CHAPTER I
INTRODUCTION

A. Background

The role of technology and information in shaping contemporary society is undeniable. As a result, there is a rising demand for careers in the STEM field as specialized expertise becomes increasingly crucial in future occupations that have yet to be conceived. Projections suggest that this demand will continue to escalate in the foreseeable future (Vennix et al., 2018). Thus, STEM employers seek a workforce with 21st-century skills to compete in the global economy (Martín-Páez et al., 2019).

Acquiring the essential skills required for future careers can be greatly facilitated by adopting an interdisciplinary approach to education that incorporates subjects from Science, Technology, Engineering, and Mathematics (STEM). By integrating these fields, individuals can develop a comprehensive skill set that enables them to effectively tackle emerging professions' challenges(Wong & Huen, 2017). STEM is an educational approach that intentionally integrates various disciplines, fostering integrated learning and connections between subjects (Vasquez et al., 2013). The emphasis on hands-on activities within real-world contexts aids in developing a wide range of skill sets (Ortiz-Revilla et al., 2020).

Teachers play a crucial role in implementing new teaching methods and curricula. Their perceptions and beliefs can either limit or enable the adoption of innovative approaches, significantly influencing the implementation process. These beliefs encompass cognitive and emotional constructs that can be descriptive, evaluative, or prescriptive (Höttecke & Silva, 2011). Furthermore, research suggests that the effectiveness of STEM instruction relies more on teachers' pedagogy than the content itself (Yeh & Hsu, 2019). Teachers' pedagogical approaches are closely intertwined with their beliefs about STEM and the competencies required for effective implementation (Holmlund et al., 2018; Thibaut et al., 2018).

Teachers' perspectives on STEM integration can serve as a filter that helps translate their knowledge into actionable steps (Chan et al., 2019). These perspectives also significantly impact their motivation to learn and grow as STEM teachers (Margot & Kettler, 2019). Teachers need to embrace an integrated epistemological framework to implement STEM curricula, teaching strategies, and materials effectively. This framework should support the integration of the four disciplines while acknowledging and appreciating the distinct characteristics of each domain of knowledge (Ortiz-Revilla et al., 2020). Therefore, it becomes crucial to delve into the thinking patterns and beliefs that shape teachers' STEM practices (Hardman, 2019). Understanding these beliefs is essential since a key factor in successful STEM learning appears to be the presence of dynamic teachers who hold a positive attitude toward STEM (Arnado et al., 2022). Examining teachers' perspectives and beliefs can give us insights into the factors enabling or hindering effective STEM instruction.

Teachers' perspectives on the desired skills students should acquire upon completing their education also play a crucial role in shaping the objectives of STEM learning. When science, mathematics, engineering, and technology subjects are integrated in an interdisciplinary manner, it fosters the development of high-level objectives, including creative skills, literacy, and problem-solving abilities (Lin et al., 2022).

The effective implementation of STEM education is also influenced by teachers' dedication and confidence in their abilities. Teachers' self-efficacy and cognitive factors impact their selection of appropriate instructional strategies, learning resources, and lesson planning for STEM (Arnado et al., 2022; König et al., 2021). Furthermore, teachers' self-efficacy significantly influences their commitment to STEM teaching. This commitment reflects their willingness to cherish and excel in their profession. Research indicates that STEM teachers' self-efficacy can predict their commitment more to being disseminators of knowledge rather than simply implementers and designers of STEM programs (Yang et al., 2021). Understanding teachers' beliefs is essential in ensuring the effective implementation of STEM education, as it helps align instructional practices with desired learning outcomes.

Neither Indonesia nor Taiwan has established official STEM integration guidelines within curriculum frameworks at any level of education. There are no explicit references about STEM program planning processes to national curriculum frameworks; if there are, they are minimal descriptions and general manner. These indicate the need for more systematic integration of S, T, and M subjects from curriculum standards (Fang & Xu, 2019; Indonesian Ministry of Education, 2022; Taiwan Ministry of Education, 2014).

