EXPLORING THE RELATIONSHIP BETWEEN THAI SCIENCE TEACHERS' METACOGNITION AND THEIR PERCEPTIONS OF METACOGNITIVELY ORIENTED LEARNING ENVIRONMENTS

by

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ABSTRACT

Thailand reports low levels of students' science achievement. Many studies suggest that developing students' metacognition, which is knowledge, control, and awareness of one's own thinking and learning processes, could enhance students' science learning. To develop learning environments that supports the development of students' metacognition, fundamental information about teachers' metacognition and their perceptions of their actual and preferred learning environments is needed. This research explored Thai science teachers' metacognition and their perceptions of the extent to which their classrooms are or could become metacognitively oriented, and the relationship between those aspects. The research is grounded on Social Constructivism that explains how students' metacognition could be enhanced by their interactions with teachers and other students in Metacognitive Oriented Learning Environments (MOLEs). A convergent mixed methods research design was adopted. There were 214 Thai science teachers at secondary level who completed questionnaires, and 29 of them were interviewed. The teachers reported their metacognition and that metacognition varied between them. Specifically, teachers reported more favorably about their metacognitive knowledge than regulation. The findings also suggest a medium correlation between all three elements of teachers' metacognition: Declarative Knowledge, Learning Process Knowledge, and Regulation; and the metacognitive orientation of their science classrooms. The differentiation of teachers' actual MOLEs and their interest in MOLEs could be explained in relation to the teachers' perceptions of their lack of knowledge, a lack of time, students' low motivation for learning, and varying expectations for learning.

Keywords: Metacognition, Metacognitively oriented learning environment, teachers' metacognition, science education, science achievement

PREFACE

This dissertation is an original work by Gamolnaree Laikram. The research project, of which this dissertation is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Exploring the relationship between Thai science teachers' metacognition and their perceptions of the metacognitively oriented learning environments", ID Pro 00109745, August 29, 2021.

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I am so grateful to my participants, science teachers in Thailand. Conducting research under the Covid-19 pandemic would not be possible without kindness and dedication from my participants. I would like to extend my sincere thanks to all kind people who leaded the ways to reach the participants under the difficult time as well.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

"I know that I know nothing", Socrates (Maden, 2020, para 8)

This dissertation is organized into five chapters. Chapter one provides information including the researcher's autobiography, research significance and relevance, and research questions. Chapter two contains information from the literature to explain the rationale for conducting the research, frameworks, and previous studies. Chapter three explains the approaches and methods used in the research including developing research instruments, establishing research quality, and identifying research limitations and delimitations. Researcher's narrative in conducting research under the Covid-19 pandemic is shown at the end of this chapter. Chapter four consists of research findings, interpretations, and discussion based on research questions together with a discussion considering on Thailand' s context. Chapter five provides a conclusion to the study.

My Autobiography Related to the Research Topic

I grew up in a small village in the northern part of Thailand. Everybody there was like a member of a big family. We knew each other's life stories and shared the same way of life, as most of us were farmers. When you are a farmer in a developing country, it means that your life depends on two things: the weather and the market. If the weather conditions were good, you get a productive crop; but if not, you would not have anything to cultivate no matter how much effort you put in. However, even if the weather was good and you had good production, sometimes the market value would be so low that you still might not make good profit from your crop. When I was a child, my family always told me to put effort into my education. They said, "keep studying hard, and you will have a good job with a good salary. You will not have to work hard and be poor on the farm." I believed they were right, and I believed that education could provide me with great opportunities leading to a better life. I studied hard, got some scholarships, finished bachelor's and master's degrees, moved to Bangkok, and got a good job with enough salary to take care of myself and my parents. I have always thought that a good education is a key for establishing a good foundation of a life, and that this concept could not apply only for me but for other people as well.

After I graduated with my master's degree in science, I shifted my career path from being a scientist to be a science educator in the Institute for the Promotion of Teaching Science and Technology (IPST), under the Ministry of Education in Thailand. The institute has a mission to support K-12 teachers and students to teach and learn science. As I still hold the belief that good education is a pathway for an improved quality of life, I seek to be a part of teams that support and develop improved education quality for the people of Thailand, and I do believe that learning science is an important part of a quality education. Learning science can assist people to learn about nature (or anything) rationally and systematically, and to not believe in something that cannot be proven (for example, believing in being lucky and winning some lottery and doing nothing with their life).

From more than ten years of working in the institution, I have had much experience in the Thailand education context. I have visited many science classrooms across Thailand. I was part of teams that developed science curriculum, science text books, learning activities, learning materials, and teacher-training programs. I attened many training programs including a one-year Teacher Education Program at Marian University, Wisconsin, USA. In that program, not only did I have a chance to learn about teaching and learning in theory, I had observed teaching and learning in science classrooms in the USA context for two semesters. From my experience, I have learned that if we want to improve quality of education, there are many factors related to, for example, curriculum, policies, learning materials, and home environments that must be considered. One of the key things, among others, is to improve the quality of teaching and learning. I contend that the ways teachers teach in classrooms has a great effect on their students. No matter what students are to learn, teachers are the ones who help facilitate students' learning, and they are the ones who, along with their students, influence the classroom learning environments. If teachers help create learning environments that support students to learn, students might learn effectively and successfully.

I heard about the concept of metacognition when participating in one of my training programs. Actually, I am quite familiar with the concept about being conscious with our own thoughts, as I am a Buddhist. I was trained to do meditations, and I have had chances to learn about Buddhist philosophy since I was young. One thing that was kept in my mind is 'Sati' (สติ). Its meaning is similar to consciousness, mindfulness, or awareness. I was taught that we should practice Sati, being conscious of what we are doing, thinking, and feeling. Then, Sati will lead to Samadhi, สมาธิ (concentration), and finally Punya, ปัญญา (wisdom, deep understanding). In relation to metacognition, I believe that being conscious of one's own thinking could improve one's thinking and learning, and lead eventually to wisdom.

At this point of my life and work, I realize that I have interacted with four key terms: education, science, teacher, and metacognition through my knowledge, passion, and experience. I am delighted that I have a chance to combine knowledge and experience based on those terms together to create some benefits to educational settings and finally to people's lives in Thailand and elsewhere.

Significance and Relevance of the Research Topic

Issues of Interest

Thailand has been recognizing unsatisfactory levels of its students' performance in science for several years. The low performance is reported both at national and international levels. This issue of low performance is considered important by the government (see Office of the National Economic and Social Development Board, Thailand, 2017), as it will negatively influence Thai people as individuals and as a whole country.

At the national level, the results from the Ordinary National Educational Test (O-Net) showed that the science levels of achievement of 6th, 9th, and 12th grade students across the country were around 30-40% of the total scores. This low level of achievement has been found since the O-Net was first introduced in 2015 (National Institute of Educational Testing Service, the O-net announcement, 2019). At the international level, results from both the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) showed that Thai students have low levels of science performance. Thai students were ranked 28th among 39 countries in TIMSS 2015 (Martin et al., 2016) and 53rd among 79 countries in PISA 2018 (Schleicher, 2019). Specifically, Thai students have an average score in science below the mean levels in both international assessments (see Mullis et al., 2016; Schleicher, 2019). In the PISA 2018 test, there were 8,633 Thai students who took the test, and they were sampled from various types of schools across Thailand, e.g., public schools, private schools, schools in rural, urban, and Bangkok area (PISA Thailand, 2020). Specifically, only 55.5% of Thai students passed the important benchmark, level 2, that is described as students having basic knowledge of science for using in their everyday lives. That number is low when compared to 78% of students from the group of countries in the Organization for Economic Cooperation and Development (OECD) who met this benchmark level (Organisation for Economic Co-operation and Development [OECD], 2019a).

Thailand has two major national goals that rely largely on people's capability in science. Thailand aims to, (1) prepare Thai people to be ready for any challenge in the 21st century, and (2) improve its economic sector to reduce poverty and economic inequality (Office of the National Economic and Social Development Board, Thailand, 2017). With quality scientific knowledge and thinking, it is envisaged that people could interpret information, make decisions, and solve problems related to scientific situations. Especially, in this challenging modern period, people may interact with science and technology in almost every aspect of life. In addition, they might also develop innovations or implement their science and technology knowledge and skills to develop their work, especially in the agriculture sector which is an important sector in Thailand. They could possibly have more options in terms of career and income that might lead them away from poverty. To sum up, people's knowledge, understanding, and capability in science is considered crucial in the Thailand context. Therefore, students' low achievement in science is a substantial problem in Thailand.

The Root of the Issue

As mentioned previously, students' low achievement is viewed as a serious problem by the Thai government. However, the issue could be just the tip of the iceberg. Results of students' achievement may reflect their learning processes in classrooms. Vermunt (2005) explored the relationship between students' achievement and their learning processes in 1,279 students at the university level in the Netherlands. The findings suggested strong relationship between those aspects. Students' low level of achievement may suggest that there are problems with their learning processes in the classroom environments within which they learn science.

Many research studies have reported problems regarding learning and teaching in science classrooms in the Thailand educational context. For example, some Thai students might not connect their claims with proper evidence in making scientific arguments (Pimvichai et al., 2019) and not identify the main concept and apply knowledge to answer basic questions even though they had been taught about the topic and concept on several occasions (Panijpan et al., 2008). Some students have been found to not be able to design science experiments based on a hypothesis (Seetee et al., 2016) or not understand how scientific knowledge is generated and how it relates to empirical evidence (Ladachart & Suttakun, 2012). The available information suggests that Thai students' low performance in science is found not only through national and international assessment. They perform unsatisfactory during learning in science classrooms in general as well.

There is evidence of Thai teachers teaching science by emphasizing scientific processes more than students' thinking (Sothayapetch et al., 2013). Some teachers have been reported to have difficulties teaching using student-centered approaches (Alsammarry et al., 2016). In addition, Wirussawa et al. (2016) reported a lack of a collaborative learning environments between teachers and students. Pitiporntapin et al. (2016) reported preservice science teachers lacked confidence in integrating socio-scientific issues into their science teaching. The socio-scientific issues, in this case, mean real world issues that impact society and could be informed by science knowledge, for example, waste management, water pollution.

Narjaikaew et al. (2016) conducted a pre-test and post-test to evaluate 30 science practicing teachers' understanding of science concepts before and after a training program. The science concepts were related to force and motion, electric circuits, and astronomy. Narjaikaew et al. (2016) reported that there was a small number of teachers who answered pre-test questions correctly. In addition, results from the post-test showed that about a half of teachers could answer the questions in relation to force and motion and electric circuit correctly. The findings of Narjaikaew et al's study suggest that even after a training program, about 50% of teachers in this group might still hold misconceptions regarding the science concepts they were taught in the training program. Kijkuakul et al. (2008) found from a case study of three biology teachers that they had difficulties when they implemented new strategies into their classrooms. In addition, Srikoom et al. (2017) explored 154 teachers across the country and found that 85.5% of teachers had outdated knowledge in relation to STEM education. Many teachers could not update their own knowledge about teaching and learning.

Buaraphan (2011) conducted a study of 30 preservice science teachers who studied to teach general science, biology, chemistry and physics to explore their attitude to teaching science at the beginning and the end of a semester. Buaraphan (2011) concluded from questionnaire findings that teachers were scared about whether they could teach science properly. The results from his study suggest that teachers may lack confidence in teaching science. In a case study of three primary science teachers, Buaraphan (2012) found that the preservice teachers also had misconceptions related to the nature of science. Further, in a study of 33 preservice science teachers, Faikhamta (2011) found that all preservice teachers reported difficulties in teaching during their field experience. Their difficulties related to, for example, asking questions in relation to elicit students' prior knowledge and specific content knowledge, or holding limited understanding of science concepts. Finally, Erawan, (2019) reported from a study in 111 novice teachers in different schools that they needed many kinds of support for effective teaching in areas such as encouraging students' learning, developing classroom curricula, or assessing and evaluating students' learning.

The findings about problems related to science teachers in Thailand are found in research regarding both preservice teachers and practicing teachers. Problems include a lack of confidence in teaching science, having misconceptions of science concepts, lacking the ability to implement new teaching strategies, and not being able to improve their own competencies or learn new material.

Further, problems related to learning and teaching science including students' low achievement as reported in the Thailand context are also evident in other countries (e.g., Al-Balushi & Martin-Hansen, 2019; Bell et al., 2003; Evagorou et al., 2012; OECD, 2019b; Schleicher, 2019). In addition, issues related to science teachers having inadequate science knowledge and low confidence in teaching have been reported in the international context (e.g., Al-Rabaani, 2014; Davis et al., 2006; Emereole, 2009; Farsakoğlu et al., 2008; Hanuscin et al., 2011; Murphy et al., 2007). Therefore, exploring possible strategies to attend to the issues in the Thailand educational setting might also be beneficial for other educational contexts as well.

Current Solutions

The Thai government is concerned about students' low achievement and has sought to attempt to fix the situation. Many projects have been implemented in education settings, for example, revising curricula, training science teachers, developing and introducing new learning activities, and improving learning materials (Office of the Basic Education Commission, Ministry of Education, Thailand, 2020; Institute for the Promotion of Teaching Science and Technology, Thailand, 2020). Attempts to implement many projects to enhance students' science achievement have been evident for more than ten years (e.g., Yuenyong, 2013; Yuenyong & Narjaikaew, 2009). However, significant change or improvements in students' learning are not yet evident. There are many possible reasons that might explain the lack of change.

Firstly, it is possible that more time after implementing supports for positive changes to the educational settings to occur is necessary. For example, teachers and students need time to adjust to a new curriculum. Secondly, the implemented projects are predicted to be effective theoretically, but could be ineffective practically. For example, new learning activities need time for teaching and learning that is more than the time available in regular classrooms. Thirdly, the educational system might not be flexible enough to change or adopt new strategies. For example, there is a national curriculum to be followed (Office of the Education Council, Thailand, 2020), a tight period of instructional time (Faikhamta & Ladachart, 2016), and overcentralized educational bureaucracy (Fry, 2018). Fourthly, the educational setting might require other strategy(s) to solve the problems, as the projects do not attend adequately the root causes of the problems. Indeed, all symptoms cannot be healed by one pill. Obviously, Thailand needs to revise and adjust its current situation, system, and strategies together with adopting some new potential strategies into educational settings.

A Call for Alternative Strategies

The National Research Council, USA (2005) introduced three foundational principles that describe learning processes and support effective learning. The three principles are 1) students learn based on their prior knowledge, 2) a good foundation of factual knowledge and conceptual knowledge will support students to understand, organize, and apply knowledge, and 3) developing students' metacognition could help them to become aware of, have knowledge of, and manage their own thinking and learning (National Research Council, USA, 2005). The first and the second principles focus on knowledge and managing that knowledge, but the third principle, metacognition, focuses on managing one's own thinking and learning processes.

It is not only the National Research Council, USA that highlights the importance of ability to control one's own learning. The concept has been considered important in many educational institutions. For example, UNESCO (2020) stated, "learning to learn and managing one's own learning journey must become basic competences" (p. 8). OECD (2018) argued that,

> [S]tudents will need to apply their knowledge in unknown and evolving circumstances. For this, they will need a broad range of skills, including cognitive and meta-cognitive skills (e.g., critical thinking, creative thinking, learning to learn and self-regulation); social and emotional skills (e.g., empathy, self-efficacy and collaboration); and practical and physical skills. (p. 5)

In addition, many educational experts give priority to metacognition as one of essential keys for effective learning (e.g., Bellanca, 2014; Binkley et al., 2012; Trilling & Fadel, 2010; Vermunt, 2005).

Metacognition was defined as knowledge about one's own cognitive processes (Fisher, 1998; Flavell, 1976). The term also refers to one's ability to control knowledge about one's own cognition (Reeve & Brown, 1985). As metacognition is related to thinking processes (i.e., cogntion), it is considered as important across educational contexts. The National Research Council, USA (2005) stated that teachers should learn about metacognition and learn to enhance students' metacognition. Indeed, many studies across subject areas have reported that when students' metacognition was enhanced, they performed better academically (e.g., Babbs & Moe, 1983; Bergey et al., 2017; Channa, et al., 2015; DiBenedetto & Zimmerman, 2013; Dirks-Naylor et al., 2019; Gilbert, 2005; Kelley & Clausen-Grace, 2007; Liu & Liu, 2020; Rozencwajg, 2003; Schraw et al., 2006; Sperling et al., 2012; Topcu & Yilmaz-Tuzun, 2009; Wu & Tsai, 2005). In addition, students in learning environments that support enhancing students' metacognition show better performance in many discipline contexts including science (e.g., Askell-Williams et al., 2012; Georghiades, 2004a; Kaberman, & Dori, 2009; Ladawan et al., 2015; Michalsky et al., 2009; Thomas, & Anderson, 2014; Zion et al., 2005; Zohar, & Barzilai, 2013). In summary, the positive influence of metacognition on student learning is found across educational contexts internationally.

In the Thailand educational context, the concept of metacognition is not widely known. The number of studies about metacognition is relatively low compared to those in other fields. Information from two major database *Education Resource Information Center (ERIC) and Education Research Complete databases (2000-2020)* show that there are only 13 research articles about metacognition conducted in the Thailand educational context (EBSCOhost, 2020a). There is little information about metacognition in the Thailand context especially in the science setting (more details are in Chapter two). From the same databases, there are only two research articles about metacognition situated in science education (Ladawan et al., 2015; Rahmat & Chanunan, 2018), and there is only one study related to teachers: early childhood teachers (Thienngam et al., 2020). However, all research studies from Thailand confirm the positive influence of metacognition on students' learning (Akkakoson, 2012; Bell, 2008; Bell, 2011; Duangnamol et al., 2018; Jirapa Abhakorn, 2014; Ladawan et al., 2015; Phaiboonnugulkij, 2018; Phakiti, 2016; Rahmat & Chanunan, 2018; Seedanont & Pookcharoen, 2019; Tanewong, 2019; Thienngam et al., 2020; Wichadee, 2011)

Research on metacognition in Thailand can also be located in Thailand's educational database. For example, there are 32 articles in Thai Journals Online database (Thaijo), and only five of them were conducted in science settings (Thai Journals Online, 2020). These articles focused largely on improving students' performance (Thai Journals Online, 2020). None of them focused in teachers' metacognition. In conclusion, we have scarce Thai metacognition research focused on Thai teachers. More importantly, there is no evidence of research focusing on teachers' metacognition or on developing metacognitive orientation in science classrooms learning environments.

Filling a Gap in Science Education Issues in Thailand Context

Among other factors that are considered that might improve teaching and learning science in Thailand educational context such as, developing curriculum, changing teachers' role from teaching to coaching, emphasizing on scientific skills, supporting active learning in classrooms, using digital technology in teaching and learning, and developing teacher quality (Office of the Basic Education Commission, Ministry of Education, Thailand, 2020), metacognition seems to be one of essential components for teaching and learning that is overlooked. Thailand's education system should focus on metacognition for many reasons.

Firstly, as mentioned previously, findings across disciplines and educational contexts internationally show that students who learn within learning environments that support developing and enhancing students' metacognition achieve better performance. Therefore, there is a good chance that developing that learning environment in Thailand context may also support Thai students to achieve better.

Secondly, some problems that were reported in science educational settings in Thailand, as mentioned previously, might be a consequence of insufficient adaptive metacognition in students. For example, as reported by Panijpan et al. (2008), some students learned a science concept and could answer questions about that concept successfully before. However, students could not answer related questions when asked later. This situation might have resulted because students remained unaware of their own successful learning processes used previously to learn that concept knowledge. More issue is about students making scientific conclusions without using supporting scientific evidence (Pimvichai et al., 2019), and student inability to design scientific experiment from a given hypothesis (Seetee et al., 2016). We might interprete that students may lack of knowledge about how to learn science, or they may not be aware of their own learning process to learn science, meaning they could not monitor if their learning process is ineffective. From those mentioned evidences, it could be interpreted that those Thai students may hold insufficient metacognition in learning science. Therefore, in order to assist students to learn science better, Thai students may need support to be more metacognitive.

Thirdly, some problems that were evident (mentioned in pages 6-8 of this document) regarding science teachers may be a consequence of insufficient state of science teachers' metacognition. For example, teachers' own lack of confidence in their ability to teach science may result from insufficient insight into their own science learning processes. The ways teachers learn can influence the way they teach (Evan, 2004; Medley & Hill, 1970). It follows that how teachers learn science could influence how they teach science. If teachers are aware of how they learn science successfully, they might be able to teach how to learn science to students.

In addition, it was reported that science teachers have some misconceptions of science concepts (e.g., Narjaikaew et al., 2016; Buaraphan, 2012). This may reflect them not being aware of their processes of learning and not monitoring if their learning processes are ineffective. From these reasons, it could be interpreted that teachers metacognition may be unsatisfactory, and this might affect how they teach science in classrooms. Therefore, it is necessary to explore the state of Thai science teachers' metacognition in relation to learning science, as it might affect teaching and learning science in their classrooms, and it might influence the development of students' metacognition in their science classrooms.

Fourthly, the research findings mentioned before (e.g., Alsammarry et al. 2016; Sonthayapetch et al., 2013; Wirussawa et al., 2016) suggest that the learning environments that students are situated in might not support developing students' metacognition. There is evidence of learning environments that focus on doing rather than thinking (e.g., Sonthayapetch et al., 2013). Therefore, it is necessary to explore to what extent science classroom learning environments in Thailand are metacognitively orientated. Such information might be used as foundational information to support the promotion of metacognitively orientated science classrooms in Thailand.

Fifthly, there is little information from research about metacognition that has been conducted in Thailand. Although the available findings confirm the positive relationships between metacognition and students' performance, much information is required in order to improve the metacognitive orientation of science classrooms. For example, "What are the factors that support the development of metacognitive orientations?", or "How do Thai science teachers view metacognition in the context of learning science?" Therefore, seeking answers to such questions is necessary.

Sixthly, the concept of metacognition is promoted by many educational organizations and researchers internationally as it is an essential component for learning in this modern educational period. OECD (2018) stated, “[S]ocieties are changing rapidly and profoundly” (p. 3) according to three factors: environmental, economic, and social challenge. “Future-ready students need to exercise agency, in their own education and throughout life” (OECD, 2018, p. 4). Furthermore, UNESCO (2020) indicated that,

> [A report by UNESCO] demands a major shift towards a culture of lifelong learning by 2050. It argues that the challenges humanity faces, those resulting from the climate crisis and from technological and demographic change, not to mention those posed by the COVID-19 pandemic and the inequalities it has exacerbated, call for societies that understand themselves as learning societies and people who identify themselves as learners throughout their lives. Realizing this vision requires a learner-centric, demand-led approach to education that enables learners of all ages and backgrounds to co-design actively and use any learning process and its outcomes to achieve their full potential. (UNESCO, 2020, p. 10)

In addition, educational researchers have suggested the need to develop students’ metacognition. Demir and Doganay (2019) stated, “with the longevity of today’s world, adaptation to scientific, technological, and social changes makes lifelong learning inevitable” (p. 134). Wilson and Bai (2010) pointed that, “[T] he demands of the twenty-first century require students to know more than content knowledge; they must know how to learn. Learning is an active process that requires students to think about their thinking or be metacognitive” (p. 269). Moreover, students with adaptive metacognition might learn better and therefore support the aim of Thailand as mentioned before in preparing people to be ready for the in 21st century— “Adaptive metacognition involves both the adaptation of one’s self and one’s environment in response to a wide range of classroom variability” (Lin et al., 2018, p. 245). Thomas (2012a) mentioned that students' metacognition should be considered as "a consequence of the psychosocial environments within which they learn to reason rather than as some innate ability or process" (p. 133). Thomas (2012a) also stated that, "[W]hat [metacognition] is adaptive for one environment might not necessarily be adaptive for another" (p. 133). This means that a learner who has metacognition in a particular context could be successful in learning in that context and task, but may not be successful in learning in other contexts and tasks. Thomas (2012a) emphasized that adaptive metacognition could assist students to achieve learning in their contexts.

In summary, evidence from the in Thailand education context suggests that Thai students may need support to develop adaptive metacognition, Thai science teachers' metacognition should be explored as it might influence teaching and learning, and the state of the metacognitive orientation of science classroom learning environments should be investigated. Thailand education should focus on metacognition to enhance teaching and learning in science classrooms.

Getting Started with Metacognition

National Research Council, USA (2005) has called on teachers to find ways to enhance students' metacognition. In addition, Pickett and Fraser (2010) sated that, "convincing evidence has been provided that the quality of the classroom environment in schools is a significant determinant of students learning" (p. 321). Thomas (2003) mentioned that, "[T]he metacognitive orientation of a learning environment is the extent to which that environment supports the development and enhancement of students' metacognition" (p. 175). In this research, that kind of learning environment will be called Metacognitively Oriented Learning Environments (MOLEs). It is reasonable to suggest that developing MOLEs in science classrooms might enhance students' metacognition in the context of learning science, and could enhance students' learning of science.

Although research results confirm the positive influence of metacognition on student learning, we require more information about how to create MOLEs in science classrooms. Branigan and Donaldson (2020) explored teacher-student interaction facilitating metacognition in a primary classroom in England, and concluded that "we found that metacognition only really occurred when teachers used modelling and elaborative questioning to elicit deep reflections about the process of thinking and learning" (p. 13). Branigan and Donaldson's findings support focusing on teachers as an important influence in developing MOLEs.

