. Through this centre, various activities – such as STEM camps, workshops, and seminars – help pre-service and in-service science teachers and students learn about STEM. This centre also collaborates with international non-profit organizations. Another example is the National Education Museum at the Indonesia University of Education. In this museum, there is a centre called the 4D Frame STEM Education Centre. In 2020, this centre hosted an activity called the International Students' STEM Camp for Pre-Service Teachers.

STEM Education as a Research Topic

During the 4-year programme, science teacher candidates need to conduct a research project and write up a thesis. STEM education has become a popular research topic among science teacher candidates. For example, research has been done on developing STEM learning material (Gustiani et al., 2017; Hartini et al., 2020), perceptions of STEM (Widayanti et al., 2019), and students' achievement towards twenty-first century skills in STEM education (Mutakinati et al., 2018; Putra et al., 2021). Such research shows the significant interest of science teacher candidates in exploring STEM education. After being exposed to integrated STEM during their courses, they are eager to extend their interest in STEM education to their theses.

Challenges of Integration

With the growing awareness of the complexity of real-life problems, it has become clear that a problem in physics is not solely a physics problem. Real-life problems often require the integration of science, technology, mathematics, engineering, and other related subjects. In Indonesia's school system, three possibilities for implementing STEM integration have been identified: STEM in the K-12 school system, building a STEM subject, and integrating STEM into compulsory subject (Arlinwibowo et al., 2020). The possibility to infuse STEM in school is similar to developing a magnet school that focuses on STEM or on developing STEM schools. In the history of the Indonesian school system, there is a possibility to develop a specific kind of school such as an environmental school called *Sekolah Adiwiyata* (Nomura, 2009; Parker, 2018). The school could be at the primary or secondary level and infuses environmental issues into the curriculum. The second possibility is to develop a new subject at school called STEM. The new subject would be separated from science or mathematics and would address the integration concept through problem-solving activities. The third possibility that is observable through the national curriculum is integrating STEM into the science subject curriculum.

In the science teacher preparation programmes in Indonesia, there are clear boundaries among each science subject. Therefore, out of the nine possible perspectives on STEM education (Bybee, 2013), integrating STEM with science and incorporating technology, engineering, and mathematics seems to us to be the most feasible. Here, science is the 'home' into which the other components are integrated. There is currently no possibility of developing a new programme, such as a STEM teacher programme, within the school and university system regulation.

Even though the requirement to design integrated STEM is found in the school science education curriculum, different science teacher preparation programmes are adopting different approaches to address this reform. Among these programmes, the integration of STEM is often an additional or optional part of the science teacher preparation programme. The different approaches in each programme need to be addressed, and a more organized reform towards STEM education is needed. Due to the different approaches adopted by the science teacher preparation programmes, the impacts of these changes are difficult to measure. We argue for a more comprehensive reform towards integrated STEM, setting common goals for the integration, and including integrated STEM as part of the Programme Learning Outcomes for science teacher preparation programmes.

Conclusion

Indonesia's science teacher education follows a centralized curriculum with the requirement of teaching licenses. An analysis of the curriculum shows that the programme prepares teachers in terms of pedagogical content knowledge in science. Various additional courses are offered according to local needs or specific targets or strengths of the universities. The programmes feature inspiring examples of good practice in integrating STEM education, such as efforts to initiate STEM centres, infuse STEM education into some courses (such as a micro-teaching course), and offer extra-curricular activities, such as an orientation programme. However, lasting systemic solutions remain elusive. Additionally, there is still much to be done to develop STEM Pedagogical Content Knowledge in science teacher preparation programmes in Indonesia. It is important that integrated STEM education is included in pre-service teacher programmes if these programmes are to align with the national goals for school science as presented in the school science curriculum.

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