However, the latest curriculum revisions in Indonesia and Taiwan indicate the emerging characteristic of STEM education in the S, T, and M subjects curriculum guidelines. Starting from the 2022/2023 academic year, the Merdeka curriculum is one of the options that can be chosen voluntarily by the education unit. The Merdeka curriculum allows academic departments to create contextual academic unit operational curricula to implement learning according to student learning needs (Indonesian Ministry of Education, 2022). Like Indonesia, the Taiwan Ministry of Education amended the General Guideline of the 12-year Basic Education curriculum to be implemented on August 2022. The 12-year National Basic Education Curriculum is based on the spirit of whole-person education, spontaneity, interaction, common good, and the vision of achieving every child -promoting talents and lifelong learning (Taiwan Ministry of Education, 2014).

At the secondary level in Indonesia, the model of Natural Sciences subject is integrated so that students have wider opportunities to study topics in physics, chemistry, biology, and Earth and space (Faisal & Martin, 2019; Indonesian Ministry of Education, 2022). Integrated science education focuses on the competence of applying scientific research principles in the learning process. Two main elements in science education exist understanding concepts and process skills to use science in everyday life (Indonesian Ministry of Education, 2022). Meanwhile, science learning starts in Taiwan by motivating students' curiosity toward science and cultivating students' desire for active learning. Students are encouraged to build their knowledge upon prior experiences and conduct active exploration, experimental operations, and multiple learning (Fang & Xu, 2019). The arrangement of the contents of science learning material must consider the development of scientific knowledge and the interconnection between science, technology, and other subjects (Lin et al., 2021; Taiwan Ministry of Education, 2018b).

The Indonesian educational system does not establish Engineering and Technology courses, while the Taiwanese do not have Engineering courses. However, Taiwan has a Technology subject, and Indonesia has a subject matter equivalent to an ICT subject. The curriculum guidelines for the technology domain of the 12-year Basic Education Program ensure that every student is equipped with basic technological literacy by shaping an adaptive and friendly learning environment, as well as inspiring and developing the talents of every student within an adaptive and supportive environment, regardless of gender (Taiwan Ministry of Education, 2018c).

On the international level, many developed countries have also established the technology domain in their curricular guidelines, emphasizing the integrated application of science, technology, engineering, mathematics, and design knowledge, thus helping students understand the link between science and engineering by reinforcing the connectivity of interdisciplinary expertise. Meanwhile, the ICT subject in Indonesia encompasses science, engineering, and technology rooted in logic and mathematics (Indonesian Ministry of Education, 2022). This subject provides a foundation for computational thinking, problem-solving ability, and a generic skill that is important in line with the rapid development of digital technology. At the end of the secondary level, students can work together to identify problems, design, implement, test, and refine computational artefacts as solutions to community problems and communicate products and their development processes in the form of fun, creative works orally or in writing.

Mathematics, in Indonesia, aims to equip students with mathematical understanding and procedural skills, mathematical reasoning and proof, mathematical problem solving, mathematical communication and representation, mathematical connections, and mathematical dispositions (Indonesian Ministry of Education, 2022). Mathematics is not only a subject matter that students must understand. It is also a conceptual tool for constructing mathematics learning materials through mental activities that form a line of thinking and a flow of understanding that can develop skills. At the end of the secondary level, students can solve contextual problems using mathematical concepts and skills. In Taiwan, mathematics echoes the idea and vision that mathematics is a language, a practical science of laws, and a humanistic quality, which should provide each student with a sense of learning opportunities and cultivate students' literacy through the correct use of tools (Taiwan Ministry of Education, 2018a). The 12-year National Basic Education Mathematics Course considers personal life planning, national economic development, and international community participation and hopes to provide high-quality 12-year introductory mathematics courses to fully prepare for entering university, the workplace, and society in the future.

Indonesia and Taiwan education do not yet have a distinct STEM subject. However, STEM education itself remains popular. The positive attitude of Indonesian students toward learning science and math, the core of STEM education, could result from the socio-economics of that country (Shin et al., 2018). Some teachers in Indonesia use STEM as a learning method, but it is not a significant component of the Indonesian curriculum (Faisal & Martin, 2019; Rahmaniar, 2020). Because STEM education is not explicitly stated as part of the Indonesia National Curriculum, teachers in Indonesia cannot apply formal integrated STEM education in their classrooms.