Research results have suggested teachers are important in developing MOLEs in at least two ways. Firstly, there is evidence about the relationship between teachers' metacognition and MOLEs. James and McCormick (2009) concluded from a study from 40 primary and secondary school teachers in England that "teachers who had most success with implementing assess for learning and learning how to learn in their classroom were those who demonstrated a capacity for strategic and reflective thinking and took responsibility for what happened in their classrooms" (p. 982). Curwen et al. (2010) concluded from a longitudinal study of 1,024 elementary students and 18 teachers in the USA that "[T]eachers' metacognition effects their own practice and lead to students' better learning as they were developed metacognition and reflection, exploration and depth in content domains, and integration of literacy in content area" (p. 128). In addition, Karlen et al. (2023) concluded from a study of 185 teachers in Switzerland that, "teachers with higher SRL skills are more inclined to implement metacognition in their classes" (p. 10). In Karlen et al. (2023) study, SRL skills refer to Self-Regulated Learning which includes four aspects: metacognitive awareness, metacognitive regulation skills, cognitive regulation skills, and motivational regulation skills. The studies from James and McCormick (2009), Curwen et al. (2010), and Karlen et al. (2023) suggest a relationship between teachers' metacognition and developing MOLEs in classrooms. However, more evidence is needed. Firstly, the relationship was suggested through only three studies. More studies are needed to ensure the relationship. Secondly, a study in more specific subject contexts is needed. James and McCormick (2009) conducted their study in England with teachers who participated in the project of learning how to learn in general classrooms. Curwen et al. (2010) conducted their study in the USA in the context of reading and writing, and Karlen et al. (2023) conducted their study in Switzerland in teachers who taught science, mathematics, German, and foreign language. Therefore, information about relationship of teachers' metacognition and developing MOLEs in specific contexts like science classrooms is needed, especially in Thailand context. Thirdly, more specific elements of teachers' metacognition should be explored. Metacognition consists of elements, for example, metacognitive knowledge and regulation (depending on frameworks, which will be discussed in Chapter two). In-depth information about what elements of teachers' metacognition (or metacognition as a whole) might relate to MOLEs is essential in terms of supporting development of MOLEs in science classrooms. Therefore, studies about any relationship between teachers' metacognition and their MOLEs are crucial and much needed. This information will be beneficial not only in Thailand educational context but also international context as well.

The second aspect of teachers as important agents in developing MOLEs is their perceptions on MOLEs, as teachers' perceptions will influence their intentions and their behaviors (Walberg, 1977). Ben-David and Orion (2013) explored of 44 primary school science teachers in Israel regarding implementing a metacognitive orientation into their science classrooms. They found that teachers were opposed to implementation of instruction for metacognition. However, once those teachers had participated in a training program, Ben-David and Orion mentioned that teachers were more willing to learn more on how to implement the instruction into their science lessons. Therefore, beside teachers' metacognition, their perceptions of MOLEs might also be important in developing MOLEs.

In the Thailand educational context, there is scarce information on metacognition research as mentioned before. To support the development of MOLEs in Thai science classrooms, educators need foundational information related to teachers: the status and overview of science teachers' metacognition, teachers' perceptions of actual MOLEs in their science classrooms, teachers' perceptions of preferred MOLEs in their science classrooms, and any possible relationship between those aspects. Understanding science teachers' metacognition and their perceptions related to MOLEs must be the first step to enhance teaching and learning science.

Purposes of the Study and Research Questions

To fill the gap in science education settings in Thailand on issues about students' low performance, considering how to develop and enhance students' metacognition is crucial. To foster the development and enhancement of students' metacognition and students' learning, teachers' metacognition and teachers' perceptions on MOLEs should be investigated and whether there is a relationship between those aspects should also be explored. This research explores Thai science teachers' metacognition, and their perceptions of their actual and preferred MOLEs. Further, the research explores if there is any relationship between the teachers' metacognition and their perceptions, and if there is any difference between teachers' perceptions on their actual and their preferred MOLEs. The research findings can be used to support developing MOLEs in science classrooms in Thailand. As mentioned previously, the research findings could be adapted and implemented in international contexts as well. The research questions for this study are as follows.

1. What are Thai lower-secondary science teachers' self-reports of their metacognition?
2. What are Thai lower-secondary science teachers' perceptions of their actual and preferred metacognitively oriented science classroom learning environments?
3. Is there a relationship between Thai lower-secondary science teachers' metacognition and their perceptions of their actual and preferred metacognitive orientations of their science classroom learning environments?
4. How do Thai lower-secondary science teachers explain any similarities and differences between their preferred and actual metacognitively oriented science classrooms?

CHAPTER TWO

LITERATURE REVIEW

This literature review is organized into three main sections to provide coherence and justification for the research questions. In the first section, the context of science education in Thailand is provided. This includes explaining why science education is considered important, what issues exist in the Thai context, how those issues have been managed, and why alternative practices for Thai science education should be considered. Secondly, metacognition is reviewed including its various frameworks and its relationship and importance for learning science. The last section contains information about metacognition research conducted in the Thailand context. This literature review provides a discussion that leads to the research questions.

Situations with Science Education in Thailand

Importance of Science Education

In Thailand, science education is considered important for many reasons. Two main reasons are to build a strong economy and strengthen people's capabilities. In relation to the direction for Thailand's overall national development, there is the *20-year National Strategy (2018-2037)* that was created to set a framework for developing the country (National Strategy Secretariat Office, Thailand, 2018). There is also the *Twelfth National Economic and Social Development Plan (2017-2021)* that was developed to serve as an implementation plan for the national strategy for the first five years (Office of the National Economic and Social

Development Board, Thailand, 2017). In the 20-year National Strategy, the national goals is indicated as,

> to maintain national security and ensure people's welfare; boost multidimensional national competitiveness to ensure consistent economic growth; empower human capital at each and every stage of life to manifest competent and moral citizenry; broaden opportunities to improve social equality; promote environmentally-friendly growth with improved quality of life; and develop governmental administrative efficiency for greater public benefits. (National Strategy Secretariat Office, Thailand, 2018, p. 2)

The national goals are focused largely on improving factors that could impact Thai people's quality of life. Those factors include the economy, environment, social equality, government system, and people. Accordingly, ten essential strategies were developed and indicated in the *Twelfth National Economic and Social Development Plan (2017-2021)*. One of the essential strategies is the development of science and technology (Office of the National Economic and Social Development Board, Thailand, 2017).

Specifically, science and technology are expected to be essential for improving the Thai economy. The Twelfth Plan aims to use science and technology to increase Thailand's capacity in the agricultural, industrial, and service sectors (Office of the National Economic and Social Development Board, Thailand, 2017). Economic issues are among the main concerns in Thailand. The average household income of the whole country is quite low at around 26,000 baht/ month (National Statistical Office, Thailand, 2020) (around 24 baht = 1 CAD, Bank of Thailand, 2020). Furthermore, around one tenth of the population (Thai population is around 66.5 million) is living in poverty with the spending poverty line at 2,700 baht/person/month (National Statistical Office, Thailand, 2020). The application of science and technology in economic sectors, as mentioned before, is expected to be one of the solutions to help reduce poverty and to decrease the income gap for Thai people. In the agriculture sector, it is proposed that farmers could use their knowledge and processes of science and technology to make appropriate decisions on how they manage their farms to produce more output in a more sustainable way. Laborers with knowledge and competencies in science could have more options for their careers. Therefore, in order to support the plan, science education has been promoted to play a major role in developing people to learn competencies, to develop and create scientific knowledge and innovation, and to apply and utilize that scientific knowledge to innovate in the production and service sectors.

Furthermore, from individuals' perspectives, the Twelfth Plan has an aim for personal development, "to prepare Thai people of all ages to acquire the skills needed for a quality life in the 21st Century world" (Office of the National Economic and Social Development Board, Thailand, 2017 p. 81). The Twelfth Plan reflects concerns that rapid change in science and technology may affect people's quality of life (Office of the National Economic and Social Development Board, Thailand, 2017). Therefore, science education, in this respect, has a role in developing and enhancing people's scientific knowledge and skills in order to prepare them to be ready to manage current and future challenging situations. People with good quality science education could potentially make informed decisions on both personal problems and public issues requiring scientific knowledge and scientific thinking, for example, the Covid-19 pandemic, myths about natural phenomena, climate change, environmental issues, health problems, and using chemical products.

Therefore, science education is perceived as important in the Thai context, as it is thought that it can positively impact the economic, social status, and welfare of Thai people individually, and Thailand as a whole. Accordingly, quality science education is placed as one of the main foci in Thailand's education system.

Issues in Thai Science Education

Even though Thailand's educational policy highlights the importance of science education, there are concerns about science education in Thailand. Information from the Global Competitive Index showed that Thailand ranked 68th for skills of its current workforce, 66th for digital skills among its active population, and 89th in critical thinking among 141 countries (World Economic Forum, 2019). This information suggests that the knowledge and skills of Thai people, as a whole, are at a low level of competitiveness compared to other countries. This situation can be traced back to the education settings that nurture Thai people. Focusing on science education settings, unsatisfactory situations are found as mentioned in Chapter one. For example, Thai students showed low achievement in science at both national and international levels, and they also showed low performance in everyday Thai science classrooms.

Students' low performance could lead to problems for them individually and collectively in real world contexts. Kyllonen (2015) stated that "[T]he evidence is fairly clear that abilities measured by cognitive tests predict important real-world outcomes" (p. 124). Kyllonen (2015) made an argument by referring to many studies, for example, exploring correlation between aptitude test and grade (Thorndike, 1986 as cited in Kyllonen, 2015), admission tests and degree completion or research productivity (Kuncel & Hezlett, 2007), and cognitive ability and success in the work place (e.g., Robertson et al., 2010; Lubinski & Benbow, 2006; Marks, 2006; Park et al., 2013). The concept of consequence of students' low performance to their real-world context might reflect the context of science education. Students with a low level of achievement in science may perform poorly in real-world situations that require science knowledge and the ability to use that knowledge.

In the Thailand context, the current situation suggests that there are some serious problems with the Thai science education system. Those problems should be considered carefully and promptly to support the strategy of development of science and technology in the Thai national plan. Current Thai science education might not prepare Thai people to develop sufficient competencies to manage current challenging situations, and it might not support Thai people to improve their quality of life.

Management of the Science Educational Issues

The Thai government is concerned about the low level of achievement of Thai students in science and about issues regarding science education. In the Twelfth plan, it was stated, "the education system and science and technology personnel development are still Thailand's weaknesses" (Office of the National Economic and Social Development Board, Thailand, 2017, p.47). Specifically, the plan stated that:

> [A]lthough currently Thailand has focused mostly on the transition to a knowledge-based economy and society, based on science, technology, research, and innovation, the potential and capability of the country in these regards is still insufficient to develop the technology and innovations which target higher levels of production and service in order to propel the economy to high-income country status. (Office of the National Economic and Social Development Board, Thailand, 2017, pp. 48-49).

The Office of the Education Council, Thailand (2020) indicated that the roots of the issues regarding students' low performance in science can be traced back to the quality of curriculum that impacts instruction and assessment and, consequently, impacts the processes of learning and the quality of learners respectively. Accordingly, the Office of the Education Council, Thailand (2020) made a suggestion to reform curriculum, instruction, and assessment. Other concerns include the quality of Thai teachers and of the learning materials in Thailand's science classrooms. Strategies and projects from government organizations have been developed and implemented. Those are, for example, revising national science curricula, developing assessment tools and learning materials, developing a digital learning platform, supporting Science, Technology, Engineering, and Mathematics (STEM) education, promoting teaching and learning about Coding, and developing teacher training programs (see Office of the Basic Education Commission, Ministry of Education, Thailand [OBEC], 2020; Institute for the Promotion of Teaching Science and Technology, Thailand, 2020). However, and importantly, those strategies and projects are not too recent. They have been developed and implemented already in the education system for several years. For example, the science curriculum has been revised three times since 2001 (Bureau of Academic Affairs and Educational Standards, Ministry of Education, Thailand, 2020), STEM has been promoted since 2012 (Promboon et al. 2018), the digital learning platform have been developed since 2014 (IPST learning space, 2014), and the Training OBEC project that supports teachers (all subjects) to be trained in more than 1,500 certified training programs (OBEC, 2018) was developed, and more than 170,000 teachers and 270,000 teachers have participated in the project in 2017 and 2018 (OBEC, 2019).

Apparently, at this stage, there seems to be no noticeable change in students' performance. Both national and international results are still below average and below what is sought by the Thai government. The ongoing unsatisfactory students' performance suggests that the strategies that Thai government has applied to Thai science educational setting are not yet effective. The situation should be re-considered and analyzed to see if there are some hidden or overlooked problems. In addition, those strategies that have been implemented should be re-examined to seek to understand their impact and/or lack of impact. The projects and strategies to attend to Thai students' low performance can be analyzed as follows.

Firstly, the quality of science curricula can impact teaching and learning, as suggested by the Office of the Education Council, Thailand (2020). However, revising and developing a new curriculum without recognizing foundational issues could not alone resolve the problems in science education. The Thai science national curriculum has been revised and released in several versions in the past twenty years. Those versions include the 2001 version, the 2008 version, and the current 2017 version (Bureau of Academic Affairs and Educational Standards, Ministry of Education, Thailand, 2020). Each version of the national curriculum was developed in attempts to be an improvement on the previous one in several ways. For example, some of the changes involved clarifying learning outcomes (learning indicators) to teachers, setting expected students' competencies to meet international standards, updating scientific content knowledge (see Ministry of Education, Thailand, 2008; Office of the Basic Education Commission, Thailand, 2017). However, each curriculum was developed from the same foundation that focuses largely on content knowledge, with the secondary focus being on cognitive skills. Specifically, there is no evidence of any expected competency that focuses on students' learning capability or ability regarding learning to learn. Developing individuals' capability for learning to learn is essential in terms of supporting students to have flexible abilities to think, to have autonomy over their own learning, and to be lifelong learners. Students with the capability of learning to learn could increasingly control, manage, and improve their learning, and they could apply that capability to learn not only expected content knowledge or skills in a curriculum but also content and/ or skills related to external unfamiliar tasks that they might face.

Secondly, teacher training programs should be revised. A number of training programs are provided to Thai teachers. Most of them are aimed at improving teachers' science content knowledge, introducing new teaching practices, or fostering effective assessment tools. Most of those programs are concerned with what teachers should do to teach and improve their students content knowledge and skills and how to do this. There is no evidence of any training program having the aim of improving teachers' or students' capability related to learning to learn (see Office of Basic Education Commission, Thailand, 2018; Institute for the Promotion of Teaching Science and Technology, Thailand, 2020).

Thirdly, there are various issues in Thai science educational settings that need to be addressed. Wirussawa et al. (2016) surveyed 344 teachers in 344 school across Thailand and conducted case studies in three schools; they reported many issues including that,

> there was the learning management in accordance with the Core Curriculum of the Basic Education AD 2008 along with school curriculum but they were not used seriously in the instructional process. The curriculum was understood broadly, not specifically. The measurement and evaluation were done based on the curriculum on the learning substances in each semester followed by report upon the roles designated by agencies. The evaluation was also done through tests only. There were tests based on the learners' performance but the measurement seemed to be ambiguous, [and] not clear enough. The measurement was not diverse. The contents were not covered by evaluation based on the curriculum. (p. 241)

In relation to the various issues in science education setting as previously mentioned, relying only on support from government sectors for every issue may not be sufficient for improvement. Teachers should be supported to be able to manage the issues they are facing, seek useful resources, and ask for any help they are as necessary. In addition, they should also be supported to develop their own capabilities and dispositions for learning to learn in order to be autonomous for their own professional learning.

Fourthly, in order to improve students' learning, not only factors in the cognitive domain, but those in the non-cognitive domain should also be considered. Many studies have reported influences on students' learning from factors including, school-family interaction (Sadiku & Sylaj, 2019), informal learning (Tang & Zhang, 2020), prior achievement (Reynolds & Walberg, 1991), or home environment (Reynolds & Walberg, 1991). Furthermore, Carnell and Lodge (2002) indicated that situations in any classroom can be unpredictable. Teachers and students have their own purposes, aims, knowledge, and experiences. Learning interactions between teachers and students and students with each other can occur many times a day. In addition, teachers and students may face pressures in teaching and learning from many sources, for example, curriculum coverage, learning activities, teachers' competencies, students' emotion, educational policies from affiliated organizations, the culture of communities, expectations from parents, learners' emotions, and the general situation in society. In addition, context of students, teachers, and schools should be taken into account, for example, students with poverty, teachers with overload school works, or schools with lack of learning materials.

In summary, in order to improve the quality of science learning in Thailand, potential strategies should be explored in addition to the current ones. However, one strategy could not cope all the issues. It may be that each potential strategy might lead to attaining the educational goals.

A Call for Alternative Solutions for Thai Science Education

The previous section suggests that in order to improve Thai science education, there might be consideration given to students' capabilities regarding learning to learn. Specifically, those strategies could focus on the following:

(1) students should be prepared not only to be competent on what to learn and how to accomplish given tasks, but also to be competent regarding their own thinking and learning processes. Doing so, they might more likely apply knowledge in new challenges and new situations, and importantly, they might be prepared to be lifelong learners who could learn apply new material.

(2) teachers should be assisted to learn about their learning processes and learn to improve their teaching processes. Therefore, they might be able to be autonomous in improving their own professional knowledge, and they could model and support their students to be more competent in learning to learn.

(3) the curriculum and the academic system should allow and support students and teachers to have opportunities to develop capabilities related to those in (1) and (2) above.

(4) educational research related to 1-3 should be conducted to provide guidelines and foundation information for fostering these capabilities in both teachers and students. Specifically, the foundation information should also include information about complexity and sociological impact on readiness and support for development of (1) and (2).

Developing individual dispositions and skills for learning to learn is closely related to metacognition. Information about metacognition and its potential influences in education settings are discussed in the next section.

Metacognition

Definition and Frameworks

World organizations, for example OECD and UNESCO, highlight the importance of lifelong learning as a crucial capability that can assist people to improve and update their knowledge and skills in order to deal with changing situations now and in the future. They point out that educational systems should focus on improving this capability in learners (OECD, 2018; UNESCO, 2020; United Nations, 2015; World Economic Forum, 2020). One of the essential mechanisms for developing lifelong learners is ‘metacognition’; as the concept supporting development of the capability for learning to learn (Cornford, 2002; Evans, 2018; Quirk, 2014).

As mentioned previously in Chapter one, metacognition is considered as one of three essential keys for learning—the others being prior knowledge and conceptual knowledge (National Research Council, USA, 2005). Engaging their metacognition, learners can control their learning by focusing on and evaluating their learning goals and the processes by what they accomplish these goals (National Research Council, USA, 2005). Metacognition is not only important for learning but for teaching as well. The National Research Council, USA (2005) suggested that teachers should learn about metacognition in order to enhance their instruction to support students’ learning.

The term ‘metacognition’ was defined by Flavell (1976) as “one’s knowledge concerning one’s own cognitive processes and products or anything related to them” (p. 232) — ‘cognition’ refers to mental processes in gaining knowledge and understanding (Britannica, 2017; LEXICO, n.d.). Since Flavell’s definition, there have been many attempts to clarify, explain, and define metacognition. Flavell’s definition of metacognition centers on one’s knowledge or awareness of one’s cognition. Reeve and Brown (1985) referred to metacognition as an ability, and they added the dimension of regulating one's own cognition to their definition of metacognition. They defined metacognition as "individuals' ability to understand and manipulate their own cognitive processes" (p. 343). Fisher (1998) emphasized metacognition in terms of the capacity for thinking. He explained metacognition as a, "uniquely human capacity of people to be self-reflexive, not just to think and know but to think about their own thinking and knowing" (p. 2). Tobias and Everson (2009) focused on metacognition's role in learning processes and described metacognition as, "a higher-order, executive process that monitors and coordinates other cognitive processes engaged during learning, such as recall, rehearsal, or problem solving to name a few" (p. 108). In 2014, Proust described metacognition as, "a set of capacities through which an operational cognitive subsystem is evaluated or represented by another in a context sensitive way" (p. 1). This definition suggested that more than one capacity or process is constituted in metacognition. There are attempts to explain metacognition in simpler ways as well, for example, "knowing that one knows", "thinking about what one is thinking", or "monitoring and controlling of cognition" (Beran et al., 2013, p. 4).

As well as its concise definitions, many frameworks for metacognition are presented. Specifically, six major frameworks are described, as follows:

Flavell (1979) explained metacognition as consisting of two elements: metacognitive knowledge and metacognitive experiences. Metacognitive knowledge is awareness about one's knowledge focusing in three sub-categories: people, task, and strategy. Metacognitive knowledge refers to one's knowledge about self-cognition, e.g., being aware that one has a good memory; knowledge about other's cognition, e.g., being aware that one's friend is not good at remembering something; and knowledge about the universal nature of cognition, e.g, being aware that most people have a better short-term memory than long-term memory. Metacognitive knowledge about tasks refers to knowledge about assigned tasks and aspects related to these tasks, e.g., awareness about nature of the assigned task, the necessary information for doing the task, or the difficulty of the task. Metacognitive knowledge about strategy(ies) refers to knowledge about, for example, awareness of effective or ineffective strategies for accomplishing particular tasks. Flavell pointed that those three sub-categories are related to each other and could be combined for accomplishing a goal., Flavell referred to metacognitive experiences as affective experience related to one's cognition. He gave the example of a metacognitive experience as, "the sudden feeling that you do not understand something about another person just said" (Flavell, 1979, p. 906). A metacognitive experience could be referred to as a form of awareness of one's feeling, for example a feeling of knowing, a feeling of satisfaction, or a feeling of difficulty (Efklides, 2006).

Flavell (1979) emphasized self-awareness of one's own cognition and Baker and Brown in turn added the element of regulation into their model of metacognition. In 1984, Baker and Brown explained metacognition as being two separate components: knowledge about cognition and regulation of cognition. The knowledge about cognition refers to knowledge about one's own cognition and that of others including knowledge about learning situations, much like that suggested by Flavell. Regulation of cognition refers to processes about managing, controlling, and improving one's cognition including, "checking the outcome of any attempt to solve the problem, planning one's next move, monitoring the effectiveness of any attempted action, and testing, revising, and evaluating one's strategies for learning" (Baker & Brown, 1984, p. 354).

Jacobs and Paris (1987) conceptualized metacognition as consisting of two elements: self- appraisal of thinking and self-management of thinking. The self-appraisal of thinking was related to individuals' declarative knowledge, meaning one's awareness about the state and nature of cognition; procedural knowledge meaning one's awareness about thinking processes; and conditional knowledge being one's awareness about the conditions in terms of when and why to apply procedural knowledge. Self-management of thinking focuses on action generated from metacognitive knowledge; this category consists of planning, evaluating, and regulating self-cognition to reach a desired goal. In this framework, self-management of thinking has a similar meaning to regulation of cognition in Baker and Brown's framework. However, the element of self-appraisal of thinking expanded the meaning of metacognitive knowledge in Flavell's model and knowledge about cognition in Baker and Brown's model from awareness about state of one's own cognition, people, and tasks (declarative knowledge) to be aware more of potential processes to do things (procedural knowledge) and potential conditions that affect their cognition, people, or tasks (conditional knowledge).

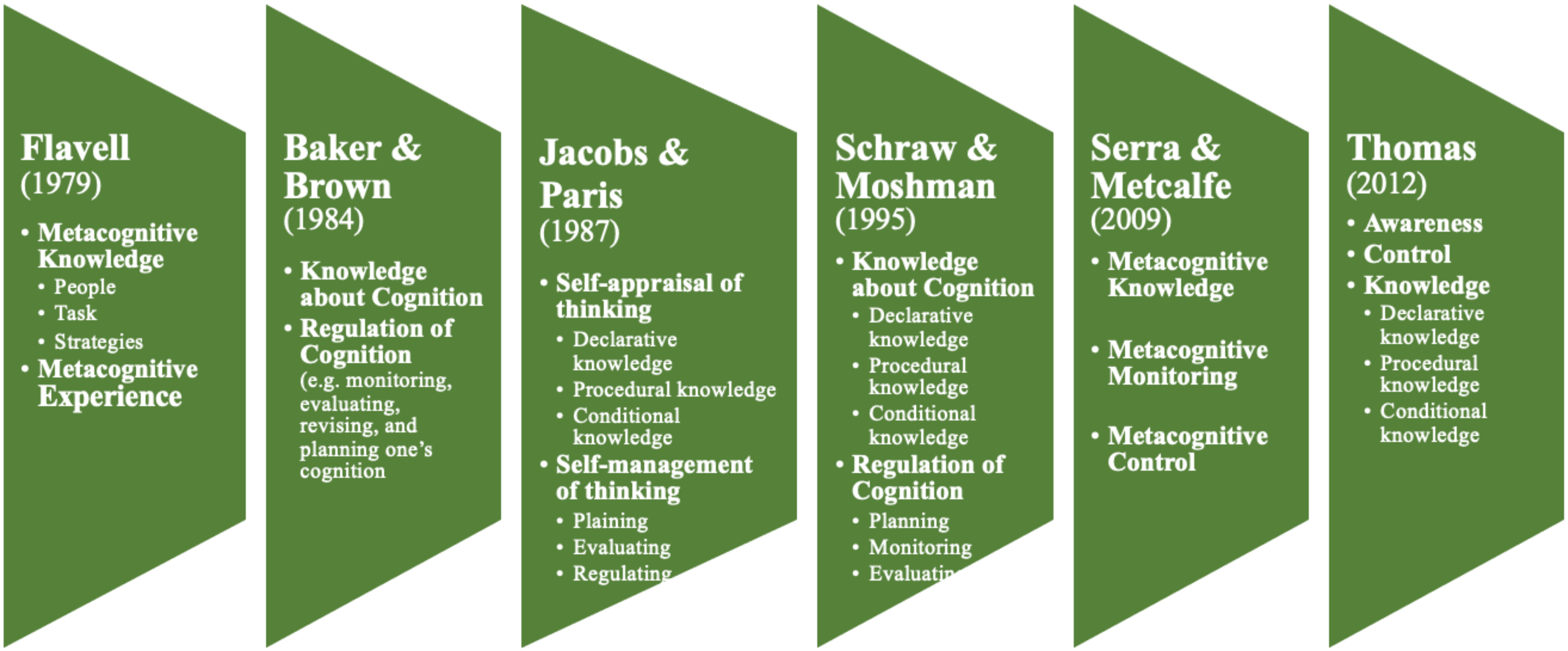
Schraw and Moshman (1995) described metacognition as consisting of two elements: (1) knowledge of cognition and (2) regulation of cognition. Although the names of the sub-components of metacognition in this framework are the same as Baker and Brown's, the content of the framework is similar to that of Jacob and Paris's. In this framework, knowledge of cognition is described as knowledge about one's cognition in general, and consists of three categories: declarative, procedural, and conditional knowledge. Schraw and Moshman (1995) explained that, "declarative knowledge refers to knowing "about" things. Procedural knowledge refers to knowing "how" to do things. Conditional knowledge refers to knowing the "why" and "when" aspects of cognition" (p. 352). Schraw and Moshman (1995) described regulation of cognition as, "metacognitive activities that help control one's thinking or learning" (p. 353). They divided the regulation of cognition into three categories: planning, monitoring, and evaluation.

Serra and Metcalfe (2009) presented a distinct framework for metacognition. They described metacognition as consisting of metacognitive knowledge, metacognitive monitoring, and metacognitive control. They explained that metacognitive knowledge refers to knowledge about a task, one's abilities to do the task, and strategies to accomplish the task; this feature aligns with Schraw and Moshman's knowledge of cognition. Metacognitive monitoring, which is distinct to other mentioned frameworks, refers to judgments of the quality of one's learning, and such judgements could be accurate or inaccurate. They suggested that to improve accuracy of the judgments involves expressing explicit bias, delaying judgment, considering results of past test performance, summarizing before making judgment, explaining about how to test the information, and creating test criteria (Serra & Metcalfe, 2009, p. 279-289). The third feature of metacognition in this framework, metacognitive control, refers to controlling learning, time, and strategies in the learning situation. In Serra and Metcalfe's framework, the precision of one's judgments of learning is emphasized (metacognitive monitoring).

Thomas (2012a) defined metacognition in terms of knowledge, control, and awareness, of one' own cognition. In his framework, metacognitive knowledge is categorized into three types. Declarative metacognitive knowledge refers to knowledge of one's own conceptualization of and state of thinking and learning, Procedural metacognitive knowledge refers to knowledge of one's own thinking and learning strategies. Conditional metacognitive knowledge refers to knowledge of one's own cognition condition and how it affects one's choosing of procedural metacognitive knowledge to achieve learning purposes. A summary of these frameworks is shown in Figure 2.1.

Figure 2.1

A Summary of Metacognition Frameworks



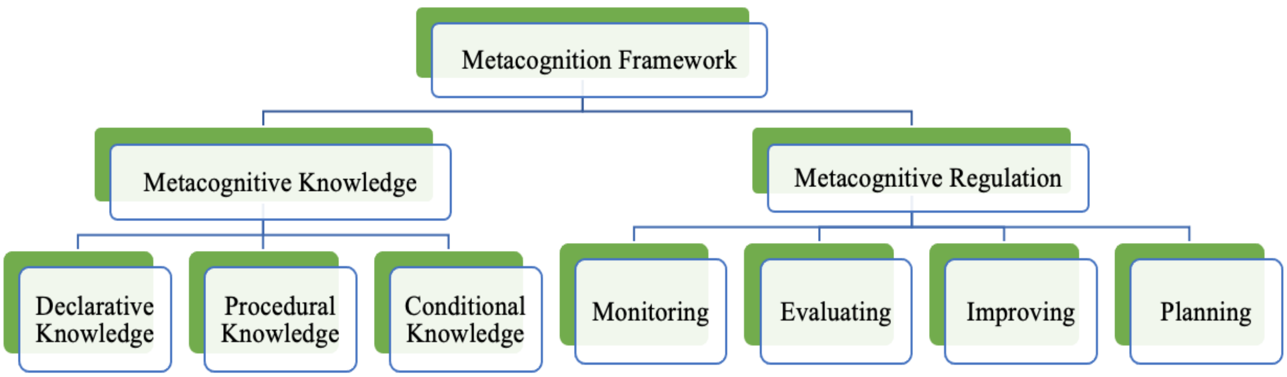
Although those six frameworks described metacognition use varying names and categories, the core components of metacognition are similar in each of them. There is a shared component about knowledge about one's own thinking about learning, for example, 'metacognitive knowledge' in Flavell's framework and Thomas's, and 'knowledge about cognition' in Baker's and Brown's. In addition, there is a component about controlling and managing one's cognition, for example, 'regulation of cognition' in Baker's and Brown's, 'self-management of thinking' in Jacobs's and Paris's, and 'metacognitive control' in Serra's and Metcalfe's, and Thomas's.

In addition, there is one further conception of metacognition proposed by Nelson and Narens (1990, 1994). They explained metacognition in terms of a theoretical mechanism of cognitive processes related to learning and memory. The theoretical mechanism was developed based on "three abstract principles of metacognition" (Nelson & Narens, 1990, p. 125). Those principles suggest that cognitive processes are evident at at least two levels: meta-level and object- level, and that these two levels are interrelated by the flow of information between them through two processes: metacognitive control and metacognitive monitoring. In this theoretical mechanism, metacognitive monitoring refers to a process by which that meta-level is notified by the object level about a current cognitive situation. Metacognitive control refers to a process that the meta-level controls the object-level as information flows from meta-level to object-level in order to initiate, continue, and terminate an action at the object-level. Nelson and Narens (1990) explained that metacognitive control and monitoring processes occur along three major stages: acquisition, retention, and retrieval of learning and memory processes. Metacognition from Nelson and Narens's perspective is interesting in terms of providing a theoretical relationship between cognition and metacognition, and a model of metacognition's mechanisms in one's learning and memory processes.

In this study, metacognitive knowledge (knowledge about one's cognition) and metacognitive regulation (regulation of one's cognition) are employed as the framework for metacognition as shown in Figure 2.2.

Figure 2.2

Metacognition Framework of this Study



These two categories are found in most of the frameworks in the literature and have been referred to in many studies about metacognition in and beyond science education (e.g., Akin et al., 2007; De Backer et al., 2012; Hargrove & Nietfeld, 2015; McKendree & Washburn, 2021; Teng, 2020; Schraw & Dennison, 1994; Stephanou & Mpiontini, 2017; Thillmann et al., 2013). In addition, those two categories attend to essential dimensions of learning that are knowledge about one's learning process and controlling these learning process. In the framework for this study, Metacognitive Knowledge refers to knowledge about one's cognition using three elements. Declarative metacognitive knowledge refers to knowledge about state of one's own learning ability and the nature of cognitive processes. Procedural metacognitive knowledge refers to knowledge about one's strategies of thinking and learning. Conditional metacognitive knowledge refers to knowledge of the how and when to choose procedural metacognitive knowledge depending on a certain learning situation. Metacognitive Regulation refers to managing and controlling one's own knowledge about one's cognition including being aware of (monitoring), evaluating, improving, and planning one's cognition.

Metacognition and Learning Science

Metacognition is an important feature in learning processes. Developing metacognition can improve one's learning, because when one knows their own strengths and weaknesses, one can manage their cognition with a given task, and such management can support their learning (Pintrich, 2002). In addition, students who are able to monitor and control their learning might be confident in their learning ability and continue to learn further complex concepts (Lundegerg & Mohan, 2009). On the other hand, students with maladaptive metacognition may hold misunderstandings of tasks without realizing it (Flavell, 1979), and lack essential experience to deal with, for example their exams (Karlen et al., 2014) and other learning tasks. For example, they may not notice if their thinking is consistent with a task's requirements. In addition, they might not be aware of their previous successful problem-solving processes and not use them to solve similar problems.

Much research has reported that as students' metacognition is improved, their performances are improved (e.g., Babbs & Moe, 1983; Bergey et al., 2017; Channa, et al., 2015; Gilbert, 2005; Kelley & Clausen-Grace, 2007; Liu & Liu, 2020; Schraw et al., 2006). Also, the development and enhancement of students' metacognition has a positive impact on those with low learning performance (Dirks-Naylor et al., 2019).

Much evidence supports the view that students who have adaptive metacognition show better outcomes in science performance. Rozencwajg (2003) conducted a study of 42 students in grade 7 in France. They found that students with adaptive metacognition show better problem-solving strategies in science tasks. In this study, Rozencwajg (2003) explored students' adaptive metacognition, for example, asking if students know differences between solving math problem and learning biology, or exploring if students have various strategies in learning in different situations. Next, students were assigned to solve four physics problems, then how students solved those problems were analyzed. The results suggested that students with higher level of adaptive metacognition, being aware of different learning strategies in different contexts or different situations, could solve the problems better.

Similar findings in science learning contexts have been reported across student levels, including elementary school, middle school, high school, and undergraduate levels. Positive impacts on science achievement have been reported in various fundamental educational contexts (e.g., DiBenedetto & Zimmerman, 2013 (51 high school students in USA); Georghiades, 2004b (60, 5th grade students in Cyprus); Ladawan et al., 2015 (40, 12th grade students in Thailand); Liu & Liu, 2020 (159 undergraduate students in USA); Sperling et al., 2012 (97, 7th grade students in USA); Topcu & Yilmaz-Tuzun, 2009 (941 elementary students in Turkey); Wu & Tsai, 2005 (69, 5th grade students in Taiwan). Undoubtedly, metacognition is important for learning science effectively.

Michalsky et al. (2009) conducted research into the influence of instruction that supports metacognition on students' performance in a scientific task. The results from 108, 4th grade students in Israel showed that students who learn within the instructions that support enhancing their metacognition after, before, and during reading scientific text showed higher performance on scientific tasks than students who did not receive the instruction. Zion et al. (2005) conducted a study of 407, 10th grade students in Israel that explored the effect of instruction to enhance metacognition on students' scientific ability and domain-specific scientific inquiry skills. The results confirmed the positive effect of the instruction on students' achievement. Similar results have been reported in many studies (e.g., Askell-Williams et al., 2012; Georghiades, 2004a, 2004b; Kaberman, & Dori, 2009; Thomas, & Anderson, 2014).

Science is a unique subject that has its own characteristics. The core aim of learning science is to understand the natural world 'scientifically' (National Research Council, USA, 2000) which is a view based on a rational orientation. Learning science involves both learning science content and the processes that help construct that knowledge (National Research Council, USA, 2000). People can learn science using various processes. One is to learn through scientific inquiry which is emphasized in science educational context in many countries including Thailand. Scientific inquiry has been embedded in Thailand's science national curriculum for students at all levels more than 20 years (see Ministry of Education, Thailand, 2001, 2008, 2017)). The National Research Council, USA (1996) stated, "scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). Learning science through scientific inquiry involves questioning the natural world, exploring possible explanations, searching for related evidence, formulating explanations based on the evidence, and evaluating and justifying explanation (National Research Council, 2000).

Students with adaptive metacognition can enhance their science learning in many ways. For example, they could be aware of their strengths and weaknesses in their process of learning science. They may recognize their strategies in identifying scientific evidence of given tasks or scientific problems. Or they could be more conscious of their thinking process when they formulate or justify scientific explanations. With more effective thinking and learning processes, they have the potential to learn science better.

The evidence of successful science learning as a consequence of enhancing metacognition in the learning context leads to considering learning environments that support developing and enhancing students' metacognition. White et al., (2009) stated, "perhaps our most important pedagogical goal in developing inquiry and metacognitive expertise is to transform students and classroom environments into [a] self-aware, self-improving systems" (White et al., 2009, p. 198).

Although adaptive metacognition can be found in students of any age (Baker & Brown, 1984), there is no guarantee that each student has metacognition that enables them to learn effectively. Karlen et al. (2014) conducted a longitudinal study to explore students' competency regarding metacognitive strategic knowledge (MSK) in high school students in Switzerland and found that students' competency in MSK had not changed through a single year. The finding suggests that students may be metacognitive, but their metacognition may not be developed enough or appropriately or continue to develop through them being in everyday classroom learning environments. Teachers should not assume that students are metacognitive. Therefore, in order to enhance students' metacognition, learning environments that attend explicitly to students' metacognition should be considered and developed carefully and systemically.

In order to develop more metacognitively oriented science classroom learning environments, important factors should be explored. Specifically, for this study, teachers are seen as having an essential role in establishing metacognitively oriented science learning environments.

Metacognition and Classroom Learning Environments

Classroom Learning Environments: A General Overview. The classroom learning environment is considered as an important factor influencing students' cognitive development and learning. "Changes in students' approaches to learning can be stimulated via changes to their classroom environments" (Thomas, 2013a, p. 1187). In addition, "[T]here is also a belief that a positive classroom environment promotes and motivates student interest in learning, hence leading to better cognitive and affective outcomes" (Fraser & Goh 2003, p. 465). Many scholars have tried to define what is meant by a learning environment. For example, Hiemstra (1991) explained that a learning environment consists of three dimensions: physical space (e.g., classroom design), psychological climate (e.g., students' emotion), and the social and cultural context that teachers and students face. This description is similar to the definition provided by the Great School Partnership (2013) that described a learning environment as "the diverse physical locations, contexts, and cultures in which students learn" (para 1.). In addition, Doppelt (2006) mentioned that methods of teaching, learning, and assessment should also be considered as part of learning environment. Kalyon (2020) added that learning environment should include interactions between teachers and students and between students and students including "what the teacher does to make the educational environment suitable for the student" (p. 156). From various definitions, it can be concluded that the term 'learning environment' refers to physical environments, context, cultures within which students are nurtured to learn including their interactions in the classroom, and also the ways that teachers facilitate learning.

Fraser (1998, 2012) considered learning environments at two levels: classroom level and school level. He stated that the school learning environment level refers to the climate of the whole school and educational management. In this study, the term 'learning environment' will be focused on the classroom level which involves the educational climate, activities, and interactions between classroom members, and will not include whole school climate or school management considerations. This is because the main focus of this research is on interactions between teachers and students in classrooms that could directly influence development of students' metacognition. In addition, learning environments in school level are also important that should be considered to be focused specifically in further research.

Research on learning environments was first started in the USA educational context more than 30 years ago, and the interest spread into educational contexts internationally (Fraser, 2018). Fraser (2012) explained that learning environments research is established based on the theory that "environment and its interaction with personal characteristics of individual are potent determinants of human behaviour" (Lewin, 1939, as cited on Fraser, 2012, p. 1192) and "the need for research strategies in which behaviour is considered to be a function of the person and environment" (Fraser, 2012, p. 1192). There is evidence from studies suggesting that the nature of a learning environment has a substantial impact student learning including in science education settings across grade levels and contexts (e.g., Allen & Fraser, 2007; Cairns, 2019, Chang et al., 2011; Cheung, 1993; Denson et al., 2015; Fraser, 1998; Gerber et al., 2001; Huffman et a., 2003; Thomas, 2003; Thomas & Anderson, 2014; Yildirim, 2020). There is evidence that learning environments influence learners' non-cognitive outcomes as well as cognitive outcomes. For example, the nature of learning environment can influence their epistemological beliefs, self-efficacy, and attitude (Khine et al., 2020; Tolhurst, 2007).

Several terms can be identified to describe good learning environments, for example, effective learning environment, positive learning environments, or optimal learning environments. Pickett and Fraser (2010) explained positive classroom learning environments as consisting of seven dimensions. Those dimensions involve, (1) “students know, help, and are supportive of one another”, (2) “teacher helps, befriends, trusts, and is interested in students”, (3) “students have attentive interest, participate in discussions, do additional work, and enjoy the class”, (4)“emphasi[zing] on the skills and processes of inquiry and their use in problem solving and investigation”, (5) “complet[ing] activities planned and focus[ing] on the subject matter”, (6)“students cooperate rather than compete with one another on learning tasks”, and (7) “students are treated equally by the teacher” (p. 322). Cantor and Gomperts (2020) proposed a model of an optimal learning environment for learners in general. Their model includes building positive relationships, establishing safety in both physical and emotional dimensions, supporting students’ wellness and readiness for learning, developing critical skills, mindset, and habits, filling with rich and flexible instructions.

In the early days of learning environments research, a quantitative approach (using questionnaires) was dominant (Fraser, 2012). Later, mixed-methods has been employed where qualitative methods have been used to gain more and varied information (Fraser & Goh, 2003). The qualitative methods employed are, for example, classroom observation, teacher interviews, and student interviews (Fraser & Goh, 2003).

Various types of instruments have been developed for learning environments research. Fraser (2018) stated that there were two questionnaires employed at the dawn of research into learning environments: *Walberg’s Learning Environment Inventory (LEI)* (Walberg & Ahlgren, 1970) and *Classroom Environment Scale (CES)* (Trickett & Moos, 1973). Later, several questionnaires were developed using, for example, the Science Laboratory Environment Inventory (SLEI) (Fraser et al., 1993) and Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991). Although many tools and methods have been using in the field of learning environments research, as there are various dimensions of learning environments, specific tools and methods could provide more accurate information for further developments of that learning environment.

Zandvliet (2018) summarized that learning environments could be differentiated according to three major dimensions: learning goals, roles of teacher and students, and roles of students and other students. Learning goals are, for example, focusing on the cognitive domain and/or the affective domain. The roles of teachers and students range between teacher-centered to student-centered. The roles of students are, for example, individual learning or collaborative learning. Fraser and Goh (2003) summarized that the focus of learning environment research could be considered around five dimensions: improving leaning outcomes, evaluating educational programs, exploring gender differences in learning, exploring across cultures and nations, and developing questionnaires (research tools).

In summary, classroom learning environments are considered crucial features that nurture learners. In order to enhance or improve students' learning and development, learning environments should be one of the dimensions to be explored and/or improved in relation to the development and enhancement of students' metacognition.

Metacognitively Oriented Learning Environments (MOLEs). As mentioned previously, research findings confirm that students who learn within metacognitively oriented classroom learning environment show better performance— the term Metacognitively Oriented Learning Environments (MOLEs) was defined in Chapter one. Thomas (2003) pointed to three characteristics of learning environments that support developing students' metacognition: discourse, language of learning, and social interaction. Thomas (2003) explained further that in MOLEs, discussion about learning and learning process should occur regularly between teacher and students and/or among students. Teachers should explicitly employ a language of learning in order to talk about learning and learning processes. Interaction (discussion about learning) between teacher and students, students and teacher, and students and students should occur regularly. The teacher should model thinking and learning processes to students. Students should have opportunities to reflect on their thinking processes and be supported to be autonomous in their thinking and learning, and students should have emotional support through the journey of developing their metacognition. Similar suggestions were found in a study by Branigan and Donaldson (2020) conducted in context of primary level. They stated that, "teachers must play a dual role-alternating between showing pupils what metacognition looks like (by modelling metacognition in response to pupils' initial reflections) and encouraging pupils to think about thinking themselves though elaborative questioning" (p. 12). They also pointed out that developing metacognition needs appropriate supports across time, and factors such as classroom culture and activity time are important to consider.

It can be concluded that teachers have major roles in positively influencing the metacognitive orientation of classroom learning environments. For example, teachers can model their thinking process to their students, employ language of thinking in their instruction, and/or encourage students to think about their own learning process. Therefore, in order to support the development of metacognitively oriented in science classroom learning environments, factors related to teachers should be focused on and explored.

Teachers' Metacognition and MOLEs

Social Constructivism posits that learning is developed through social interaction (Macblain, 2014). The Social Constructivism has assumptions that learning is a social process, and knowledge is a product of human activities (Kim, 2001). Learning and knowledge occur when individual interacts with each other, and are shaped by social and cultural context (Kim, 2001). Vygotsky, a leading social-constructivist theorist, stated that one's behavior changes according to the environment that one interacts with (Cole et al., 1978). Vygotsky's concepts focus on social and cultural factors that influence how people think, and he suggested that psychological tools (devices and procedures, for communicating and exploring the external world) are the most important things that people pass to others through social interaction (Snowman et al., 2012). Turner (1988) concluded that social interaction refers to, "a situation where the behaviors of one actor are consciously reorganized by, and influence the behaviors of, another actor, and vice versa" (p. 13-14). Karpov (2014) explained that, based on a social constructivist perspective, to improve students' learning we have to "exteriorize" psychological tools and present them to individuals explicitly. The target individual appropriates this tool and uses it initially in the same form of an external device as it was presented. Then educators have to orchestrate and monitor the process of the individuals' use and mastery of this tool. As the individuals increasingly master the tool, it gets internalized and turns into an internal element of the individuals' mental processes. In addition, Adam (2006) summarized principles of theory to practice in teaching and learning context based on Social Constructivism. Those principles suggest that (1) the focus in teaching and learning should center on learning not performance, (2) learners should be seen as active agents in constructing knowledge, (3) teachers should guide rather than instruct students to learn, (4) student should be engaged in learning task, and (5) assessment should be seen processes to elicit understanding.

Grounded on Social Constructivism, the teacher, as potentialy a more knowledgeable person in terms of metacognition, could model how they think and their learning processes explicitly to students. In addition, teachers could provide directions and opportunities for students to think about their own thinking, and give students advice related to their metacognition. Then, students could observe the thinking behavior, practice that kind of thinking, adjust it to their own thinking system and adopt, possibly with modifications, that way of thinking (and learning). Finally, students could have adaptive metacognition that leads to better learning and performance. Therefore, theoretically, teachers' metacognition is considered important in terms of developing students' metacognition within metacognitive orientation in classroom learning environments.

Research about teachers' metacognition and their views on the metacognitive orientation of their classroom learning environments is rare. However, there are some studies on students' views on metacognitive orientation in their classrooms (e.g., Chantharanuwong et al., 2012a; Thomas, 2003, 2006, 2013a; Thomas &Anderson, 2014). In terms of teachers' views, two studies are found in educational context of Turkey and the USA. Ozturk (2017) conducted a study with 30 language teachers at the university level in Turkey to explore he possible relationship between teachers' metacognition and their competency in enhancing students' metacognition in their classroom learning environments. They employed the Metacognitive Awareness Inventory, MAI (Schraw & Dennison, 1994) to assess teachers' metacognition, and they used teachers' self-reports and interviews to assess the teachers' competency related to instruction for metacognition. They found that only teachers who reported high and medium scores in the MAI showed the competency. They stated that, "one-third of the participants, who scored below 226 on MAI, could not show any evidence of integrating [instruction for] metacognition in their lesson plans even after PD [professional development]" (p. 257). In addition, Wilson and Bai (2010) explored 105 graduate students who were K-12 teachers in the USA and stated that "[T]eachers' understandings of metacognition appear to be related to their perceptions of the instructional strategies that assist students in becoming metacognitive" (p. 285).

Therefore, the available information suggests that teachers' metacognition could be an influence for their developing MOLEs. Teachers' metacognition may influence developing MOLEs directly, and teachers' metacognition might relate to their perceptions on MOLEs and then might influence how they might develop MOLEs. Accordingly, in order to promote the development and enhancement of MOLEs in science classrooms in Thailand's context, information about teachers' metacognition must be one of crucial factors that should be explored.

Teachers' Perceptions and MOLEs

A perception is defined in Merriam-Webster as "awareness of the elements of environment through physical sensation" (Merriam-Webster, 2020, para 3). It also refers to results of processing a given environment or situation (West, 2018). Perceptions are considered as being thoughts related to decision making, action, or behavior (Briscoe, & Grush, 2020; Creem-Regehr, & Kunz, 2010; Gençer, 2018; Hurley, 2001; Walberg, 1977). A perception is different from an opinion as an opinion is the results from a judgement or judgements. An opinion is made using information from people's perceptions, beliefs, etc. Opinion in Merriam-Webster refers to "a view, judgment, or appraisal formed in the mind about a particular matter" (Merriam-Webster, 2021, para 1).

"All behavior from the simplest to the most complex is organized around the control of perceptions" (Powers, 2016, p. 10). Perceptions are important in educational practice and research (Johnson, 1987; Lewis, 2001). Walberg, (1977) explained that teachers' perceptions can influence their intentions and their behaviors. Understanding people's perceptions could lead to understanding their related actions. In educational contexts, many studies have attempted to explore teachers' perceptions in order to understand specific situations, such as, teachers' perceptions on STEM education (Margot, & Kettler, 2019), trained and untrained teachers' perceptions on the role of media in classroom (Taiwo, 2009), or teachers' perceptions on their knowledge about expert teaching (Jegede et al., 2000).

In the context of considering learning environments, "[S]tudents' and teachers' perceptions of important social and psychological dimensions of the learning environments really matter in terms of educational outcomes" (Koh & Fraser, 2014, p. 158-159). Therefore, exploring teachers' perceptions of learning environments can be considered to be essential. Identifying classroom learning environments through students' or teachers' perceptions can be useful for gaining information that external observers overlook (Fraser, 2012, 2018). Many researchers have conducted research to study students' or teachers' perceptions of learning environments in order to provide information to improve teaching and learning (e.g., Anagün, 2018; Cook et al., 2011; Doppelt, 2006; Johannes et al., 2013; Lizzio et al., 2002, Maor & Fraser, 2005; Mueller et al., 2005; Tsai, 2003; Wong et al., 2006).

Furthermore, Fraser (1999, 2012, 2018) suggested that assessing perceptions of actual and preferred learning environments is beneficial. The information could be used as "a practical basis for planning environmental changes that will align the actual environment with students' or teachers' preferred environment" (Fraser, 1982, p. 518). Theoretically, teachers' perceptions of preferred and actual learning environment should be similar. If the two aspects are different, it could mean that there may be some reasons that cause any such difference.

Examples of research that explored teachers' or students' perceptions of their actual and preferred learning environments and provided information for improvements for the learning environments are as follows. Lee and Quek, (2018) explored preschool teachers' perceptions of actual and preferred learning environments of their classrooms (100 teacher participants in Singapore) and found significant differences between the actual and preferred environments. The results suggested that teachers required, for example, better relationship with coworkers, more chances in professional developments, and more supports to be innovative. The researchers concluded that, "the overall findings suggested ways to improve preschool learning environments" (p. 383). Wong et al. (2006) explored students and teachers' perceptions of actual and preferred learning environments in their computer-supported project work classroom (260 students and 26 teachers in Singapore). They found differences between perceptions of the actual and preferred learning environments for both teachers and students, for example, students preferred more accessible online materials, or teachers preferred more collaborating interaction on the web-based learning environments. The researchers discussed their findings and provided suggestions to improve computer-supported learning environments.

Information about science teachers' perceptions of MOLEs is scant. Yenice (2015) studied teachers' perceptions of metacognition regarding scientific processes in 336 pre-service teachers in Turkey. The findings suggested that those participants reported high levels of positive views of metacognition in context of scientific processes. However, this was only one piece of information that was in the Turkish context. In addition, no evidence about teachers' perceptions of their actual metacognitive orientation in classroom learning environments can be located. More information is needed accordingly, specifically in Thailand's educational context in order to support development of MOLEs.

In summary, in Thailand's context, information about teachers' metacognition and teachers' perceptions of their actual and preferred MOLEs are not evident in the literature. Such information could lead to understanding the situations of MOLEs in Thailand's learning environments and enhancing these environments. For example, teachers may report that they preferred MOLEs, but they may report lack of MOLEs in their actual learning environments. The differences between actual and preferred learning environments based on teachers' perceptions could lead to exploring factors that impact the differences. Finally, those factors could be highlighted for improvements further. In addition, as those elements of teachers' metacognition and dimensions of teachers' perceptions of actual and preferred MOLEs might be related. There is no research that has previously explored this. The findings regarding relationship between teachers' metacognition and their perceptions of actual and preferred MOLEs (if there is or there is not) could provide deeper understanding on those aspects situated in the field of metacognition research together with benefits further in developing metacognition and MOLEs.