Research that surveyed teachers' perceptions of STEM found that, from the teacher interview, the Ministry of Education and Culture's website publishes information about STEM learning (Permanasari et al., 2021). The government also held policy socialization and workshops through the Center for Development and Empowerment of Science Educators and Education Personnel for all science teachers in secondary and vocational schools. The teacher representative disseminates the result of training to other science teachers within the scope of the Science Teacher Council. One of the issues in STEM education is inequitable STEM discipline representation. Various models of STEM education offer leeway for teachers to highlight some disciplines and neglect others (Tambunan & Yang, 2022).

Taiwan's educational efforts in promoting STEM education can be traced back to when nature and life science and technology were merged into the field of nature, and life science and technology in the 9-year curriculum framework opened the promotion of cross-disciplinary integration between mathematics, science, and technology (Thi & Loan, 2019). STEM education-related policies in Taiwan have not been clearly defined, and the core literacy. The learning focus in the syllabus has not been systematically planned and implemented in STEM education. Although the related connotations of integration of STEM are mentioned in the content of the curriculum outline, its planning concept, core literacy, and learning focus are all in science and technology rather than STEM.

Although the Taiwanese government did not issue any official policy on STEM per se, secondary school educational programs widely adopted STEM as an essential teaching concept in mid-2010, and it had become a new trend for developing school curricula. The core value of STEM was integrating hands-on and mind-on learning, such as problem-based and inquiry-based solving. Technology and engineering shaped the country's economy and created the need to prepare students to learn and develop 21st-century skills (Fang & Xu, 2019; Taiwan Ministry of Education, 2018c).

Considering the comparable state of STEM education in Indonesia and Taiwan, there is an intriguing opportunity to explore the teaching beliefs of STEM teachers in these two culturally distinct countries. These teaching beliefs influence the educational objectives and approaches teachers choose, as well as their self-efficacy and dedication to STEM teaching. The outcomes of this study will provide insights into teachers' STEM teaching beliefs across different nations and cultures, facilitating the formulation of cross-cultural recommendations for enhancing STEM instruction in the future.

B. Research Problem

The research problem of this study is stated as ‘’To what extent do STEM teachers' teaching beliefs in Indonesia and Taiwan differ and influence their instructional designs?’’

C. Research Questions

Based on the research problem, this study attempts to elaborate on the following research questions:

1. What are the STEM teaching beliefs held by secondary STEM teachers in Indonesia and Taiwan?

2. Is there a significant difference in STEM teachers' teaching beliefs between Indonesia and Taiwan?
3. How do Indonesian and Taiwanese STEM teachers differ in their characteristics of STEM lesson plans and overall beliefs about STEM?

D. Operational Definition

1. STEM Education

In this study, STEM education is defined as an interdisciplinary instructional approach to learning that integrates the teaching of science and mathematics through the infusion of the practice of scientific inquiry, technological and engineering design, and mathematical analysis by using real-world problems as contexts for students (Holmlund et al., 2018; Honey et al., 2014; Wahono et al., 2020). The framework is shown in Figure 1 below.

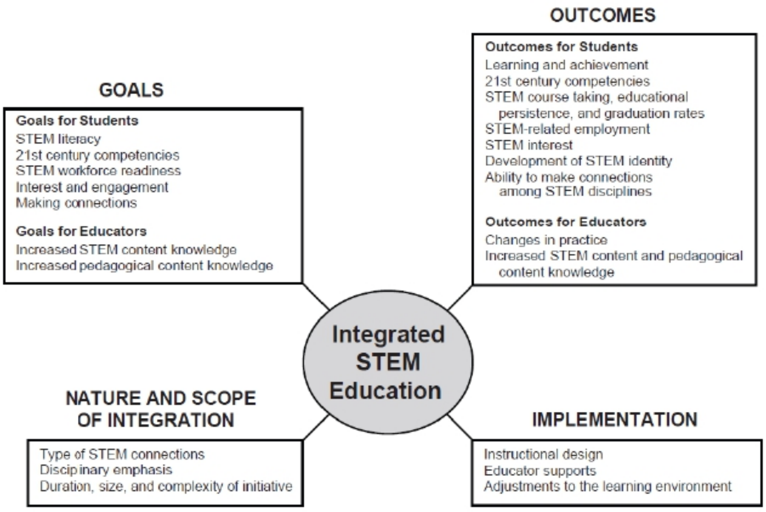

Figure 1. Descriptive Framework Showing General Features and Subcomponents of Integrated STEM Education (National Research Council [NRC], 2014, p. 32)