Research on Metacognition in Thailand

The construct of Metacognition is not widely known of in the Thai educational context. According to the *Education Resource Information Center* (ERIC) and *Education Research Complete* database, there were only thirteen research articles under searching terms metacognitive or metacognition in title and Thailand in any field (EBSCOhost, 2020a). Compared to other research topics in education area, the number of published research papers about metacognition conducted in Thai context is low. The number of research papers conducted in Thailand educational context in various topics including metacognition identified in Education Resource Information Center and Education Research Complete Databases (2000-2020) is shown in Table 2.1.

Table 2.1

The Number of Research Papers Conducted in Thailand Educational Context in Various Educational Topics Found in Education Resource Information Center and Education Research Complete Databases (2000-2020)

Topic	No. of papers*
Metacognition	13
Inquiry	44
Problem based learning	18
Critical thinking	15
STEM	14

Note. *No. of papers from searching results of using topic term in the research title, for example, using metacognition or metacognitive for the topic about metacognition

This low number of research papers suggests that metacognition may not be considered sufficiently in Thailand's educational context. Moreover, the number is also low when compared to research papers on metacognition in other countries (see Table 2.2). Focusing on the science education context, the number of research papers on metacognition in this field in Thai educational context is very low. There are only two papers on research about metacognition in the science education context in the thirteen papers on research about metacognition in all fields. Although the low number of research papers on metacognition in the science education context could be found internationally (see Table 2.2), the low number of the research in Thailand educational context is concerning.

Table 2.2

The Number of Research Papers Conducted in Thailand and Other Countries about Metacognition in General Domain and Science Domain in Education Resource Information Center (ERIC) and Education Research Complete Databases (2000-2020)

Country	No. of papers about metacognition*	No. of papers about metacognition in science education context**
Thailand	13	2
Canada	148	12
USA	328	37
England	200	11
Singapore	28	0
Taiwan	72	7
Turkey	247	41
Israel	73	7

Note. *No. of papers using searching term Metacognition or Metacognitive in title

**No. of papers using searching term Metacognition or Metacognitive in title and science in abstract

Focusing on the Thai context, the summary details of 13 research papers on metacognition are shown in Table 2.3 (EBSCOhost, 2020a). The majority of the research papers are in the language education setting; the two research papers on science education are focused on improving students' learning (Ladawan et al., 2015; Rahmat & Chanunan, 2018). There is only one paper conducted in Teacher domain which is in early childhood setting not in science education setting.

Table 2.3

The Number of Papers about Metacognition in Various topics Conducted in Thai Educational Context in Education Resource Information Center (ERIC) and Education Research Complete Databases (2000-2020)

Topic	No. of paper
Learning science (Ladawan et al., 2015; Rahmat & Chanunan, 2018)	2
Learning language (reading, writing, etc.) (Akkakoson, 2012; Bell, 2008; Bell, 2011; Jirapa Abhakorn, 2014; Phaiboonnugulkij, 2018; Seedanont & Pookcharoen, 2019; Tanewong, 2019; Wichadee, 2011)	8
Testing (Phakiti, 2016)	1
Learning mathematics (Duangnamol et al., 2018)	1
Early childhood teachers' metacognition (Thienngam et al., 2020)	1

Besides the mentioned databases, research about metacognition in Thailand's context could be found additionally in Google scholar and academic databases in Thailand. Focusing on Google scholar database the number of studies about metacognition in Thailand centered in science learning or teachers is found for six additional papers (Google scholar, 2020a) (Chantharanuwong et al., 2012a, 2012b; Janjai, 2012; Park & Prommas, 2017; Rompayom et al., 2010; Sanium, & Buaraphan, 2019).

Furthermore, focusing on the Thai databases, the *Thai Journals Online* database collects data on academic journals published in Thailand in all disciplines including science and technology, social science and humanities; there were 866 journals and 158,346 articles in the database. The number of papers about metacognition in this database was 32 articles (Thai Journals Online, 2020). The majority of the papers focus on instruction for enhancing metacognition or strategies to improve students' learning or achievement, especially in the mathematics context. There were six articles of metacognition research conducted in the science context, and all of them focus on students. The summary details could be found in Table 2.4.

Table 2.4

The Number of Research Papers about Metacognition Conducted in Thailand Educational Context in Thai Journals Online database

Topic	No. of Papers
Using metacognitive instruction to improve learning/performance/ ability of:	
Mathematics (Boonchan et al., 2015; Kudhom et al., 2019; Ponsim & Pavaputanon, 2011; Riyapan et al., 2019; Ruenrom & Pavaputanon, 2011; Saeaw & Luenam, 2013; Srihamart, & Heangraj, 2009; Sruangsomboon et al., 2019; Wijitklang & Kritkharuehart, 2020; Xaysombath, 2017; Yamgleb et al., 2016)	11
Problem-solving ability (Intharaksa et al., 2018; Pannao, & Charoen-In, 2020)	2
Reading ability (Jankong et al., 2019; Loicharern & Chamnankit, 2014; Phanprom & Kaewurai, 2019; Sangkri, 2017; Thongpo & Khanto, 2007)	5
English language (Chansangsri & Raksasat, 2015; Phoonsavat, & Thipatdee, 2019; Rojanabenjakun et al., 2018)	3
Health science (Boon-asa et al., 2017)	1
Science and Scientific thinking (Boonsit et al., 2018; Kliangklin, & Pavaputanon, 2014; Mudcharoen & Limyingcharoen, 2011; Neangchompol & Wijakkanalan, 2010; Pannao & Ruangsuwan, 2013)	5
Enhancing/ exploring students' metacognition in context of:	
Science (Martsalee & Ruangsuwan, 2018)	1
Project based learning (Palacheewa et al., 2017)	1
Innovation and technology course (Palacheewa & Chunlasewok, 2015)	1
Nursing students (Patharasatjathum, 2016)	1
Mathematics diagnostic test based on metacognition (Nuntapanich et al., 2013)	1

Considering the research into metacognition in science education settings in Thailand from all databases, the key findings could be concluded as follows.

Firstly, it has been found that students who were instructed to develop their metacognition showed higher performance. Ladawan et al. (2015) found that students achieved higher performance in environmental science knowledge after they were instructed through a "good science thinking moves method" approach (p. 1848). This method consisted of teaching learning processes, for example inquiry, reflection, and opinion comparison with metacognition techniques. They explained that the metacognition techniques involved guiding students to think about their thoughts and discuss and share with peers. The participants were 40 students in 12th grade level. Similar findings are found in Mudcharoen and Limyingcharoen's (2011) research. They studied the influence of metacognitive strategies on 34, 11th grade students in context of learning physics.

Secondly, students' metacognition was found to be insufficient for high performance. Chantharanuwong et al. (2012a) explored students' metacognition regarding learning about nuclear energy. The participants were 219 students in grade 11th -12th. The results suggested that students had insufficient metacognition, as most of them could not explain how they think, know, and learn in context of learning about nuclear energy.

Thirdly, teachers and preservice teachers' metacognition could be improved after they were trained in professional development programs or workshops about metacognition. Thienngam et al. (2020) aimed to develop early childhood teachers' metacognition. They explored the training of 60 early childhood teachers on the "Metacognitive Development Project" (p. 24). The project consisted of learning activities and learning materials designed for developing the teachers' metacognitive knowledge and regulation. They found that the teachers' metacognition was enhanced significantly, and they also found that the education background, supports, attitudes towards pedagogy, and self-efficacy affect teachers' metacognitive skills (Thienngam et al., 2020).

Fourthly, some teachers were found to improve their teaching abilities after they had been trained in programs using metacognitive strategies. Janjai (2012) employed an instructional model based on constructivism and metacognition to improve preservice students' ability to design lesson plans. The findings from 18 preservice students showed that the quality of their lesson plans was improved. Park and Prommas (2017) explored using a technique called 'metacognitive reflection' to improve teachers' pedagogical reasoning in instruction on science, technology, engineering. and mathematics education (STEM). The participants were 23 teachers who trained in a professional development. The results showed that metacognitive reflection could improve some teaching abilities. Park and Prommas (2017) explained that metacognitive reflection led teachers to think about what it means to learn STEM and how they learn STEM, and that knowledge could assist them to learn to teach students to learn STEM in more logical and meaningful ways.

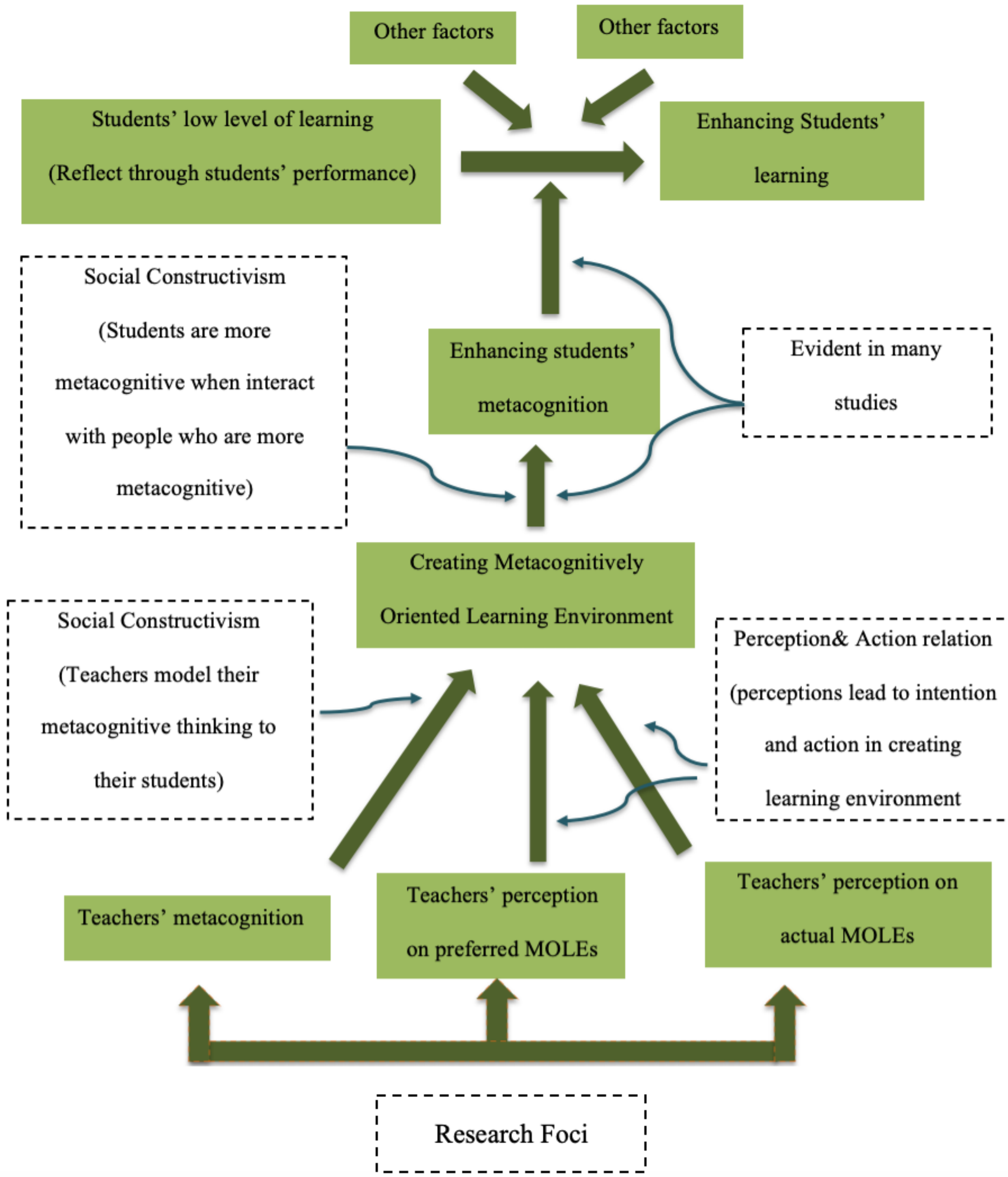
Fifthly, Chantharanuwong et al. (2012b) employed the Metacognitive Orientation Learning Environment Scale-Science (MOLES-S) (Thomas, 2003) to explore students' perceptions about the metacognitive orientation in their science classroom learning environments. The participants were 1,376 students in10th -12th grade level. The mean score of all items was 3.59/5.00. However, regarding the dimension of 'Distributed control' that refers to students having autonomy to plan their learning in science classrooms, the average score from the study was found to be lower than other dimensions; the average was lower than 2.50/5.00. They also found that there was no significant difference of metacognitive orientation of the classroom between schools, grades, genders, and ages. The findings were drawn from students' perceptions at the upper secondary school level. More information is required. For example, findings from more studies are requires to confirm or disconfirm the results, or findings from teachers' perceptions are requires to understand learning environments from teachers' views.

Sixthly, research in metacognition in Thailand has been focused largely on students, and there is much less research on teachers. Sanium and Buaraphan (2019) reviewed metacognition research conducting in Thailand context during 2001-2016 from the Thailand Library Integrated System (ThaiLIS) database. Twenty-two studies under the heading of basic education (K-12) were found. They organized the studies into five categories, and they reported that most populate categories related to research about impact of one's metacognition on one's capabilities, for example, critical thinking, problem solving skill, and instruction for improving metacognition. They stated that most of the research focused on students, and they suggested metacognition research in Thailand should focus more on preservice teachers or practicing teachers. The findings from Sanium and Buaraphan (2019) reflect the information in Table 2.4 as there was only one study about metacognition on teachers (ThaiLis database focuses on thesis or research report, but Thaijo database, as the resource for information in Table 2.4, focuses on articles that published in Thai journals).

The information from research findings on metacognition in Thailand confirms the positive influence of students' metacognition to their performance. However, more information is required, especially information related to teachers' metacognition and developing learning environments to enhance students' metacognition. In summary, this research is based on the theoretical orientation as in Figure 2.3.

Figure 2.3

Research Theoretical Orientation Diagram



In order to improve Thai students' science performance, alternative and effective teaching strategies to develop and enhance their metacognition are needed. The literature has shown that students who learn within metacognitively oriented science classroom learning environments can show better performance in science learning. Therefore, developing the metacognitive orientation of the science classroom learning environments should be focused as one crucial strategy. Available information from educational theory and research suggests that teachers' metacognition and their perceptions of their preferred and actual metacognitively oriented science classroom learning environments may relate to the development of such metacognitively oriented learning environments. In addition, teachers' metacognition may relate to their perceptions of their preferred and actual metacognitively oriented learning environments.

However, information about teachers' metacognition and perceptions of their preferred and actual MOLEs in both international and Thailand educational contexts is scarce. Especially, there was scarce information about how teachers' metacognition including elements of metacognition relate to MOLEs. Therefore, it is crucial and necessary to conduct research to explore these matters. The findings from such research might be beneficial not only in the Thai educational context but in educational contexts internationally. The information about any relationship about teachers' metacognition and their perceptions related to MOLEs (if any) could be considered in attempts to foster developing MOLEs in science classrooms internationally.

In educational contexts internationally, the number of research studies about metacognition in science education disciplines is low compared to other fields. For example, from the same databases as mentioned before, Canada has only 12 articles about metacognition in science education settings, metacognition in all settings at 149, and educational research on inquiry-based learning at 633 (EBSCOhost, 2020b). Similar trend was found in other countries as shown in Table 2.2. This present research on metacognition, even though it was conducted in the Thailand educational context, is hoped will generate more knowledge of metacognition in educational contexts overall.

From information presented above, this research was conducted to find explanations of the questions as follows.

1. What are Thai lower-secondary science teachers' self-reports of their metacognition?
2. What are Thai lower-secondary science teachers' perceptions of their actual and preferred metacognitively oriented science classroom learning environments?
3. Is there a relationship between Thai lower-secondary science teachers' metacognition and their perceptions of their actual and preferred metacognitive orientations of their science classroom learning environments?
4. How do Thai lower-secondary science teachers explain any similarities and differences between their preferred and actual metacognitively oriented science classrooms?

CHAPTER THREE

METHODOLOGY

In this chapter, information about the research methodology is organized into nine sections. The information about the research context is first to provide readers with an understanding about the educational system, science teachers, and learning science in the Thailand context. The sections following outline the research design. Then research methods are introduced, including processes used to develop the of research instruments in the pilot and main studies. Then, research sampling is presented. Next, information about how data were collected and analyzed is provided. The next part explains about how the research quality was established and how the research was conducted ethically. Limitations and delimitations of the research are presented at the end of this chapter.

Research Context

The study was situated in the Thai educational context. To provide an understanding of the context, information about the Thai system and its students, science teachers, and science curriculum are presented.

Thailand's formal education is divided into five major levels: kindergarten, primary education (grades 1-6), lower-secondary education (grades 7-9), upper-secondary education (grades 10-12), and tertiary education. Vocational education starts at the upper-secondary level. Compulsory education in Thailand is nine years, from the 1st grade to 9th grade (Office of the Education Council, Thailand, 2018a). According to information collected in 2017, more than

98.8% of the population aged 6-14 years was in compulsory education, and around 95% of the population aged 6-18 years old was in formal educational settings (Office of the Education Council, 2018a). This information suggests that most of Thailand's younger generation are in the education system. The Thai educational system has a major role in nurturing Thai citizens.

The National Statistical Office, Thailand (n.d.) reported that in 2018 the number of Thai students in 1st -12th grade was about nine million students, and there were around 38,000 schools and 700,000 teachers across the country. However, from the same data base, there is no information specifically about the number of science teachers.

There are two educational pathways to become a science teacher in Thailand. Science teachers can graduate from a faculty of education with a science major, or they can graduate from a faculty of science and then take a diploma program in education. However, science teachers in primary schools generally graduate from a general education major program, and teachers in primary schools are trained to teach every subject in their assigned teaching level. Besides their formal education, science teachers in Thailand can receive professional development from various sources including their school, district, the private sector, universities, or governmental organizations.

Science is one of the compulsory subjects for students from 1st to 10th grade. It is an optional subject for students in 11th and 12th grade where it is divided into specific subjects, for example, chemistry, biology. Science teachers can be found in all schools in Thailand, and all Thai students have the opportunity to learn science and interact with science teachers for at least the nine years of their compulsory education.

According to Thailand's science national curriculum, *Indicators and basic core curriculum: Science (Revised 2017) based on basic education core curriculum 2008, (*Ministry of Education, Thailand, 2017), Thai science teachers should facilitate students learning of science content in four strands including biological science, physical science, earth and space science, and technology. In addition, scientific inquiry is promoted as the important approach for teaching science.

Research Design

This research was designed based on a pragmatic worldview, as it centers on seeking research results, gives priority to research questions rather than research methods, and uses various methods to collect data to seek answers to the research questions (Creswell & Creswell, 2018). A mixed - methods approach with a "convergent design" (Creswell & Plano Clark, 2018, p. 65) was adopted. The mixed - methods approach combines quantitative and qualitative methods to provide in-depth explanations regarding the matters explored in the research questions (Creswell & Creswell, 2018; Johnson et al., 2007; Leech & Onwuegbuzie, 2009). The convergent design refers to a design in which the data from quantitative and qualitative are brought together to compare or combine (Creswell & Plano Clark, 2018). Creswell and Plano Clark (2018) explain a convergent design as follows:

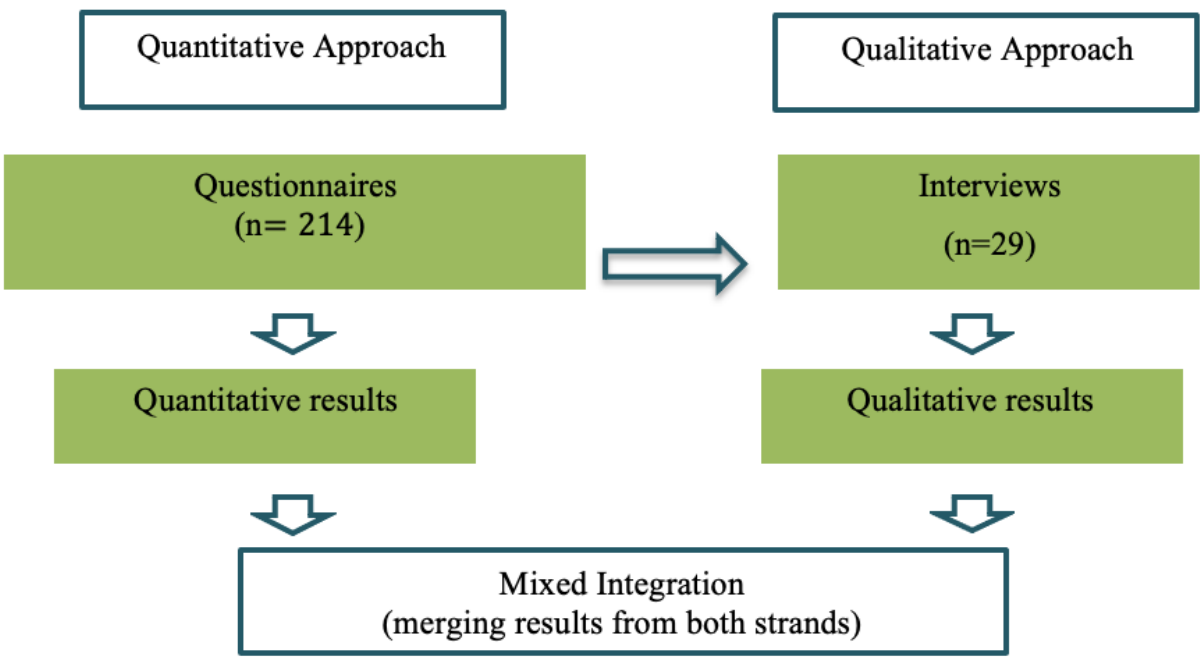
> [T]he basic idea is to combine the two results with the intent of obtaining a more complete understanding of a problem, to validate one set of finding with the other, or to determine if participants respond in a similar way if they checked quantitative predetermined scales and if they are asked open-ended qualitative questions. (p. 65)

This design has been adopted in many studies including those in educational contexts (e.g., Ata & Cevik, 2019; Balantekin, 2020; Saeed & Ali, 2019; Sewagegn, 2019; Ünlü, 2018) and in the field of metacognition (e.g., Innali & Aydin, 2020; Ozgelen, 2012; Pratt & Coleman, 2020; Schafer-Mayse, 2015; Thomas & Anderson, 2014; Wang, 2015).

In this study, two sets of questionnaires were employed in the quantitative phase. The first collected data about teachers' metacognition, and the second collected data about teachers' perceptions of the metacognitive orientation of their actual science classroom learning environments. In the qualitative phase, selected teachers from the quantitative phase were interviewed to explore their metacognition, and their' perceptions of their actual and preferred MOLEs. Data from both phases were analyzed and interpreted. Finally, findings from quantitative and qualitative phases were combined and compared to answer and explain answers to the research questions. The research design diagram is shown in Figure 3.1.

Figure 3.1

Research Design Diagram



Research Methods

In this section, methods for assessing teachers' metacognition and teachers' perceptions of their actual and preferred MOLEs are explained. Then, the selected methods, questionnaires and interviews are reviewed. In the questionnaire section, the processes of questionnaire development are described.

Methods in Metacognition Research

Metacognition is an internal process that occurs within an individual. Therefore, assessing metacognition in terms of its existence, level, or characteristics requires careful consideration. From reviewing research papers, methods for assessing metacognition could be categorized according to at least three criteria: the nature of the methods, the person who performs the assessment, and online-offline methods.

Firstly, the methods could be qualitative, quantitative, or mixed methods. Qualitative methods employed are, for example, interview (Hughes, 2017), reflection analysis (Wu et al., 2020), observation (Bene, 2014), and think aloud protocols (Meijer et al., 2012). The quantitative methods are, for example, using inventories, questionnaires, or rating scales (e.g., Cooper, & Sandi-Urena, 2009, Hughes, 2019; Settanni et al., 2012; Sungur, 2007; Thomas et al., 2008). Qualitative and quantitative methods could be mixed together for seeking information about individuals' metacognition (e.g., Desoete, 2008; O'Bryan & Hegelheimer, 2009).

Secondly, assessing metacognition could be done by self-report where participants provide information about themselves (International Encyclopedia of the Social Sciences, n.d; Paulhus & Vazire, 2007) or other-reports where other persons give information about participants (International Encyclopedia of the Social Sciences, n.d.). For example, learners could use a questionnaire to rate their activities reflecting their metacognition (e.g., De Backer et al., 2012; Ozgelen, 2012; Zhang et al., 2015) or observers could observe learners' behaviors in classrooms to assess learners' metacognition (e.g., Antonio, 2020; Blank, 2000; Zohar, 1999).

Thirdly, online and offline method can be used to characterize methods. Online methods are employed during doing a task, and offline methods are employed before or after an activity (Veenman et al., 2006). Online methods are, for example, logfile registration via digital activity (e.g., Li et al., 2015), think aloud protocols (e.g., Meijer et al., 2012; Sonnenberg, & Bannert, 2019), or observation. Offline methods are, for example, interviews or using questionnaires.

Each method for assessing metacognition has both advantages and disadvantages. Quantitative methods, for example questionnaires, provide overview information, require less time and cost, and can be used to collect data from large sample of participants (Veenman, 2011). Questionnaires are often used in metacognition research as they are practical and time efficient (Schellings & Van Hout-Wolters, 2011). Qualitative methods, for example interviews, can provide insightful information; however, the method requires time to collect and interpret data (Hughes, 2019). Self-report methods, for example using questionnaires, require consideration of whether participants might hold inaccurate perceptions of their activities and their thought processes (Schellings, & Van Hout-Wolters, 2011) or give responses in more than accurate, positive way (Veenman, 2011). In addition to self-report methods, Craig et al. (2020) conducted a meta-analysis research of 22 research articles to explore the use of self-report methods use in research about metacognition (e.g., questionnaire, self-report question in a task, self-report in interview). They concluded that "Current self-reports can provide a general overview of [metacognitive] knowledge and regulation skills" (p. 370). Other-report methods, for example observation, have flaws involving inference as there might be some disconnect between participants' external performances and internal processes (Hughes, 2019).

When using online methods, for example think-aloud protocol, participants may not be able to talk about all their emerging thoughts (Veenman, 2011), and logfile registration methods may collect data through participants' behavior, but may not be able to collect data about participants' thinking activities (Veenman, 2011). Offline methods, for example questionnaires or interviews, may be impacted by memory limitations, as the methods are employed to explore activities in the past (Veenman, 2011). In addition, Thomas (2013b) stated, "[T]he interview itself and the ideas students are asked to consider can stimulate students' contemplation and reflection about their thinking and learning processes" (p.9). Using offline methods such as, questioning in interviews or questionnaires may lead participants to think about their thinking processes that they may not think about before, and give responses based on their emerging thoughts. For example, participants may not have metacognitive knowledge about their learning strengths and weaknesses before. However, when they are asked about theirs, they may think about their strengths and weaknesses, and give responses accordingly. Therefore, researchers should be acknowledged about this when they choose the offline methods to assess participants' metacognition.

Further, there are inconclusive results from studies using those online and offline methods. Veenman et al. (2006) claimed that online methods seem to have more relationship to learning performance than offline methods. On the contrary, Saraç and Karakelle (2012) concluded that online and offline methods may assess different constructs. They considered that online and offline methods both have potential to assess valuable data. Sarac and Karakelle (2012) made the conclusion based on their research that explored the relationship between two offline methods (teacher rating scale and questionnaire) and two online methods (think aloud protocol and accuracy ratings of text comprehension).

Azevedo (2020) mentioned that methods such as self-report questionnaires, interviews, and observations have been using widely in metacognition research in the past decade. In addition, using more than one method to assess metacognition is often suggested (Azevedo, 2020; Saraç & Karakelle, 2012; Veenman et al., 2006).

In conclusion, as this research was conducted during the Covid-19 pandemic, online methods were considered to be inappropriate. It was impossible to access the classrooms of teachers and students. Accordingly, this research employed two offline methods to assess science teachers' metacognition and science teachers' perceptions of their metacognitively oriented learning environments in their science classrooms: questionnaires (a survey method) and interviews. Combining the advantages of the two methods, it was thought would lead to both in-depth and overview information and findings.

Specifically, there were two questionnaires developed and used in this study: a questionnaire for assessing science teachers' metacognition (Mc questionnaire) and a questionnaire for assessing science teachers' perceptions of the metacognitive orientation of their actual science classroom learning environments (ActualMOLEs questionnaire). The processes of developing and qualifying the questionnaires are explained in the next section. Then, the interview method used in this research is reviewed. A summary of methods used in this research is shown in Table 3.1.

Table 3.1

A Summary of Methods/Instruments Used in This Research for Assessing Teachers' Metacognition, and Teachers' Perceptions of Their Actual and Preferred MOLEs

Methods	Quantitative Strand (Survey)	Qualitative Strand (Interview)
Teachers' Metacognition	Questionnaire for Assessing Science Teachers' Metacognition (Mc questionnaire)	Interviews
Teachers' Perceptions of Their Actual MOLEs	Questionnaire for Assessing Science Teachers' Perception of the Metacognitive Orientation of Their Actual Science Classroom Learning Environments (ActualMOLEs questionnire)	Interviews
Teachers' Perceptions of Their Preferred MOLEs	–	Interviews

The Questionnaire for Assessing Science Teachers' Metacognition.

In this study, a questionnaire for assessing science teachers' metacognition was developed. The literature was reviewed to provide the rationale for developing a new inventory.

The inventories for assessing one's metacognition in educational context are summarized in Appendix A. The majority of these inventories were developed for assessing students' metacognition, for example, Metacognitive Reading Awareness (Chen, et al., 2009), Physics Metacognition Inventory (Taasoobshirazi et al., 2015) or Self-Efficacy and Metacognition Learning Inventory—Science (Thomas et al., 2008). Five inventories for assessing teachers' metacognition were identified in the literature. Of the five, three are domain-general (e.g., Metacognitive Awareness Inventory for Teachers (MAIT) by Balcikanli, 2011). The other two are for English teachers and for teachers in supporting students' metacognition. There is no inventory developed specifically for assessing science teachers' metacognition related to their science learning processes. Therefore, this research fills a need for such an instrument.

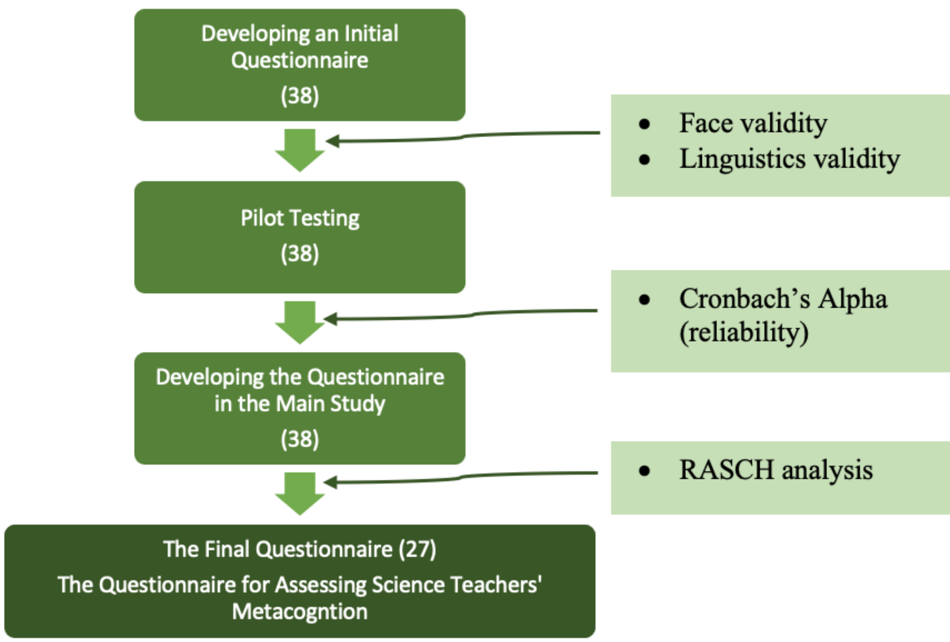
In addition, seventeen research papers related to exploring science teachers' metacognition were located in ERIC and Educational Research Complete database from 2000-2023 (EBSCOhost, 2023). Participants of all of these studies were preservice students. Ten of these studies employed the Metacognition Awareness Inventory, MAI (Schraw & Dennison, 1994), or translated versions of the MAI for assessing metacognition (e.g., Bedel, 2012; Celiker, 2015; Pantiwati & Husamah, 2017; Psycharis et al., 2014; Tosun & Senocak, 2013; Yildiz & Akdag, 2017). Although the Metacognitive Awareness Inventory (Schraw & Dennison,1994) has been recognized widely in educational context (according to Google scholar search, the article was cited over 4,000 times (Google scholar, 2020b), and the elements of metacognition in the inventory include knowledge of cognition: declarative, procedural, and conditional knowledge, and regulation of cognition: planning, information management, monitoring, debugging, and evaluation (Schraw & Dennison,1994), the inventory was developed for assessing adults' metacognition in the general domain.

Kelemen et al. (2000) stated, "differences in metacognitive accuracy are routinely demonstrated between groups as a function of task demands and altered physiological states" (p. 103). Therefore, this researcher considered that one's metacognition could differ according to task, activity, or subject as suggested by Flavell (1979). As science is a subject that has its own characteristics, learning science requires some distinct processes as well (National Research Council, USA, 2000). Assessing the metacognition, in this case, of science teacher with a domain specific inventory could provide more precise information on their metacognition as it related to their learning of science.

Therefore, a new inventory, a questionnaire for assessing science teachers' metacognition in area of learning science, was developed. As it was a new inventory, many processes for developing the questionnaire were employed to establish questionnaire's reliability and validity. A summary of processes in developing the Mc questionnaire is shown in Figure 3.2.

Figure 3.2

A Summary of Processes in Developing the Questionnaire for Assessing Science Teachers' Metacognition



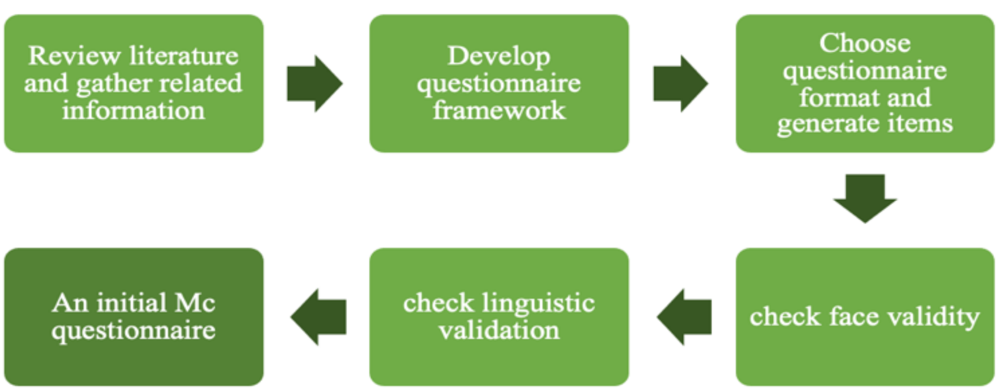
Note: a number in () is the number of items in the questionnaire used in that stage

The processes of developing Mc questionnaire started with developing an initial questionnaire. Then the initial questionnaire was tested in a pilot study. Next, the questionnaire was developed further for the main study of this research. In the main study, Rasch analysis was adopted to examine questionnaire responses, and the results were employed to develop the final Mc questionnaire. The number of items in the initial Mc questionnaire was 38, located in seven subscales. The, number of items in the final Mc questionnaire, as constructed in the main study, was 27 in three subscales. The details of developing the Mc questionnaire are explained in the following section.

Developing an Initial Mc Questionnaire. Several steps have been suggested for developing any questionnaire including: identifying the questionnaire's purpose, reviewing related literature, gathering and synthesizing related information, developing items, expert checking, revising items, conducting pilot testing, checking reliability and validity, and revising a questionnaire (Artino et al., 2014; Boynton & Greenhalgh, 2004; Rattray & Jones, 2007; Streiner & Kottner, 2014). In this study, the process for developing an initial questionnaire for assessing science teachers' metacognition is shown in Figure 3.3.

Figure 3.3

The Process for Developing an Initial Questionnaire for Assessing Science Teachers' Metacognition



The purpose of developing this instrument was to assess science teachers' metacognition specifically from the perspective of learning science. Therefore, the framework guiding the development of the questionnaire focused on two core elements: metacognition and learning science. For the metacognition framework, as mentioned earlier, this study considered metacognition as consisting of in two elements: knowledge of cognition and regulation of cognition. The element and its description were mentioned in Chapter two, Section *2.2.1 Definition and Frameworks.*

Each questionnaire item contains a situation or statement related to science teachers' metacognition based on elements of metacognition in the context of learning science. The participants were asked to what extent they agreed with each item. A five-point Likert rating scale of agreement was utilized. Those rating scales are *Strongly Disagree, Disagree, Neither Agree or Disagree, Agree, and Strongly Agree.* The scales of this initial questionnaire are shown in Table 3.2.

Table 3.2

Scales of the Questionnaire for Assessing Science Teachers' Metacognition

Scales	Description
Metacognitive Knowledge	Teachers are asked about their knowledge of…
Declarative knowledge (dk)	The state of their personal thinking and learning in the context of learning science
Procedural knowledge (pk)	their personal thinking and learning processes/strategies regarding in context of learning science
Conditional knowledge (ck)	their conditions for implementing their strategies of thinking and learning in the context of learning science
Metacognitive Regulation	Teachers are asked how likely the extent to what they…
Monitoring (mn)	are aware of/monitor their own cognition when learning science
Evaluating (ev)	evaluate their cognition when learning science
Planning (pl)	plan when learning science
Improving (im)	revise and improve their cognition when learning science

Once every item in the first draft of the questionnaire had been developed, it was sent to two experts in the field of metacognition in the science education context for checking face validity. The details of the two experts are shown in Appendix J. This was done to confirm whether the items in the instrument aligned with the concept that the items aimed to measure (Bolarinwa, 2015; Taherdoost, 2016). In this phase, the two experts gave feedback such as asking, (a) should an item be in procedural knowledge scale?, (b) should this item be considered as cognition not metacognition scale?, or (c) should not double negative sentence be used in the item?. The researcher discussed with the two experts back and forth, and the items were revised on the basis of that feedback and discussion.

Next, the questionnaire was translated into the Thai language by the researcher. The translation was checked, given feedback on, and back translated to English language by two experts who are proficient in Thai and English language and in the field of science education. This process was to ensure understanding of the items and to identify errors in translation and bias (if any). The qualifications of the two experts is shown in Appendix J.

The two experts gave feedback, for example, asking if the intended meaning of the item was to ask or to demand students to do something, what the intended meaning of “it is ok” in an item was, or to consider if the term “how to learn science” was used usually in Thai context, and whether it might cause some confusion because teachers may think about how to learn science content and not about their processes in learning science. Then the researcher compared the back translation with the original one, discussed again with the experts, and revised items. Finally, the initial Mc questionnaire consisted of 38 items with seven subscales. Next, the questionnaire was pilot tested. In the pilot test phase, the initial Mc questionnaire was called the pilot Mc questionnaire.

Pilot Testing: the Pilot Mc Questionnaire. A questionnaire invitation was sent to 50 Thai science teachers at lower secondary level (grade 7 – 9). Twenty-seven responses were collected in the pilot study. One response was deleted as it showed abnormal response giving only level 4 in all items. Therefore, the total number of responses was 26. Receiving responses from 24 – 36 participants is considered acceptable in initial scale development (Johanson & Brooks, 2010); the number of participants in the pilot study was sufficient.

The pilot Mc questionnaire was analyzed to examine its internal consistency. The Cronbach's alpha test was employed to test the internal reliability, this is, if a set of questionnaire items is in the same group that measures similar characteristics (Gliem & Gliem, 2003; Bonett & Wright, 2015; Pallant, 2010). The Cronbach's alpha coefficient in SPSS program version 28 was applied to examine each questionnaire subscale. The results of descriptive statistics and the Cronbach's alpha coefficient are shown in Table 3.3.

The pilot Questionnaire for Assessing Science Teachers' Metacognition (Mc) contained seven subscales with 38 items in total. The mean score of each subscale ranged from 4.28 –4.42. The Cronbach's alpha coefficient values in each subscale ranged between 0.72 – 0.90. In general, the sought-after value of the Cronbach's alpha is above 0.7 (Gliem & Gliem, 2003; Pallant, 2002). Therefore, the pilot Mc questionnaire is considered to have acceptable internal consistency. Because of the analysis of the data from the pilot testing, it was concluded that items in each subscale of the questionnaires correlate to one another. They are considered in the same group measuring similar characteristics. The questionnaire was considered to be ready to utilize in the main study. The Mc questionnaire items used in this main study phase are shown in Appendix B.

Table 3.3

Descriptive Statistics and Cronbach's Alpha of Each Subscale in the Initial Mc Questionnaire

Subscale	number of items	min	max	mean	Cronbach's Alpha
Declarative knowledge (dk)	6	4.25	4.67	4.42	0.72
Procedural knowledge (pk)	5	4.24	4.52	4.40	0.78
Conditional knowledge (ck)	4	4.16	4.56	4.36	0.80
Monitoring (mn)	8	4.14	4.41	4.28	0.88
Evaluating (ev)	6	4.17	4.39	4.30	0.90
Improving (im)	5	4.19	4.69	4.39	0.77
Planning (pl)	4	4.19	4.62	4.42	0.77

Continuing the Development of the Mc Questionnaire in the Main Study: Rasch Analysis. The Questionnaire for Assessing Science Teachers' Metacognition (Mc) was further developed in the main study. Details about how questionnaire data was collected is shown in the Data Collection section. In summary, the total acceptable responses from participants in the main study was 214.

In this stage, the Rasch model analysis using WINSTEPs program version 5.2.3.0 was applied. The main aim of this process was to examine the questionnaire's construct validity. If each subscale of the questionnaire assesses the same underlying construct (which is preferable), its values from Rasch model analysis should indicate unidimensionality (Boone, 2016; Bradley et al., 2015; Hamon & Mesbah, 2002). In addition, the Rasch analysis also offers some measures which are useful for developing questionnaires. In this study, the measures focused on are described in Table 3.4.

Table 3.4

Description of the Rasch Model Analysis

Measure	Descriptions	Suggested Value
Person Reliability	The analysis shows replicated degree of person ordering if the same group of participants give response to another set of items that measures the same construct (Bond & Fox, 2015). Person reliability refers to the similar reliability as the Cronbach's Alpha (Tennant & Conaghan, 2007).	<0.67 poor, 0.67-0.8 fair, 0.8-0.9 good (Fisher, 2007)
Person Separation	The analysis shows how participants are differentiated based on their scale responses (Bond & Fox, 2015).	>1.5 (Tennant & Conaghan, 2007)
Item Reliability	The analysis shows replicated degree of item ordering if the same set of items are tested by another group of participants who have the similar behaviors (Bond & Fox, 2015).	<0.67 poor, 0.67-0.8 fair, 0.8-0.9 good (Fisher, 2007)
Item Separation	The analysis shows how items within its scale are differentiated (Bond & Fox, 2015).	>1.5 acceptable (Tennant & Conaghan, 2007); <2 poor, 2-3 fair (Fisher, 2007)
Item fit	The analysis shows how actual responses patterns match with expected patterns in the Rasch model in terms of item pattern across participants (Bond & Fox, 2015).	Productive for measurement 0.5-1.5 (Linacre, 2002)
JMLE Measure (Item difficulty)	The estimation of the difficulty of the item (Bond & Fox, 2015).	Each item in a scale should not have the same value (Boone, 2016)
Eigenvalue in 1st contrast.	The value shows possibilities of multidimensionality. The high value shows the probably of more than unidimensional in a scale. (Bond & Fox, 2015).	<2 suggested unidimensional (Linacre, 2006)
Raw Variance explained by measure.	The variance that could be explained by the Rasch measures (percentage of observed variance around predicted Rasch measure) (Bond & Fox, 2015).	>30% appropriate for survey data (Linacre, 2006)
Unexplained Variance.	The variance that could not be explained by a measure (Bond & Fox, 2015).	>15% poor, 10- 15% fair (Fisher, 2007)
Residual Correlation.	The correlation between items. The high correlation of two items within the same subscale shows that those items are similar. One item should be deleted to avoid item redundant.	Within ±0.7 (Linacre, 2006)
Wright Map	The map shows person and item distribution (Bond & Fox, 2015).	Good distribution along the axis with no large gap and no items at the same location (Boone, 2016)

To recall, the Mc questionnaire used in the main study contained seven subscales with 38 items. After the Rasch model analysis was applied, the results suggested that the seven subscales as a whole could not form as one unidimensional scale. Furthermore, focusing on each of the seven subscales, only the subscale Declarative knowledge could form as one unidimensional scale. The other six subscales could not form their own unidimensional subscales. The analysis results for the other subscales showed poor conditions, for example, more than 2 or 3 for Eigenvalues, poor reliability, or too many misfit items. The analysis suggested an appropriate structure for the questionnaire of three underlying constructs. Accordingly, some original subscales were collapsed together to form three unidimensional subscale/constructs. Also, some questionnaire items were removed as the analysis showed that those items did not fit with the Rasch model.

The new subscales in the final Mc questionnaire were renamed Declarative Knowledge subscale (D), Learning Process Knowledge subscale (LP), and Regulation subscale (R). The relationship between subscales in the initial Mc questionnaire and subscales in the final Mc questionnaire is shown in Figure 3.4. The final number of questionnaire items after analysis using the Rasch model was 27. A summary of the Rasch analysis of the final Mc questionnaire is shown in Table 3.5.

The justification of the Rasch model analysis of Mc questionnaire in relation to the three subscales is discussed as follows. To begin with, the Rasch model analysis requires a sample size of 100 for 95% significant level, and 150 for 99% significant level (Linacre, 1994). Therefore, a sample size of 214 in this study is sufficient for conducting the Rasch model analysis.

Figure 3.4

The Diagram of Relationship of Subscales in the Initial Mc Questionnaire and the Final Mc Questionnaire

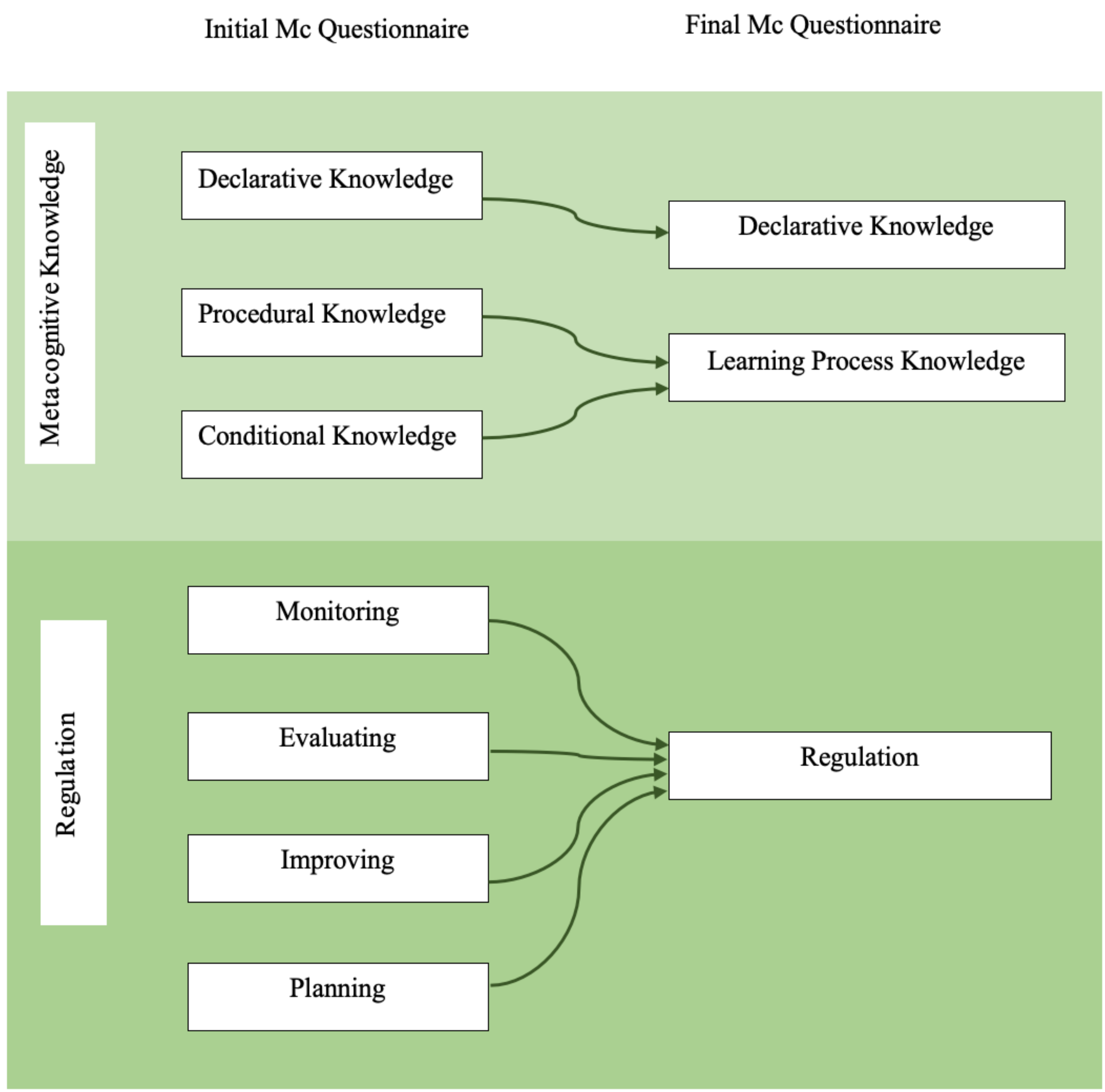


Table 3.5

A Summary of Rasch Model Analysis Results of the Questionnaire for Assessing Science Teachers' Metacognition

Subscales	Person Reliability/ Separation	Item Reliability/ Separation	Residual Correlation range	Eigen value of unexplained variance in 1st contrast	Raw variance explained by measure	Unexplained variance in 1st contrast
Declarative Knowledge.	0.69/1.47	0.90/3.00	(-0.32) – 0.08	1.46	40.5%	14.5%
Learning Process Knowledge.	0.83/2.18	0.92/3.45	(-0.32) – 0.38	1.85	52.6%	10.9%
Regulation	0.86/2.47	0.68/1.46	(-0.30) – 0.18	1.80	43.6%	7.8%

Next, the results of Rasch model analyses shown in Table 3.5 are discussed. Firstly, the Person and Item Reliability of all three subscales range between 0.68 – 0.92 which corresponded to the fair to good range according to Fisher (2007), as mentioned in Table 3.4. An acceptable value of the Person Reliability suggests that items in those subscales are reliable, this is, the participants are likely to give the similar responses when they get to do the same or a similar questionnaire. In addition, an acceptable value of the Item Reliability suggests that items in those scales have strong characteristics that will maintain their difficulty rank when those items are given to another similar group of participants.

Person Separation values in subscales Learning Process Knowledge and Regulation are over 2, over the suggested value is over 1.5, which mean items in each two subscales could differentiate participants responses at least 2 levels. In other words, not all participants give the same response to the questionnaire items. If all participants give the same response to the items, it could be interpreted that the item is not good enough to encourage participants to express their intention/characteristics (if the participants' intention/characteristics are different). In this case, the items could encourage participants to express their characteristics differently at least two levels. However, the subscale Declarative knowledge has the value less than 1.5 (1.46) which suggests the items in the subscale have poor ability to separate individuals in this group of participants. Further, it could be interpreted that this group of participants share the similar characteristics in terms of their Declarative knowledge. More varieties in teacher characteristics and more numbers of participants might increase the Person Separation value. This could be a goal of future research.

Regarding Item Separation, the subscales Declarative Knowledge and Learning Process Knowledge have an acceptable value of separation as more than 3 (3.00 and 3.45 respectively).

These two subscales show acceptable values in item separation. However, the subscale Regulation has value 1.48 which is below the acceptable level (1.5). It could be interpreted that items in the Regulation subscale are similar or have similar difficulty. More distinct items in this subscale could increase the item separation which could be done in a future study.

Next, values in the Residual Correlation suggest whether items in each subscale are independent of each other. If they are, the Residual Correlation values should be less than 0.7 and more than (-)0.7. Data from Table 3.5 suggest that all three subscales of Mc questionnaire have their values within the suggested range. Therefore, there are no redundant items any of the three subscales.