The implementation of integrated STEM education can vary based on different models, each suggesting distinct planning approaches, resource requirements, implementation challenges, and expected outcomes (Honey et al., 2014). The integrated STEM education framework comprises four key features: (1) goals, (2) outcomes, (3) nature and scope, and (4) implementation strategies.

Our study aimed to investigate the teaching beliefs of STEM teachers within the context of the integrated STEM education framework developed by the National Research Council (NRC). This study aligns with the NRC framework, which provides a descriptive overview of the fundamental components of integrated STEM education.

The goals specified in the integrated STEM education framework establish a sense of direction and purpose, ultimately influencing the desired outcomes of STEM education. Teachers' beliefs play a pivotal role in shaping their understanding of these goals and subsequently influencing the objectives they set for their students.

Furthermore, the nature and scope of integrated STEM education, as defined by the framework, guide the integration of STEM disciplines and align with the intended outcomes. Teachers' beliefs become instrumental in this regard as they influence how they perceive and interpret the interdisciplinary nature of STEM education. These beliefs inform their design of learning experiences that effectively integrate STEM disciplines, promoting meaningful connections. When teachers' beliefs align with the principles of integration, it enhances the effectiveness of their instructional practices.

During implementation, teachers translate the goals, outcomes, and nature and scope of integrated STEM education into practical plans within the classroom. Teachers' beliefs strongly influence this phase, guiding their instructional strategies, curriculum design, and resource allocation decisions. When teachers' beliefs align with the principles of integrated STEM education, it fosters coherence and effectiveness in the implementation process.

In conclusion, teachers' beliefs intersect with the integrated STEM education framework, playing a crucial role in shaping its various components. They influence the goals established for students, guide the understanding and integration of STEM disciplines, and impact the implementation of integrated STEM education in the classroom. Recognizing this connection is vital for educators as it allows them to align their beliefs with the framework, facilitating purposeful and impactful integrated STEM instruction.

2. STEM Teaching Beliefs

This study defines teaching beliefs as a teacher's core values, which direct teachers' decisions in the classroom (Song & Zhou, 2021). STEM teaching beliefs include teaching approaches, education goals, teacher self-efficacy, and teacher commitment.

There are three types of STEM teaching approaches. STEM teaching approach A is synchronized, meaning teachers design the course plan before instructing lessons separately according to their subject strengths. STEM teaching approach B is thematic and relies on team teaching on a specific topic. Teachers need to discuss and arrange the knowledge and skills acquired by students in each discipline together beforehand. STEM teaching approach C is based on project-based learning, and teachers jointly prepare integrated materials to assist students in problem-solving.

STEM education goals include three dimensions, which are 21st-century skills, Scientific, Technological, Engineering, and Mathematical literacy, and interdisciplinary problem-solving. Teacher self-efficacy and commitment refer to the perceived self-efficacy and commitment to being designers, implementers, and disseminators of STEM teaching.

E. Research Objectives

The objectives of this research are listed below:

1. To identify the STEM teaching beliefs held by secondary STEM teachers in Indonesia and Taiwan.
2. To determine whether there is a significant difference in STEM teachers' teaching beliefs between Indonesia and Taiwan.
3. To describe the characteristics of STEM lesson plans and overall beliefs about STEM of Indonesian and Taiwanese STEM teachers.

F. Research Benefit

The findings of this study offer educational researchers and practitioners a comprehensive understanding of the teaching beliefs held by secondary STEM teachers in Indonesia and Taiwan, including the similarities and differences between these beliefs and how they impact teachers' readiness for STEM instruction. The comparisons made in this research provide valuable insights for enhancing the preparation of STEM teachers in Indonesia and Taiwan to improve their teaching practices in STEM education.