As mentioned before, the main purpose of the Rasch analysis of Mc questionnaire was to investigate if the questionnaire/subscales are unidimensional. If the questionnaire/subscale is considered as unidimensional, it could be interpreted that the questionnaire subscale is valid, as it contains items that relate to and assess the same construct (one construct).

Tennant and Pallant (2006) mentioned that there are three general approaches to assess unidimensionality, including Factor analysis, Item Fit, and Principal Component Analysis (PCA) of the residual (focusing on Eigenvalues). Researchers could adopt one approach to assess unidimensionality of their data. However, Tennant and Pallant (2006) also suggested that in addition of Item Fit, examining PCA of the residual could provide more information if a scale is multidimensional. Brentani and Golia (2007) highly recommended the approach of combining Item Fit and PCA of the residuals to assess if a new instrument is unidimensional. Therefore, in this study, two approaches which are item fit and PCA of the residuals were employed to examine if each subscale in Mc questionnaire was unidimensional.

The Rasch Model analysis provides results of both Item Fit and (PCA) of the residual. In the Item Fit approach, if items in a subscale fit with the Rasch Model, the Infit and Outfit values (focusing on mean-square values: MNSQ) should be in the range between 0.5 – 1.5. Accordingly, Infit and Outfit values of the Rasch Model analysis of items in three subscales of the Mc questionnaire are shown in The Misfit Order table is shown in Table 3.6.

Table 3.6

Misfit Order of Items in Subscales in the Mc Questionnaire

Subscale	item	Total score	Total count	JMLE measure	Infit		Outfit	
					MNSQ	ZSTD	MNSQ	ZSTD
Declarative knowledge	D2	925	213	-0.47	1.27	2.38	1.20	1.67
	D4	891	214	0.38	1.12	1.06	1.19	1.45
	D5	897	213	0.16	1.16	1.34	1.09	0.73
	D1	937	212	-0.87	0.86	-1.41	0.86	-1.18
	D3	880	212	0.44	0.82	-1.54	0.86	-1.14
	D6	888	213	0.36	0.76	-2.16	0.72	-2.42
Learning Process Knowledge	LP8	862	210	0.88	1.23	2.00	1.31	1.66
	LP5	900	212	-0.15	1.06	0.57	1.11	0.63
	LP4	909	214	-0.15	1.09	0.84	0.90	-0.47
	LP7	883	213	0.58	1.00	-0.01	0.98	-0.04
	LP3	881	211	0.42	0.96	-0.32	0.79	-1.20
	LP2	903	207	-1.02	0.91	-0.81	0.79	-1.19
	LP6	889	214	0.54	0.88	-1.11	0.75	-1.45
	LP1	922	211	-1.09	0.72	-2.68	0.56	-2.82
Regulation	R7	861	214	0.43	1.42	3.18	1.44	2.88
	R12	874	214	0.10	1.27	2.16	1.29	1.92
	R13	880	214	-0.06	1.07	0.61	0.96	-0.25
	R10	864	213	0.25	1.00	0.00	0.96	-0.26
	R1	862	214	0.41	0.95	-0.43	0.98	-0.09
	R9	873	213	0.01	0.98	-0.11	0.96	-0.23
	R4	885	214	-0.20	0.95	-0.40	0.82	-1.28
	R8	862	213	0.31	0.94	-0.48	0.93	-0.44
	R6	883	212	-0.38	0.92	-0.69	0.87	-0.88
	R2	896	214	-0.49	0.91	-0.79	0.81	-1.36
	R11	867	211	-0.04	0.85	-1.26	0.76	-1.77
	R3	889	213	-0.42	0.83	-1.50	0.78	-1.63
	R5	870	213	0.09	0.82	-1.55	0.79	-1.52

From Table 3.6, data of the Item Fit show that all items of each of all three subscales of Mc questionnaire are in the suggested range. It could be interpreted that, based on Item Fit approach, each subscale of Mc questionnaire is considered unidimensional.

Further, in the PCA of the residuals approach, the main focus of this approach is to explore Eigenvalues. Theoretically, as mentioned in Table 3.4, if the Eigenvalue of a subscale is below 2, that subscale is considered unidimensional. The results of Eigenvalues of three subscale of Mc questionnaire are shown in Table 3.5. It shows that each of subscales of Mc questionnaire has Eigenvalue below 2. Therefore, all subscales can be considered unidimensional.

The PCA of the residuals also provided two analyses to confirm unidimensionality. Firstly, the 'raw variance explained by measure' provides information of the extent to which questionnaire response data, of each subscale, corresponds to the Rasch model. Information in Table 3.4 suggests that the value should be more than 30%. Secondly, the 'unexplained variance in the first contrast' provides information regarding the extent to which questionnaire response data, of each subscale, do not correspond to the Rasch model. Information in Table 3.4 suggests that the values should not exceed 15%. Accordingly, the 'raw variance explained by measure' and the 'unexplained variance in the first contrast' of all three subscales of Mc questionnaire are shown in Table 3.5. The data show that the values are within the suggested range which are more than 30% and less than 15% respectively. It suggests that all three subscales are unidimensional. Therefore, as the results ensured by both Item Fit and PCA of the residuals approaches, all three subscales of the Mc questionnaire can be considered unidimensional.

Further, the item difficulty of all items in the three subscales were explored. The item difficulty values were plotted on the same diagram to show how their difficulties spread. The result is shown in Figure 3.5.

Figure 3.5

The Diagram of Item Difficulty of Items in Each Subscale of the Questionnaire for Assessing Science Teachers' Metacognition

Item difficulty	Declarative K	Learning Process K	Regulation
0.8			
0.7			R1(31) R7(12)
0.6			R8(19)
0.5			R10(27)
0.4			R5(36) R12(38)
0.3		LP8(5)	R9(22)R11(37)R13(33)
0.2			
0.1	D3(6)	LP7(26)	R4(32)
0.0	D6(34)	LP3(35) LP6(10)	R6(24)
-0.1	D4(18)		R2(15) R3(25)
-0.2			
-0.3	D5(29)		
-0.4		LP5(9)	
-0.5		LP4(30)	
-0.6			
-0.7			
-0.8			
-0.9			
-1.0	D2(8)		
-1.1		LP1(2) LP2(3)	
-1.2			
-1.3			
-1.4	D1(1)		
-1.5			

Note: a number in () is item number in the questionnaire using in the main study

Item difficulty provides information about the extents to which participants endorse the item. If the item difficulty value is high, it suggests that the participants are less likely endorse to the item. On the contrary, if the item difficulty value is low, it suggests that the participants are more likely to endorse to the item. Data of item difficulty could be used as supporting data to identify subscale unidimensionality. When considering the item difficulty in the same subscale, each item in the same subscale should not have the same difficulty, as this suggests those items may measure the same elements of an intended construct. However, the difficulty value of items should not be too distinct to one another, as this suggests those items may measure a different construct or that they are not unidimensional. In summary, under the same construct, items should have similar difficulty. In addition, in different constructs, in this case each subscale, their difficulty trends should be different from the others as each construct is unique to others.

In the Mc questionnaire, as shown in the diagram in Figure 3.5, item difficulties in each subscale are clustered and not distinct to one another which is preferable. Specifically, over all, the subscale Regulation has the highest difficulty followed by the subscales Learning Process Knowledge, and Declarative Knowledge respectively. Items in the subscale Regulation are more clustered than the other subscales with less gaps between item difficulties. The subscales Declarative Knowledge and Learning Process Knowledge spread more along difficulty continuum, but they contain some gaps between item difficulties. In this case, developing more items to fill in the gap is suggested (Boone, 2016). This could be done in a future study.

In conclusion, the analysis of the Rasch model shows that each of the three subscales in the metacognition questionnaire can be considered unidimensional. The analysis confirms the questionnaire's reliability and validity. The questionnaire is acceptable to be used to assess teachers' metacognition using the subscales Declarative Knowledge, Learning Process

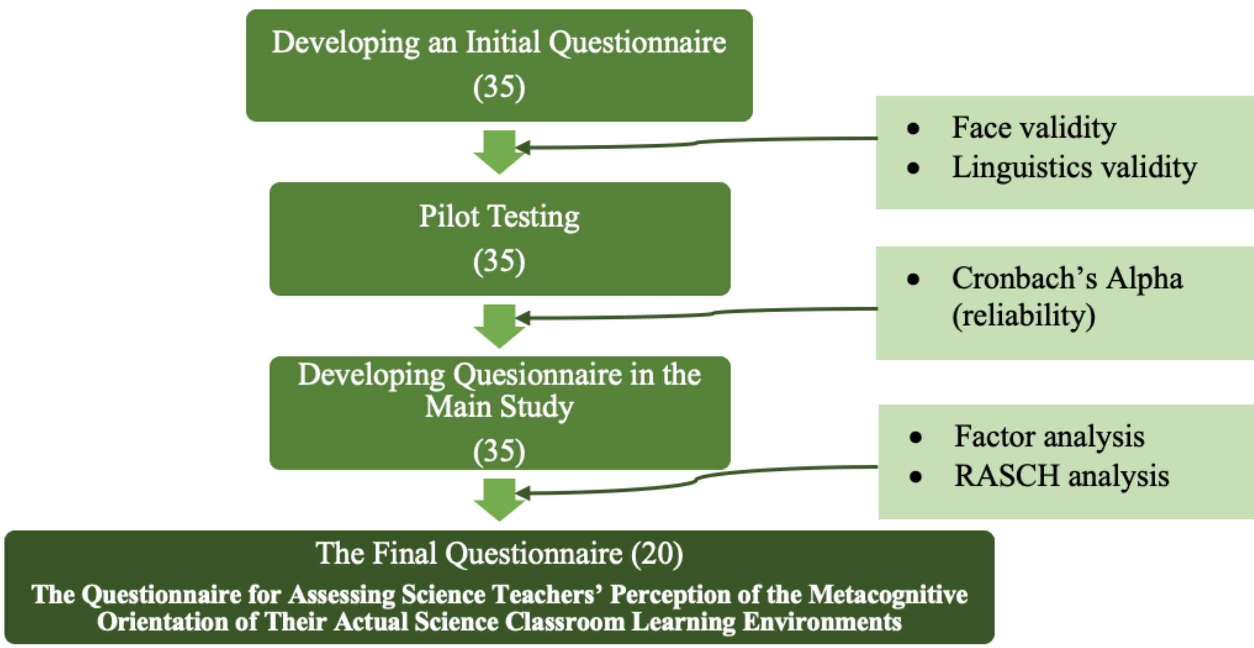
Knowledge, and Regulation. Data of the Rasch Model analysis of all three subscales of Mc questionnaire can be found in Appendix F. In summary, the Questionnaire for Assessing Science Teachers' Metacognition, the final version, consists of 27 items with three subscales: Declarative Knowledge, Learning Process Knowledge, and Regulation. The questionnaire subscales and their items are shown in Appendix H.

The Questionnaire for Assessing Science Teachers' Perception of the Metacognitive Orientation of Their Actual Science Classroom Learning Environments

According to references located in ERIC and Educational Research Complete database from 2000-2020, there is only one inventory developed for assessing the metacognitive orientation of science learning environments (EBSCOhost, 2020c): the Metacognitive Orientation Learning Environment Scale-Science (MOLES-S) (Thomas, 2003). The MOLES-S was developed to evaluate the metacognitive orientation of science classroom learning environments according to students' perceptions. The MOLES-S has been cited in over 70 research articles (Google scholar, 2021). Many studies have adopted the instrument to assess students' perceptions of the metacognitive orientation of their science classroom learning environments (e.g., Hug et al., 2015; Nikpour et al., 2011; Peters & Kitsantas, 2010; Şahin, 2015; Thomas, 2013a) including within the Thailand education context (e.g., Chantharanuwong et al., 2012b; Thomas & Chantharanuwong, 2022). Further, Thomas and Chantharanuwong (2022) validated the MOLES-S (T) (T as Thai version) with 5,418 Thai science students across Thailand. They concluded that, "The MOLES-S(T) can also be used to ascertain measures of the overall metacognitive orientation of science classroom learning environments" (p. 812) in Thai science classrooms. Therefore, the MOLES-S was considered to be an instrument that could be, with qualifications, suitable for use in this study to assess teachers' perceptions of the metacognitive orientation of their science classrooms in Thailand. Accordingly, the MOLES-S inventory was adopted and adjusted to use as a questionnaire to explore science teachers' perceptions of their actual MOLEs of their science classrooms. A summary of process in developing the ActualMOLEs questionnaire is shown in Figure 3.6

Figure 3.6

A Summary of the Processes in Developing the Questionnaire for Assessing Science Teachers' Perception of the Metacognitive Orientation of Their Actual Science Classroom Learning Environments

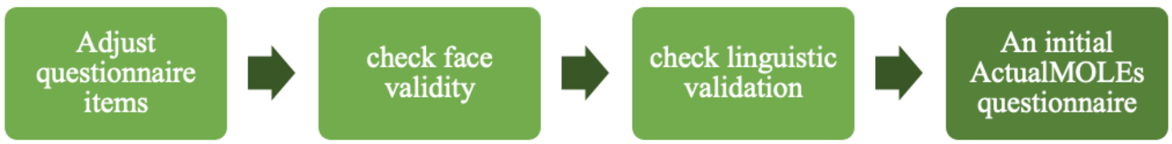


Note: a number in each () is the number of questionnaire items used in that process

Developing an initial ActualMOLEs Questionnaire. The process of developing of the questionnaire to explore teachers' perceptions of their actual MOLEs in their science classrooms is shown in Figure 3.7. This process is similar to the process for developing the questionnaire for assessing science teachers' metacognition. However, it has fewer steps, as the questionnaire was developed from the already validated employed questionnaire (e.g., Chantharanuwong et al., 2012b; Thomas & Chantharanuwong, 2022).

Figure 3.7

A Process for Developing an initial Questionnaire for Assessing Science Teachers' Perception of the Metacognitive Orientation of Their Actual Science Classroom Learning Environments



As mentioned before, the MOLE-S was developed originally to assess students' perceptions. In order to adjust the questionnaire items for used to assess teachers' perceptions, the statement of each item needed to be changed to capture teachers' perceptions instead of students' perceptions. Given the previous use of the MOLES-S including in the Thailand context, the scale dimensions of the MOLES-S as described in Table 3.7 were seen as relevant for the study at the time when researcher begin to develop the teacher version. Specifically, there were 35 items classified in seven categories/subscales in the questionnaire (five items in each subscale).

In each item, teachers were asked how often their actual science classroom learning environments reflected each statement. The Likert scale of *Never, Rarely*, *Sometimes, Often, Always* was used. The questionnaires were sent to two experts to check face validity, and two experts to check linguistic validity as per the process described regarding the questionnaire for assessing the science teachers' metacognition. The initial Questionnaire for Assessing Science

Teachers' Perceptions of their Actual Metacognitively Oriented Learning Environments (ActualMOLEs questionnaire) contained seven subscales with 35 items in total. Then the 35-item questionnaire was pilot tested. In the pilot test phase, the initial ActualMOLEs questionnaires was called the pilot ActualMOLEs questionnaire.

Table 3.7

Scales of the MOLES-S

Scale	Description (extent to which:)
Metacognitive demands	students are asked to be aware of how they learn and how they can improve their science learning
Student-student discourse	students discuss their science learning processes with each other
Student-teacher discourse	students discuss their science learning processes with their teacher.
Student voice	students feel it is legitimate to question the teacher's pedagogical plans and methods
Distributed control	students collaborate with the teacher to plan their learning as they develop as autonomous learners
Teacher encouragement& support	students are encouraged by the teacher to improve their science learning processes.
Emotional support	students are cared for emotionally in relation to their science learning

Note. adapted from "Conceptualisation, development and validation of an instrument for investigating the metacognitive orientation of science classroom learning environments: The Metacognitive Orientation Learning Environment Scale–Science (MOLES-S)" by G. P. Thomas, 2003, *Learning Environments Research, 6*(2), p. 184. Copyright 2003 by Kluwer Academic Publishers.

Pilot Testing: the pilot ActualMOLEs questionnaire. The processes of pilot testing the pilot ActualMOLEs questionnaire were the same as the processes of pilot testing the pilot Mc questionnaire. Specifically, the participants in this pilot testing were the same participants who gave responses to Mc questionnaire (the invitation letter were sent to the participants asked them to give responses to both questionnaires). There were 26 qualified responses to total. The responses of Actual questionnaire were analyzed to identify its internal consistency (Cronbach's alpha). The results are shown in Table 3. 8

Table 3.8

Descriptive Statistics and Cronbach's Alpha of each subscale the initial Actual MOLEs questionnaire

Scale/Subscale	number of items	min	max	mean	Cronbach's Alpha
Metacognitive demands (md)	5	3.54	4.04	3.84	0.62
Student-student discourse (ss)	5	3.52	4.13	3.80	0.85
Student-teacher discourse (st)	5	3.60	4.20	3.94	0.87
Student voice (sv)	5	4.08	4.36	4.21	0.85
Distributed control (dc)	5	3.08	3.68	3.50	0.84
Teacher encouragement & support (ts)	5	4.04	4.42	4.19	0.84
Emotional support (es)	5	4.28	4.84	4.54	0.75

The results show that the mean score of each subscale ranges from 3.50 – 4.54. The Cronbach's alpha coefficient values in each subscale were over 0.7 except for the subscale Metacognitive demand (md). The Cronbach's alpha coefficient for that subscale was 0.62. As mentioned before, the sought-after value of the Cronbach's alpha is above 0.7 (Gliem & Gliem, 2003, Pallant, 2010). However, a Cronbach's alpha coefficient above 0.6 is also considered as acceptable (Clark & Watson, 1995; Taber, 2018). In addition, in a scale that contain less than ten items, a low level of the Cronbach's Alpha as 0.5 could be possible and, in that case, mean inter-item correlation should be reported (Pallant, 2010). The acceptable mean inter-item correlation ranges between 0.2 – 0.4 (Briggs & Cheek, 1986) or 0.15 – 0.50 (Clark & Watson,1995). In the subscale Metacognitive demands, the mean inter-item correlation is 0.24. Therefore, even that the Cronbach's Alpha coefficient in the Metacognitive demand subscale was low, the inter-level correlation of items in the subscale is acceptable. This suggests that those items can be considered as being in the same factor. Therefore, the subscales of the initial ActualMOLEs questionnaire were considered to have acceptable internal consistency. The questionnaire was further developed in the main study. The questionnaire items in this phase are shown in Appendix C.

Continuing the Development of the Questionnaire for Assessing Science Teachers' Perceptions of their Actual MOLEs in the Main Study: Factor Analysis and Rasch Analysis. The development of the Questionnaire for Assessing Science Teachers' Perceptions of their Actual MOLEs (Actual MOLEs questionnaire) employed a different approach from the development of the Questionnaire for Assessing Science Teachers' Metacognition. As mentioned before, this questionnaire was developed based on the Metacognitive Orientation Learning Environment Scale – Science (MOLES-S) (Thomas, 2003) which was developed using factor analysis method and then using Rasch Model (Thomas, 2004). The process of analyzing data by the Factor analysis first then follows by the Rasch Model analysis was also mentioned as an appropriate procedure to elicit underling construct by Schumacker and Linacre (1996). To follow the processes of developing MOLES-S, the Questionnaire for Assessing Science Teachers' Perceptions of their Actual MOLEs was examined using factor analysis first to assess the underlined construct (Brown, 2015; Knekta et al., 2019; Strickland, 2003). Then, the Rasch model analysis was employed to investigate questionnaire unidimensionality.

Factor Analysis. In factor analysis, there are many suggestions on sample size. For example, 100 is the minimum sample size (MacCallum et al., 1999; Mundfrom et al., 2005; Sapnas & Zeller, 2002) and 200 is adequate (Comrey & Lee, 1992). Therefore, a sample size 214 as in this study can be considered sufficient.

In order to conduct the factor analysis, SPSS program version 28 was employed. The analysis employed the Principal Component as the extraction method, Varimax as the rotation method, and asked for item coefficients >0.4. The factor analysis result is shown in Figure 3.8.

Figure 3.8

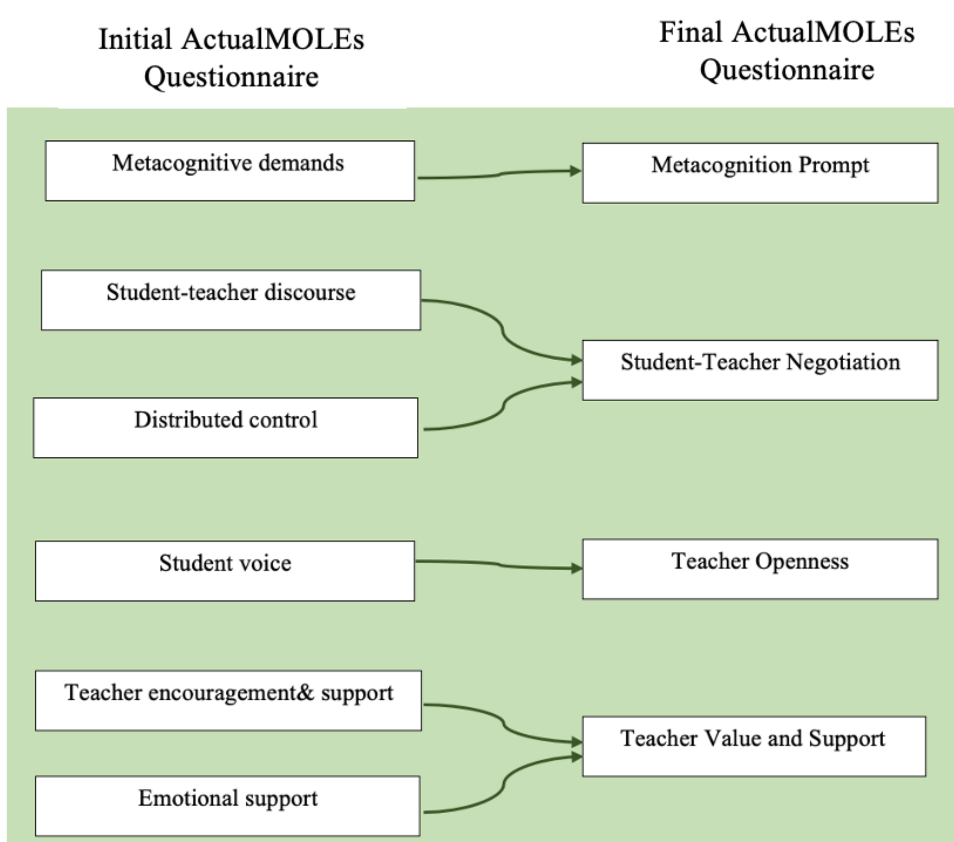
The Factor Analysis Result of the ActualMOLEs Questionnaire

	1	2	3	4
StN1	O.817			
StN4	0.807			
StN7	0.761			
StN3	0.757			
StN5	0.730			
StN2	0.722			
StN6	0.661			
TO4		0.803		
TO2		0.783		
TO1		0.760		
TO5		0.715		
TO3		0.632		
VS2			0.846	
VS4			0.838	
VS1			0.695	
VS3			0.647	
MP3				0.750
MP1				0.728
MP4				0.696
MP2				0.658

The original Actual MOLEs questionnaire contains seven subscales with 35 items. After the factor analysis was undertaken, the analyses showed that, based on this group of 214 participants, the questionnaire contains four underlying factors/constructs, and the total number of the remaining questionnaire items was 20. Those four factors/subscales were named Student-Teacher Negotiation (StN), Teacher Openness (TO), Teacher Value and Support (VS), and Metacognition Prompt (MP). Relationships between subscales in the initial and final ActualMOLEs questionnaire are shown in Figure 3.9.

Figure 3.9

The Diagram of Relationship of Subscales in the Initial ActualMOLEs Questionnaire and the Final ActualMOLEs Questionnaire



In order to examine internal consistency of each factor, the Cronbach's Alpha was analyzed. The results are shown in Table 3.9

Table 3.9

Cronbach's Alpha Coefficients of Subscale in the Final ActualMOLEs Questionnaire

Subscale	Cronbach's Alpha Coefficient
Student-Teacher Negotiation (StN)	0.90
Teacher Openness (TO)	0.88
Teacher Value and Support (VS)	0.86
Metacognition Prompt (MP)	0.76

The Cronbach's Alpha coefficients of all four subscale are all above 0.7. In addition, the factor analysis result shows no cross-linked item between factors. Therefore, it could be concluded that those subscales in the ActualMOLEs questionnaire are considered reliable and each of the four subscales is independent of each other. Each of all four subscale is considered acceptable to be used to assess their own construct.

Rasch Model Analysis. The questionnaire was further analyzed using the Rasch model analysis. The result showed that the questionnaire with all four subscales could not form as one unidimensional scale, as its eigenvalue exceed 2 (4.96) which indicated multidimentionality. However, each four subscales could form as a unidimensional subscale. A summary of the Rasch model analysis of each four subscales in the AMOLEs questionnaire is shown in Table 3.10. Misfit Order of items in each subscale is shown in Table 3.11. Data of the Rasch Model analysis of ActualMOLEs questionnaire in relation to the table of Standardize Residual and the Wright map can be found in Appendix G.

Table 3.10

A Summary of Rasch Model Analysis Results of the ActualMOLEs Questionnaire

Subscales	Person Reliability/ Separation	Item Reliability/ Separation	Residual Correlation range	Eigen value of unexplained variance in 1st contrast	Raw variance explained by measure	Unexplained variance in 1st contrast
Student-Teacher Negotiation.	0.88/2.66	0.94/3.89	(-0.39) – 0.16	1.97	62.6%	10.5%
Teacher Openness.	0.77/1.82	0.72/1.62	(-0.41) – (-0.06)	1.55	59.2%	12.7%
Teacher Value and Support.	0.71/1.56	0.92/3.43	(-0.48) – 0.13	1.75	58.7%	18.1%
Metacognition Prompt.	0.73/1.66	0.96/4.63	(-0.50) – (-0.05)	1.69	56.9%	18.2%

Table 3.11

Misfit Order of Items in Subscales in the ActualMOLEs Questionnaire

Subscale	item	total score	total count	JMLE measure	Infit		Outfit	
					MNSQ	ZSTD	MNSQ	ZSTD
Student-Teacher Negotiation	StN6	679	213	0.63	1.35	3.31	1.33	3.09
	StN7	694	213	0.46	1.11	1.15	1.13	1.32
	StN2	767	212	-0.62	0.98	-0.21	0.91	-0.83
	StN3	760	214	-0.40	0.93	-0.66	0.87	-1.29
	StN5	724	214	0.10	0.89	-1.16	0.92	-0.79
	StN1	759	211	-0.56	0.85	-1.52	0.82	-1.89
	StN4	692	211	0.39	0.82	-1.92	0.80	-2.07
Teacher Openness	TO3	847	213	0.40	1.49	3.76	1.50	3.95
	TO5	862	212	0.10	0.94	-0.45	0.97	-0.19
	TO1	878	213	-0.09	0.96	-0.28	0.96	-0.35
	TO2	879	214	-0.03	0.86	-1.24	0.81	-1.74
	TO4	891	212	-0.38	0.68	-2.93	0.68	-3.01
Teacher Value& Support	VS3	942	212	0.52	1.27	2.40	1.25	1.62
	VS1	940	213	0.84	1.10	1.00	1.11	0.82
	VS2	964	213	-0.18	0.82	-1.49	0.79	-1.32
	VS4	976	211	-1.18	0.68	-2.29	0.61	-2.31
Metacognition Prompt	MP2	707	212	0.90	1.26	2.40	1.31	2.85
	MP3	824	214	-0.77	0.97	-0.28	0.95	-0.46
	MP1	770	214	0.08	0.88	-1.22	0.88	-1.17
	MP4	789	214	-0.21	0.87	-1.32	0.85	-1.56

The results from the Rasch model analysis show that the subscales have Person and Item Reliability in range of 0.71 – 0.96 which are above the fair value of 0.67. In addition, their Person and Item Separation are all above acceptable value of 1.50. This result supports the reliability of each subscale in the questionnaire. There is no pair of items in the same subscale that has higher correlation than 0.7 which suggests all item are independent to each other. No items are redundant.

The item fit data of all items in all subscales are within the range of 0.5 – 1.5 which suggests that all items fit with the Rasch model. The Eigenvalues of all subscales are below 2 which suggests that each subscale is unidimensional. In addition, the values of raw variance explained by the measure of each of four subscales are more than 50% which is sufficient (the suggested value for survey data is > 30%). The unexplained variance in the 1st contrast of subscales Student-Teacher Negotiation and Teacher Openness are lower than 15% which is fair (the suggested value is <15%). However, the values in the subscales Teacher Value and Support and Metacognition Prompt are higher than 15% which is poor. However, as their percentages of the raw variance explained by measure were above 50%, the high value of unexplained variance will not violate their measures. In summary, results from both Item Fit and PCA residuals approaches support that all four subscales are unidimensional.

The diagram of item difficulty of all items in each subscale is shown in Figure 3.10. The diagram shows that items in each subscale are clustered together. There are some small gaps in each subscale cluster, but overall, this distribution can be considered acceptable. The difficulty of the whole subscale ranks from the highest to the lowest as Student-Teacher Negotiation, Metacognitive Prompt, Teacher Openness, and Teacher Value and Support respectively.

In conclusion, according to all analyses, it can be considered that all four subscales of the Actual MOLEs questionnaire show acceptable values for both validity and reliability. Each subscale is considered unidimensional. All items are independent, but also clustered in their own subscale. Therefore, the questionnaire is considered acceptable for using to assess science teachers' perception of the metacognitive orientation of their actual science classroom learning environments with respect of the four dimensions represented be the subscales. In summary, the

ActualMOLEs questionnaire consisted of 20 items with four subscales. The questionnaire items are shown in Appendix I.

Figure 3.10

The Diagram of Item Difficulty of Items in Each Subscale of the ActualMOLEs Questionnaire

Item difficulty	Student-Teacher Negotiation	Teacher Openness	Teacher Value and Support	Metacognition Prompt
1.3	StN6(5)			
1.2	StN7(23)			
1.1	StN4(25)			
1.0				MP2(2)
0.9	StN5(11)			
0.8				
0.7				
0.6	StN3(28)			MP1(8)
0.5	StN1(24)			
0.4	StN2(32)			MP4(7)
0.3				
0.2				
0.1				MP3(3)
0.0				
-0.1				
-0.2		TO3(10)		
-0.3				
-0.4		TO5(14)		
-0.5		TO2(22)		
-0.6		TO1(26)		
-0.7				
-0.8		TO4(19)		
-0.9				
-1.0				
-1.1				
-1.2				
-1.3			VS1(17)	
-1.4			VS3(12)	
-1.5				
-1.6				
-1.7			VS2(15)	
-1.8				
-1.9				
-2.0				
-2.1			VS4(16)	

Note: a number in () is an item number in the questionnaire using in the main study

Interviews

Another method used for data collection in this study was interviews. The interviewees were selected from teacher participants who gave questionnaire responses in the quantitative phase. Further details are shown in the data collection section. Some essential literature reviews about interview method, interview protocol, and suggestions on online interviews are as follows.

Punch and Oancea (2014) stated, “it [an interview] is a very good way of exploring people’s perceptions, meanings, definitions of situations, and constructions of reality. It is also one of the most powerful ways we have to understand others” (p. 182). An interview allows a researcher to collect data from a participant directly. The story or experience data that has not been converted to any form of data would build strong trustworthiness as the data were delivered directly from participants to researchers (Rasmussen et al., 2006). Three types of interviews are: structured interviews, semi-structured interviews, and unstructured interviews. Researchers could choose from these depending on their purposes (Punch & Oancea, 2014). Many studies in the field of metacognition research have employed interview methods to collect data (e.g., Ben-David & Orion, 2013; Boyle et al., 2016; Caliskan & Sunbul, 2011; Choi et al., 2005; Doğanay, & Öztürk, 2011; Thomas, 2013a). In addition, many studies in the field of learning environments research, in relation to exploring perceptions, have employed interview method as well (e.g., Allen & Fraser, 2007; de Souza Fleith, 2000; Gamage et al., 2011; Richardson et al., 2016; Shevlin et al., 2013; Tsai, 2003).

There are suggestions from many researchers on how to conduct a good interview. Rasmussen et al. (2006) suggested, “a good interview is not a question and answer session, but the dialog between two people that leads to the establishment of a common understanding” (p. 101). Rasmussen et al. (2006) also suggested that “[T]he interview guide must contain the central themes that are to be examined in the study. These themes will be based on the research questions formulated in the frame of reference" (p. 102). Lodico et al. (2010) suggested that interviewers should prepare an interview protocol including brief introduction about the research, recording information about participants, time and date of the interview, and preliminary interview questions. In addition, Lodico et al. (2010) suggested general procedures for conducting any interview that include introducing yourself, reminding participants about confidentiality of their responses, providing brief information about a study, being a good listener, not making judgements, using questions and follow-up questions, and recording interview data. Brown and Danaher (2019) proposed the CHE principles as a guide framework for conducting a semi-structured interview in educational research. CHE principles consist of connectivity, humanness, and empathy. Connectivity refers to building a trust connection between the interviewer and interviewee. Humanness refers to conducting interviews which of both researchers and participants are respected. Empathy refers to showing courtesy to participants, for example, respect their information and privacy.

As mentioned before, this research employed interviews to collect data. Because of the Covid-19 situation, the interviews were conducted through via telephone, mobile application, and computer program (i,e., Zoom). There are some considerations for conducting such interviews that were taken into account. Novick (2008) reviewed 14 research articles related to using telephone interviews in qualitative research. Novick concluded that there are both disadvantages and advantages of using this method. The disadvantages include a lack of nonverbal data to guide researchers to probe with more questions, distraction during telephone interview, and less interview time than in-person interviews. The advantages include decreasing cost, there being no obstacle on locations, and a potentially more relaxed environment for participants. Novick also provided some suggestions for conducting telephone interviews that, (a) researchers should build rapport to participants before conducting an interview, and (b) researchers should prepare a script to introduce participants to the research at the beginning of the interview. These suggestions are similar to these of Glogowska et al. (2011). Glogowska et al. (2011) suggested that researchers should have information about the research or interview beforehand, ethical considerations should be implemented in the interview process, the interview script should be prepared, the participants should feel that their participation is valued, and they should be informed about research findings.

In this research, interviews using telephone, mobile application, and computer program were conducted employing the suggestions as mentioned above. The interview protocol included connecting with participants about the interview before conducting the interviews, building rapport between the researcher and the participants, preparing research questions and preparing for emerging questions, preparing brief information about the research to introduce it to participants, explaining the confidentiality of participants' information, providing interview environment based on CHE principles (Brown & Danaher, 2019), giving them transcript of interview data for them to verify (member checking), and informing them about how they could access research findings if they were interested. All in all, the interview practice followed ethical considerations as are explained in the later section of this document. The semi-structured interview questions are shown in Appendix D.

Research Participant Sampling

The participants of this study were Thai science teachers who teach at the lower secondary school level (7th-9th grade). The lower secondary level is the highest level of compulsory education in Thailand. Students in this level have options regarding if they would continue to study in the higher level or would leave school system. Therefore, supporting the development of metacognition for students in this level is considered important as it could assist them to have the chance to develop and enhance their metacognition for futures outside of or within school.

The sampling in the quantitative strand employed convenience sampling as the participants were selected because they made themselves available (Battaglia, 2011; Collins et al., 2007). The researcher's estimation of population of science teachers at the lower secondary level is around 20,000 people (based on the total number of teachers in all subjects in 7th-12th grade being around 230,000 people, and the number of schools in secondary level is around 15,000 school (Office of the Education Council, Thailand, (2018b)). In random sampling, there are suggestions on sample size of 378 for confidence level at 95% is suitable for populations less than 25,000 people (Krejcie & Morgan, 1970; Taherdoost, 2017). However, in relation to the convenience sampling method, the suggested number of sample size based on population could not be found to be documented. The results from convenience sampling should not be used to represent the whole population (Acharya et al., 2013, Stratton, 2021), but they might be useful for establishing hypotheses for further study (Stratton, 2021) or for representing knowledge gained from participants (Etikan et al., 2016). Therefore, in this study, the sample size was determined based on statistical techniques used in the analysis phase in order to strengthen the significance of the quantitative results. More details and the criteria for sample size are explained further in each stage of the analysis. In summary, in the quantitative phase, there were 26 participants in the pilot study and 214 participants in the main study.

The sampling in the qualitative phase was selected using a criterion scheme. The 'criterion scheme' refers to a sampling where the participants were selected as they matched with one or more criteria (Collins et al., 2007). In this research, the purpose of sampling in the qualitative phase was to select participants to cover all range of questionnaire responses from the quantitative phase. Therefore, the participants in this phase were selected from teachers who were willing to be interviewed and matched with these criteria: (1) their responses from metacognition questionnaire (Mc questionnaire) came from across all the response range, (2) their responses from actual MOLEs questionnaire came from across all the response range, and (3) their score distributions from both questionnaires came from across all the response range. The score distributions are, for example, Miss Manee had high score on Mc questionnaire and high score on ActualMOLEs questionnaire, so she was selected to be interviewed as she came from a group of teachers who had score distribution as high score on Mc questionnaire and high score on ActualMOLEs questionnaire. Mr. Pita, who had low score on MC questionnaire and low score on ActualMOLEs questionnaire, was selected to be interviewed as he came from different score distribution than Miss Manee. Interviewed participants were selected accordingly in order to have interviewed participants from across all the possible response range.

To ascertain the required number of participants for the interviews, the concept of data saturation was adopted. Data saturation refers to the condition in which no new information is added from interviewees during the data collection as interviews proceed (Bowen, 2008). In order to reach data saturation for an interview process, there are many suggestions on a number of interviewees, for example, 6-10 participants (Morse, 2000) or thirteen participants (Francis et al., 2010). Guest et al. (2006) proposed twelve as a number of interviewees, as they conducted a research with more than 30 interviews to explore the appropriate number of interviews in one study. They reported that “based on our analysis, we posit that data saturation had for the most part occurred by the time we had analyzed twelve interviews” (Guest et al., 2006, p. 74). In this research, from the 214 participants in the main quantitative phase, 29 participants engaged in the interview phase.

Data Collection

As mentioned previously, there were two methods of data collection: using questionnaires (a survey method) and interviews. The processes of data collection were as follows.

Questionnaires

Data about science teachers' metacognition and perceptions of the metacognitive orientation of their actual science classroom learning environments were collected through two questionnaires as mentioned before. Participants' information, for example, name, education level and major, teaching level, years of teaching, and phone or email were collected through the first part of the questionnaire about teachers' metacognition.

The study employed a convenience sampling method for approaching participants,. There were three ways that participants were accessed. Firstly, the researcher contacted the Institute for the Promotion of Teaching Science and Technology (IPST) to send an invitation letter to schools they were connected with. The invitation letter contained the QR code that linked to the online questionnaires. There were 489 schools in total in this phase. Secondly, the researcher searched for school information across Thailand other than those schools connected to the IPST, and sent out the invitation letter to their principal asking them to pass information to their science teachers. The invitation letter contained both paper questionnaires and the QR code linked to the online questionnaires. There were 462 schools in this phase. Thirdly, the researcher contacted science teachers, university teachers, teacher trainers, district officers, and administrators of webpages and chat groups related to science teachers to advertise and invite science teachers to do the questionnaires. The information contained the QR code linked to the online questionnaires. The estimated number of science teachers who got the information this way was about 2,000 (the estimation is based on one group chat of science teacher association that has about 1,000 science teachers, three districts which each has about 200 science teachers, and about 20 connectors of science teachers, teacher trainers, and university teachers who, each of them, have connection about 10- 40 science teachers).

The initial number of responses was 225 which consisted of 38 paper questionnaire responses, and 187 online questionnaire responses. The responses were filtered based on criteria mentioned earlier, and the final number to proceed in data analysis was 214 responses.

All responses from paper and online questionnaires were transformed into digital data in an Excel program, and kept in the password protected researcher's personal computer. The questionnaire papers were kept in a safe cabinet. Online questionnaire platform used in this study was the REDCap under the University of Alberta. The account was also password protected.

Interviews

In-depth information about science teachers' metacognition and their perceptions related to actual and preferred MOLEs were collected through semi-structured interviews. The interview questions were developed focusing in three aspects: state of teachers' metacognition, teachers' perceptions of the actual MOLEs in their science classrooms, and teachers' perceptions of their preferred MOLEs in science classrooms including any challenges in developing MOLEs in their science classrooms. Furthermore, some additional aspects were explored, for example, their context, their perspectives on learning, their science instruction, their students' participation, and obstacles in teaching and learning science. Interview questions are shown in Appendix D.

The interview phase started during survey data collection. Specifically, the questionnaire invitations were sent at the beginning of November, 2021, and the first interview was started in the mid-December, 2022. The last interview was in early April, 2022. The interviewed participants were selected from across the range of the participants' questionnaire responses. Specifically, the distribution of all participants' average response scores for the Mc questionnaire is shown in Figure 3.11. The interviewed participants were selected within each group of those distribution scores. Consequently, the distribution of interviewed participants' average response scores for Mc questionnaire is shown in Figure 3.12. Similarly, the distribution of all participants' average scores and interviewed participants' average scores for the ActualMOLEs questionnaire are shown in Figure 3.13 and 3.14 respectively.

Figure 3.11

All participants' Average Response Score Distribution of Mc Questionnaire

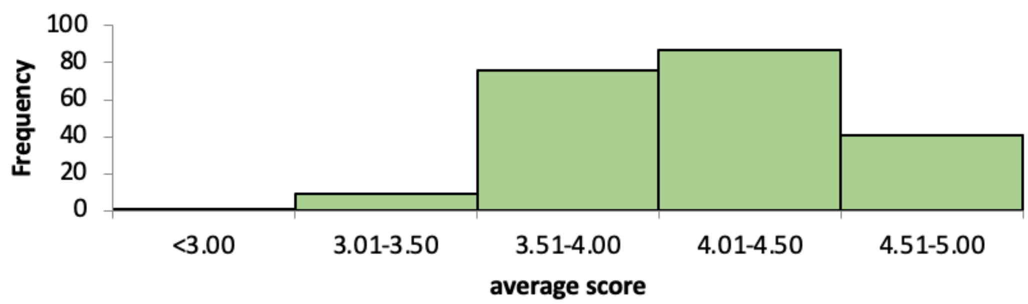


Figure 3.12

Interviewed Participants' Average Response Score Distribution of Mc Questionnaire

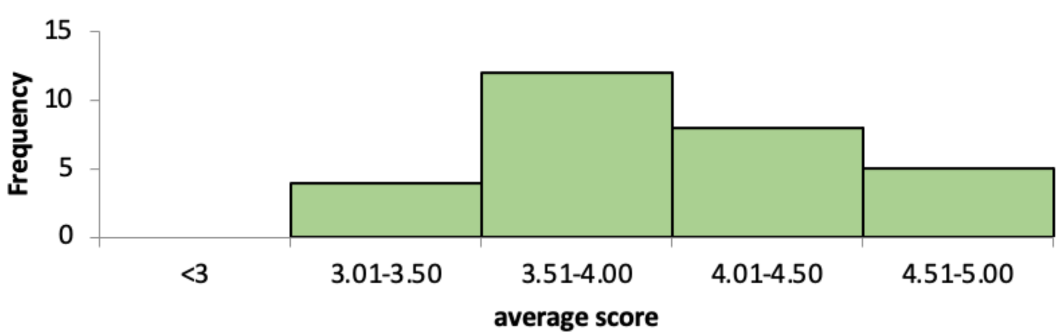


Figure 3.13

All Participants' Average Response Score Distribution of ActualMOLEs Questionnaire

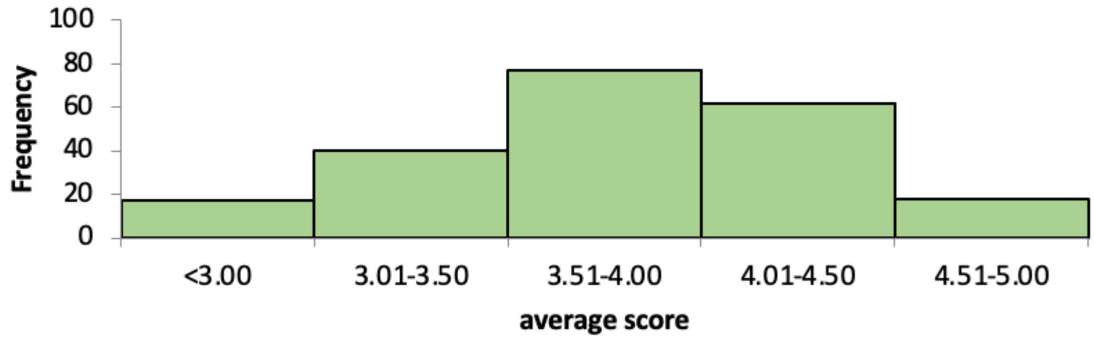
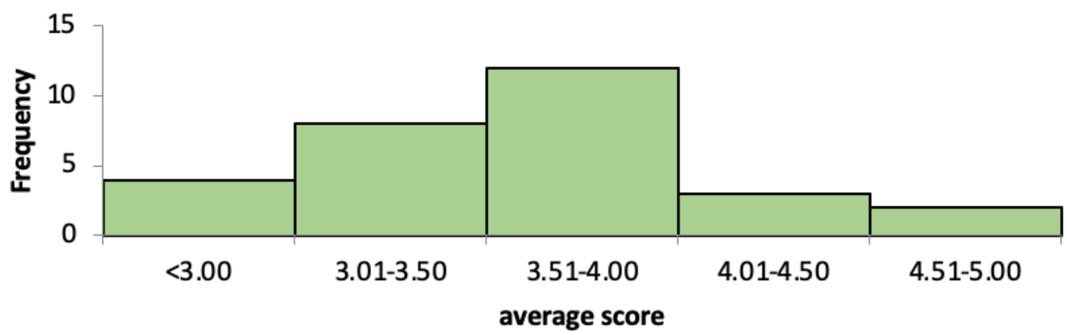


Figure 3.14

Interviewed Participants' Average Response Score Distribution of ActualMOLEs Questionnaire



In relation to the Mc questionnaire, Figure 3.12 shows a similar distribution to Figure 3.11. In relation to the Actual MOLEs questionnaire, Figure 3.14 shows a similar distribution to Figure 3.13. The participants in the interview phase were selected from across range of scores which align with score distribution of the participants in the questionnaire phase for both questionnaires. However, for the score level <3.00 for the Mc questionnaire, the only participant in this level declined to participate in the interview phase.

The selected participants were contacted to ask if they were interested in being interviewed. Even if participants indicated in the questionnaire responses that they were willing to be interviewed, some declined to be interviewed as they were busy and stressed with the Covid-19 situation. Each interview was around 30-50 minutes and was audio recorded. Then, the audio data was transcribed and sent back to each participants for a member checking. The consent forms were sent together with the transcripts to confirm their verbal consent. All digital data including audios, transcripts, and consent were kept in the researcher's computer. The paper data was kept in the locked safe cabinet.

Later, the transcriptions were read by the researcher. Some were translated to English and sent to the supervising Professor to check the interview content. Then, all interviewees were asked to be interviewed for the second time to probe for deeper details. Some were willing to participate, but some were not available. Then, the second interview for some available participants were conducted. In total, there were 29 participants in the first interview, and 21 of them engaged in the second interview.

Data Analysis

The collected data were analyzed in three phases: a quantitative phase, a qualitative phase, and an integration phase. The description of each phase is as follows.

The Quantitative Phase

In this phase, data from two questionnaires (the final versions of the Mc and ActualMOLEs questionnaires) were analyzed in three steps using the SPSS program version 28.

Firstly, the Cronbach's alpha was calculated to explore the reliability or internal consistency of the questionnaires (Bonett & Wright, 2015; Gliem & Gliem, 2003; Tavakol & Dennick, 2011). The reliability of the questionnaire shows the extent to which items in questionnaire consistently measure the same concepts or relate to each other (Tavakol & Dennick, 2011).

Secondly, the mean score and standard deviation of each scale were calculated to provide information about teachers' metacognition, and teachers' perceptions of their actual MOLEs.

Thirdly, the Pearson correlation was calculated to find a correlation (if any) between (1) among subscales of Mc questionnaire, (2) among subscales of ActualMOLEs questionnaire, and (3) between subscales of Mc questionnaire and ActualMOLEs questionnaire.

The Qualitative Phase

In the qualitative phase, the data from the interviews were analyzed using two methods: thematic analysis method and case study.

Thematic Analysis. This method is used to identify, analyze, and report themes that might be identified in the collected data (Braun & Clarke, 2006). Specifically, a theoretical thematic approach was employed. The approach is driven by some theoretical or analytic interests (Braun & Clarke, 2006; Maguire & Delahunt, 2017). In this study, the thematic analysis approach was driven by the research questions. The approaches of the thematic analysis suggested by Braun and Clarke (2006) were employed as follows.

Firstly, to become familiar with the data, each transcript was read and re-read. Then, short notes were written for each interviewee about the participants' metacognition and their actual and preferred metacognitively oriented learning environments. The short notes are, for example, "Miss Nicha showed high level of metacognition, and her classrooms showed activities related to MOLEs. Miss Nicha showed high interest in instruction for metacognition".

Secondly, initiating codes, sentences in transcripts that may relate to the research questions were highlighted. An initial code for each highlighted sentence was created. The process was done manually. The examples of the codes are, for example, able to identify learning strengths, able to identify learning weaknesses, having different processes for learning science, being aware if the teacher understands a science concept, improving cognition, always discussing with students about learning, sometime students discuss with each other about learning science, positive attitude to MOLEs, and tight curriculum as an obstacle. The summary of all codes, sub-themes, and themes is shown in Appendix K.

Thirdly, generating themes was done. Codes were collated and grouped. Sub-themes and main themes were generated. Examples of the sub-themes are: learning strengths, learning strategies, being aware if the teacher understands science, managing own cognition, sharing learning techniques, attitude to MOLEs, and obstacles to instruction for metacognition. Example of themes are metacognitive knowledge, actual MOLEs, and preferred MOLEs

Fourthly, reviewing themes was done. The generated themes were reviewed to see if they fitted with the research questions. Information about what sub-themes and themes fits with which research question is shown in Appendix K.

Fifthly, the final themes and sub-themes were defined and described.

Sixthly, the results were reported. The results of thematic analysis were reported in relationship with research questions. In this document, some excerpts from interview data that relate to the reported themes are presented. Abbreviations of elements of metacognition or dimension of MOLEs that relate to the excerpts will be presented at the end of each excerpt. Those abbreviations are the same as shown in Table 3.3 and 3.9.

The cycle of the second, third, and fourth step were repeated until the themes were saturated.

Furthermore, two transcripts were sent to two individuals who were familiar with conducting thematic analysis in the educational field for peer debriefing process. Their qualifications can be found in Appendix J. Their suggestions were explored in terms of consistency and inconsistency of the analysis themes to improve the thematic analysis in this study.

Case Studies. In order to seek to provide a deeper understanding of teachers' metacognition, their Actual MOLEs, their Preferred MOLEs, and any relationship between those, a Case study approach was adopted. Stake (2006) indicated that "the first objective of a case study is to understand the case" (p.2). Using Case study can facilitate researchers capturing components and factors underlining phenomenon in the case (Mill et al. (2010). Yin (2013) explained a case study methodology as, "an in-depth inquiry into a specific and complex phenomenon (the 'case'), set within its real-world context" (p. 321). Stake (1995) stated, "in qualitative case study, we seek greater understanding of the case. We want to appreciate the uniqueness and complexity of the case, its embeddedness and interaction with its contexts" (p. 16). It can be concluded that case study research focuses on understanding phenomenon or interactions within the focused case in real world situation.

Case study research can be conducted in many contexts including in educational research. Hamilton and Corbett-Whittier (2012) described case study in context of educational research as follows.

> [Case study as a mean] to enhance our understanding of contexts, communities, and individuals. By helping to provide an accessible text which guides you through both practicalities of carrying out research and deeper issues surrounding them, powerful progress can be made in enabling new researchers to make constructive use of a research approach which can begin to capture the complexity of learning and teaching and the contexts and communities surrounding them. (p. 4)

Lincoln and Guba (1990) explained that results from case study research could be transferred for at least three reasons. First, the results can be learned, and that learning knowledge could be then applied in other situations, either similar or different. Second, “a case might be used as a metaphor or used in a metaphoric sense” (p. 58), and third, a case could be used as reference in order to re-evaluate or re-develop knowledge of activities in the case.

Stake (2006) suggested three general rules in selecting cases: “is the case relevant to the quintain [the focus of a study]? do the cases provide diversity across contexts, [and] do the cases provide good opportunities to about complexity and contexts” (p. 23).

Stake (1994, 2003) explained two major types of case study research: intrinsic case study and instrumental case study. The intrinsic case study refers to case study research that focuses primarily on understanding a unique case. The instrumental case study refers to case study research that focuses on providing the deep understanding of issues in the case or making generalizations. The instrumental case study is led more by research questions than researchers’ interest (Mills et al., 2010). Further, Mills et al. (2010) explained instrumental case study as follows.

> The instrumental case study is a tool that facilitates understanding of a particular phenomenon. In developing new theory or testing out existing theory, it allows researchers to use the case as a comparative point across other cases in which the phenomenon might be present. (p. 475)

Yin (2009) mentioned that analyzing a case study may need more than coding as coding may focus on text than meaning underlining the text. Yin suggested four broad strategies in case study analysis, (1) pattern matching, predicting pattern and comparing actual event in a case; (2) evidence-explanation building, using evidence in a case to explain situation in terms of how and why; (3) chronology, arranging evidence chronologically in order to provide consequence explanation; and (4) logic model, looking for any relationship of events over time.

In this study, instrumental case study and evidence-explanation building strategy were adopted. Four case studies were explored and developed for presentation to provide explanations and understandings on teachers' metacognition, their Actual MOLEs, their Preferred MOLEs, and any relationships among those aspects.

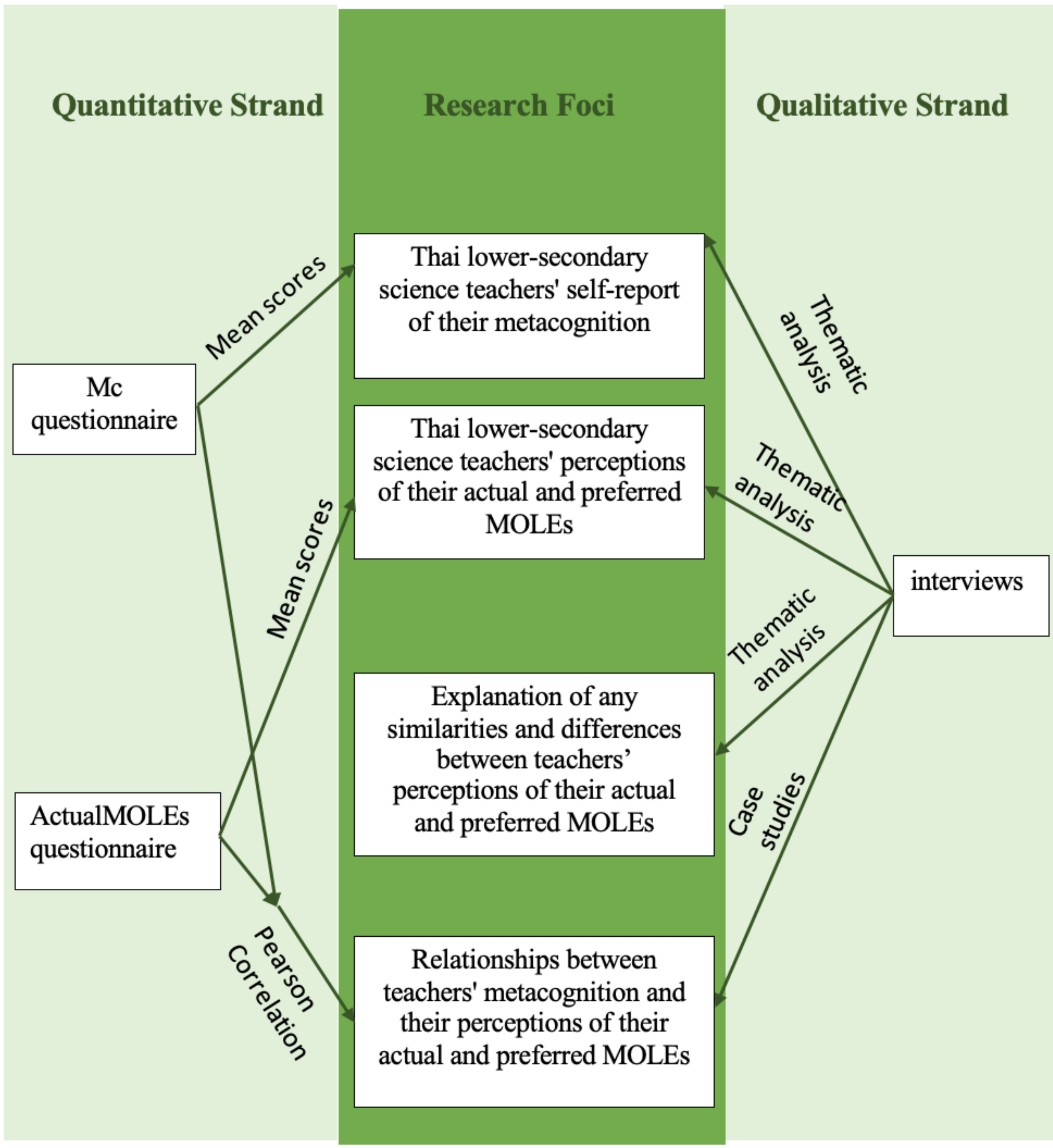
The Integration Phase

In this phase, results from the quantitative and qualitative phase were merged to provide answers to and explanations for the research questions.

For each research question, the quantitative results were explored and consolidated first because the quantitative results can provide a summary overview of participants' perception. Then the qualitative results in relation to that research question were overlayed. The qualitative results provided explanation of participants' responses to the quantitative phase. Any similarity or divergence between quantitative and qualitative data was identified for discussion. Both sets of results were then combined to provide answers to each research question. Finally, the results and answers were reviewed and discussed in relation to related research results from other studies, metacognition theory, and Thailand's cultural and educational context. The summary of data analysis is shown in Figure 3.15.

Figure 3.15

A Summary of Data Analysis in This Research



Research Quality

As the study was designed to employ a mixed methods approach, how research quality was established must be explained. In a mixed methods research study, research quality can be assessed in three ways: the generic research approach (using a generic tool to assess a mixed method research the same way as general research), the individual components approach (using specific criteria to assess each quantitative and qualitative approach), and the mixed methods approach (using criteria that assess the study as a whole unit) (O' Cathain, 2010). The quality of this research was established by considering specific criteria for each quantitative and qualitative approach and also as a whole mixed methods approach. Specifically, the study employed procedures to ensure research quality in three strands: the quantitative strand, the qualitative strand, and the mixed methods strand. Suggestions and justifications of the processes for establishing research quality in quantitative, qualitative, and mix-method research are provided in following sections.

Research Quality in the Quantitative Strand

There are suggestions for establishing quality in quantitative research. Bryman et al. (2008) explored researchers' views on using quality criteria for this research approach. Those criteria from Bryman et al. are, ordering from the most viewed as crucial, validity (data accuracy), reliability (data consistency), generalizability (applicable to new situations), and replicability (ability to reproduce). In addition, Creswell and Plano Clark (2018) suggested procedures for quantitative research, for example, choosing appropriate statistics and certified statistical software for analyzing quantitative data. Teddlie and Tashakkori (2009) suggested similar criteria such as focusing on suitable and acceptable statistical procedures, and further criteria, for example, validity of analysis methods.

The research quality for the quantitative approach in this study was established through following processes. Firstly, the research instruments, as described earlier, were checked for reliability and validity including linguistic validity before using the instruments in the main study.

Secondly, the collected data was checked for reliability and validity using appropriate technique as the Cronbach's alpha, Factor analysis, and Rasch model analysis.

Thirdly, standard statistics methods to interpret collected data were employed, in this case mean score, standard deviation, and Pearson correlation.

Fourthly, the certified software in this case, the SPSS version 28 and WINSTEP version 5.2.3.0 were used to process the mentioned quantitative techniques.

The summary of processes for establishing quality of this research in the quantitative strand is shown in Table 3.12.

Table 3.12

The Summary of Processes for Establishing Research Quality in the Quantitative Strand

Research Strand	Processes for establishing research quality
Quantitative Strand	• Establishing reliability and validity of research instruments • Checking reliability and validity of collected data • Employing standard statistics methods • Using certified software in interpreting data

Research Quality in the Qualitative Strand

For establishing the quality of qualitative research, several sets of criteria were introduced by Lincoln and Guba (1986) who suggested "The parallel criteria of Trustworthiness" (p. 76) as a set of criteria of qualitative research that parallel the criteria used in quantitative research. These criteria include credibility, transferability, dependability, and confirmability. Credibility focusses on the truth value of research data or data accuracy. Processes that could be used to ensure credibility are for example, triangulation (using different sources, methods, time, and investigators to cross-check data); peer debriefing (using peers to check research processes and data); member checking (using participants to confirm information they had provided).

Transferability refers to the ability of the readers to transfer results to other contexts, and using thick descriptions could provide context and enough data for judging if the results are transferable. Data receivers will take responsibility to make the decision regarding if research findings can be transferred into their context (Lincoln & Guba, 1990; Ruddin, 2006).
Lincoln and Guba (1990) suggested that there are at least three ways of transferring research results. First, the results can be learned, and that learned knowledge could be then applied in other situations, either similar or different. Second, "a case might be used as a metaphor or used in a metaphoric sense" (p. 58), and third, results could be used as reference in order to re-evaluate or re-develop knowledge of activities in a future study.

Dependability refers to focuses if the results are consistent over time. Using an external audit could strengthen results consistency. Confirmability refers to the researchers having a neutral position in relation to the research data and results, and not being influenced by bias. These criteria could be established through using external audit.

In addition, Roller and Lavrakas (2015) proposed the “Total Quality Framework” (p. 21). The framework consists of four criteria including credibility, focusing on data accuracy and completeness; analyzability, focusing on interpretation accuracy and completeness; transparency, focusing on disclosure research in all aspects; usefulness, focusing on research benefits.

As those mentioned criteria (credibility, transferability, dependability, and confirmability) are developed based on the quantitative paradigm, Lincoln (1995) proposed other criteria for qualitative research, for example: researchers positionality; stating their standpoint as the researcher’s position could influence how research is conducted, interpreted, and reported; community, being concerned with the relationship between the research and community, as research takes place in communities, it is influenced by community knowledge; voice, focusing on the researcher’s intention; reflexivity, being concerned about self-awareness related to research processes in order to transfer knowledge to benefit self and others.

In this study, the quality (trustworthiness) of the qualitative approach was ensured through the following processes.

Firstly, the researcher collected data based on the data saturation concept meaning that the number of interview participants were increased until there was no new information arising during the interview processes. The total number of interviewed participants were 29 which is greater than the suggested number at 12.

Secondly, the interview transcriptions were confirmed through member checking process.

Thirdly, peer debriefing was used to ensure results from the thematic analysis.

Fourthly, the research context including the Thailand educational context and conducting research under the Covid -19 pandemic were provided in order to establish audience’s understanding about the context of the study.

Fifthly, this researcher's position was disclosed (Researcher's information can be found in Chapter one: researcher's autobiography related to the research and in the special Chapter: researcher narrative in conducting research under the Covid-19 pandemic.).

The summary of processes for establishing quality of this research in the qualitative strand is shown in Table 3.13.

Table 3.13

The Summary of Processes for Establishing Research Quality in the Qualitative Strand

Research Strand	Processes for establishing research quality
Qualitative Strand	• Data saturation • Member checking for interview description • Peer debriefing of thematic analysis • Providing context of study • Disclosed researcher's position

Research Quality in Mixed Methods Strand

Regarding mixed methods research, there are suggestions for establishing research quality. Bryman et al. (2008) suggested four quality criteria for a mixed methods study. Those criteria are, (1) relevance of a mixed methods approach to research questions; (2) transparency of all procedures used in the research; (3) the need or degree of integration of mixed method findings, and (4) the rationale for using mixed methods research.

Tashakkori and Teddlie (2008) proposed two criteria for a mixed methods research: "Design Quality and Interpretive Rigor" (p. 112). The design quality is focused on all processes used in a mixed methods research studying, that is, if they are suitable and effective. The interpretive rigor is focused on interpretating results in terms of, for example establishing if the conclusions align with the findings, if the conclusions are integrated from findings from both quantitative and qualitative strands, and the degree of consistency of findings from quantitative and qualitative strands.

In this study, the research was concerned with design quality and with whether the research design was transparent and causal. Quality of each quantitative and qualitative approach was ensured. Integration points where data from quantitative and qualitative strands were combined were identified. The summary of processes for establishing quality of this research in the mixed-methods strand is shown in Table 3.14.

Table 3.14

The Summary of Processes for Establishing Research Quality in the Mixed-Methods Strand

Research Strand	Processes for establishing research quality
Mix-Methods Strand (A whole research unit)	• Transparent and causal research design • Ensuring quality of each research strand • Identifying integration across quantitative and qualitative strand

Ethical Considerations

The research ethics were established based on three principles of ethical consideration: respect for persons, concern for welfare, and justice (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, Social Sciences and Humanities Research Council of Canada, 2014).

Regarding respect for persons, participants in the research including their institution were treated with respect. There are four protocols related to this principle. First, consent forms were sent to ask for permission from teacher participants for collecting data and using the collected data in the research. Second, the identity of each individual (name of participant) was covered using a pseudonym. Third, each participant had been informed about their autonomy to make a decision if he or she would like to withdraw from participating in the research at any time within one month after data is collected. Finally, the research was conducted by respecting participant dignity. All activities including texts, questions, or speeches were prepared for avoiding any potentially sensitive issues.

In relation to the welfare principle, the research was conducted by regarding the welfare of the participants in all aspects including physical risk, psychological risk, and social risk. Especially during the situation under this Covid-19 pandemic, three protocols were employed. Firstly, all interpersonal physical interaction was avoided. Secondly, questionnaires were sent and collected through mail or an online platform. Thirdly, participant interviews were done through telecommunication (e.g., telephone and mobile application as LINE).

Regarding the justice principle, the research was conducted taking into consideration the benefits to the participants. Research activities were developed with the aim of providing benefit(s) to participants and educational settings as a whole. The benefits are for example, teachers coming to understand their views on MOLEs in order to support MOLEs in their classrooms, their own metacognition, and their science instruction. In addition, in the interview phase, member checking was employed, as transcriptions were presented to participants for precision approval before proceeding to the analysis phase.

Limitations and Delimitations of the Study

There were some limitations in conducting this research, as follows. Firstly, the sampling method of this study could not be done using random sampling, as there is a limitation on being able to approach all science teachers in Thailand. The school-management structure in Thailand is complex. Generally, most schools in Thailand are affiliated with the Ministry of Education. However, around 10% of schools in Thailand are under control by other ministries, for example, the Ministry of Interior, the Ministry of Culture, or the Ministry of Public Health (National Statistical Office, Thailand, n.d.). In addition, there are also complex structures under the Ministry of Education, as there are many offices that have a role to control schools separately. Around 65% of schools under the Ministry of Education are affiliated by the Office of the Basic Education Commission, OBEC. Other schools are under the control of other offices (National Statistical Office, Thailand, n.d.). Obviously, approaching all Thai teachers or representative teachers across country is almost impossible. Therefore, the study could not employ random sampling, as the method requires that every person in a population to have the equal chance to be a participant in a study (Hibberts et al., 2012). Consequently, the findings from this study might not be able to be generalized to and be representative of the views of all Thai science teachers. However, through using the convenience sampling method, research results could present some possible trends or patterns from Thai-teacher participants.

Secondly, Thai culture may impact data precision. Even though, the participants were informed that their identities were protected, and informed that the research results were to improve Thai educational settings, the participants may not have given accurate responses to questionnaire items. With Thai culture, people always show respect to each other and seek to maintain their reputation. Therefore, participants may give responses to questionnaire items in more positive ways than that which reflects their actual situations on perceptions.

Thirdly, teachers' knowledge regarding science pedagogy may impact how they understand MOLEs in the science teaching and learning context. The questionnaire items about teachers' perceptions on MOLEs were developed based on their contexts of teaching and learning science. Teachers' understanding of instruction to facilitate students to learn science may impact how teachers respond to the questionnaire items. For example, if teachers' instruction is focused on teacher-centered orientation, they may not agree with even the possibility of giving opportunity to students to suggest alternative ways of learning in science classrooms.

Fourthly, the context or culture of participants could influence their perceptions. Every context has its own characteristics, and this could affect how people in that context think and what they believe. Thai teachers' perceptions on learning environments may be different from teachers' perceptions from other contexts or cultures. For example, Thai culture focuses largely on respecting each other, especially older people. It is possible that teachers, as older people, could perceive that in quality learning environments students as younger people should respect teachers' decisions about learning activities, and this could affect their perceptions of MOLEs that focuses on supporting students to think about their own thinking. Therefore, in attempting to transfer research results into other educational contexts, others should be aware about the context as described.

Lastly, regarding the Covid-19 situation, participant interviews by interpersonal interaction was to be avoided. Therefore, all interviews in this study were managed through telecommunication. Some limitations in collecting interview data were found. For example, the researcher were not able to capture interviewees' non-verbal language that related to the content of the conversation. So, the researcher may have missed the chance to develop probing questions to gain more information on a topic. In addition, processes of building trust between the researchers and participants may have been incomplete, and the participants may not have provided some essential information to the researchers. In this case, the researcher was prepared and paid more attention to building trust with participants at the beginning of the interviews and provided opportunities for them to share more information after the interview. In addition, the transcript of each interview was sent to each participant in order to confirm their meaning and intention regarding their verbal expressions. Lastly, the researcher concluded the research results by referring the limitation in this research report.

Apart from those limitations, the delimitation in this study could be addressed as follows.

As the research focuses on teachers' perceptions, teachers theoretically could have misperceptions. Those misperceptions could occur as individuals may have flaws in gathering information, processing information, or self-deception (Brumley et al., 2006). However, the Covid-19 situation made classroom observations impossible. Therefore, establishing the accuracy of teachers' perceptions through classroom observation was impossible. In this research, the collected data of teachers' perceptions was analyzed, and the factor of having misperceptions is referred to in the discussion section.

In the next section, I present my personal narrative on conducting this research especially during the Covid-19 pandemic. There are three parts of them. Hopefully, it could provide more understanding and context of this research.

Conducting my Research Under the Covid-19 Pandemic

Part One

When the Covid-19 pandemic hit the world, I was in my last semester of the second year of my PhD program. By the end of that semester, I would fulfill all my course requirements, and was ready to move further to conduct my research. At that time, beside working to accomplish my two study courses, I was working to prepare for my candidacy paper altogether. I got scholarship from my institution in Thailand to study in the program for only 4 years, so I had to be well prepared. I planned ahead with my supervisor, and we had worked back and forth developing the paper since I started my second year. I already reached the 6th draft of the candidacy paper, the full version (I didn't count several writing pieces before the full version). It was almost ready to submit to internal committee. Then the school was closed, and everything was moved to online. I had about one month till the end of that winter semester 2020.

Personally, I was not worried about Covid-19. I considered myself as a cautious, knowledgeable, and healthy person. I thought I could survive the disease. The thing that I was worried about was that if I could conduct my research and finish my program. The research was to be about using metacognitive prompts to improve student learning in science classrooms in Thailand. Observing classroom activities was to be the main data collection method. Not long after the pandemic was announced, the shocking news came to me that many countries including Thailand had plans to close their borders. It was the early stage of the pandemic; anything and any policy could be implemented. The border could be closed for a long time, or it could take so much effort and many procedures to go back to Thailand and collect my research data. I ran many scenarios in my head to find the best way to work with my research. I proposed to my supervisor that I should get back to Thailand as soon as possible. Everything could be done online: finishing my last two course works, meeting with and receiving feedbacks from committee, and doing candidacy exam or even having a theses defense exam if the pandemic would take longer time than two or three years. One thing that could not be done is observing classrooms in person in Thailand. Therefore, by the end of March 2020, I managed to get back to Thailand. I will not mention details about how much chaos there was in the three airports and three airplanes on the way to Thailand, or how the girl who was sitting next to me used a big plastic bag cover over her body from head to toe all the 10 hour-flight long from Vancouver to Taiwan. Those situations did not relate to my research directly; however, those situations were quite the experience, and reminded me that I was not facing the difficulty all alone.

Since I was back in Thailand and had the potential to observe classrooms as I had planned in my research, I thought my plan was good enough and working. Apparently, it was not. I forgot to include one important factor: research ethics. Even though, during that time, there were not many Covid-19 cases in Thailand, schools were still open. Teachers and students were in their classrooms. There were some concerns about conducting research in classrooms during pandemic from the ethics board of the University of Alberta. There should not be any potential risk of Covid-19 contagion to teacher or student participants. Therefore, it was impossible to observe classrooms in person. The situation left me with two options. I could wait until the pandemic passed to collect my research data, or I could develop a new research topic as that I could collect data without any in-person interaction. I did not consider observing classrooms online as another option, as that approach would use a lot of effort from my possible teacher participants. Under the pandemic, they had so much work to do already. In addition, I did not know if observing online classrooms would allow me to collect the regarded data.

Of the two available options, I chose to depend on myself and not wait for the pandemic to clear. Even though in developing a new research topic, I had to start over at least I could control my own pace. There was one more thing that I worried about; it was that my supervisor. The year 2020 was his sabbatical year. If I had to develop a new research topic, I still needed his suggestions along the way. He had to start over with me. Then I asked him, and he was kind enough to be willing to do that. Therefore, my first research topic, my proud 6th draft of candidacy paper, was dropped to my computer's 'old' folder. It was so hard to accept that since I had put so much time and effort into that work, but I just knew I did the right thing.

Part Two

Finally, my new research topic, this current one, was created. Even though this one is the one that I developed to replace the old one, I tried to develop it in the way that this topic is also valuable to educational settings both in context of Thailand and for metacognition. Also, this research could be possible to conduct under the pandemic. The main methods of data collection of this research are online survey and online interview. However, in order to conduct the research, I had to take at least one more course about quantitative method to ensure that I had enough knowledge to manage statistics, or standard processes and meanings in survey research. I was in Thailand which has 13 or 14 hour-time difference with Edmonton. Although the course was asynchronous, if I would like to discuss with the class and professor, I had to attend the class at 2 or 3 am during that Fall semester twice a week. Also, the final exam was at 4 am. One time, I forgot that daylight saving time ends during November, I just waited to study at 2 am and found nobody there, as I was early for one hour. Actually, taking another course or waking up at 2 am to study was not an issue for me, having an academic environment was. Motivating myself to focus in developing my research topic, reading papers, or crafting a candidacy paper in such academic isolating environment was challenging. There were several moments that I had a blurred picture about if I was still a PhD student who used to study abroad, and used to live in Edmonton. Finally, my candidacy exam was in July 15, 2021. It took me about one year and three months from deciding to drop my first research to passing the candidacy exam.

Part Three

Developing and getting passed the candidacy exam was one story, but managing to collect data during the pandemic was another whole story. By the time that I passed research ethics approval, and was ready to collect my data, Thailand was facing Covid-19 a great deal. The Covid-19 new cases reached over 20,000 each day. People were in panic. The government released policies, for example, province border closure, curfew after 9 pm, close contact quarantine, etc. Schools were switched on and off between online and in-person instruction. Teachers were busy adjusting with new instructional approaches, and they were overwhelmed. Inevitably, my participants are those teachers, science teachers who teach in lower secondary level. My plans for data collection were that I would do an online survey for a pilot study with 20-30 teacher participants, then an online survey in the main study with 400 participants, and interview with around 20 participants. My data collection in the pilot study worked smoothly, as I made phone calls to some teachers who I used to work with. I asked them if they were interested to do an online survey and asked them if they could share the online survey link to other potential participants whom they know. I got enough participants for my pilot study within two weeks. Next, in the main study, the invitation letters were sent to about 500 schools that have a connection with my workplace, the Institute for the Promotion of Teaching Science and Technology (IPST). There are at least 3 science teachers teaching in the lower secondary level at each school. I expected that I could get over 400 responses. The invitation letters were sent out around the beginning of November, 2021. After waiting for two months, there were only around 80 responses back. Teachers must have been swamped and exhausted with the Covid-19 situation. However, the number was far less than needed for my proper sample size. After that, I sent invitation letters again to school that are not in the IPST network. The total was about 500 schools, randomly in rural and urban area across 77 provinces in Thailand. Another two months passed, and there were around 80 more responses back. In the meantime, I tried to send online invitations through many channels such as IPST Facebook page, science teacher influencer pages, the Thai science teacher association online group chat, my colleagues who have connection with potential participants, or online workshops for science teachers. I extended the data collection period from during the school semester (November 2021- mid March 2022) to the school break (mid-March to mid-April2022). The number of responses were just a bit over 200 after almost six months of data collection. At that time, I believe more than 3,000 science teachers in Thailand had heard about my research invitation. Some teachers may have heard about it twice or more than that. I checked if the response number pass the minimum criteria for data analysis statistically. Indeed, the number just passes the criteria about 10 responses. Then, I decided to stop sending invitation otherwise those teachers could be more overwhelmed by my research than the Covid-19 situation.

I interviewed teacher participants along the period of collecting survey data; actually, my first interview was around mid-December, 2021 after sending the first online survey invitation for about one and a half month. From the number of responses back form my online survey, I could sense that teachers were very busy and had to concentrate on their classrooms. However, I could feel their stress clearly during I made phone calls asking them if they would like to participate in my interview. Even some teachers who indicated on the online survey that they were willing to be interviewed in my research refused politely to be interviewed when I contacted them. They were already very busy and stressed with teaching and school work. Many teachers had to re-schedule time for interviewing many times, and some finally canceled the interview for good. Once I got to interview teacher participants, most of teachers carried their stress of teaching under Covid-19 with them. They were frustrated to adjusting themselves to online instruction and trying to keep their students learning in their online class, not to mention about their students' lacking online learning equipment and internet connections. Some teachers talked to me about thinking of quitting their job, even they loved teaching so much. The worst part of the Covid-19 pandemic may be not about getting the disease, the Covid-19, itself, but the results of it. When I interviewed those teachers, I was willing to hear their stories, but sometimes I got distracted. I was moved by their stories. I had to put a lot of effort to focus on my interview about teaching and learning in classrooms related to my research questions. My last interview was just a couple of days before mid-April 2022. Finally, I got almost 30 interview transcripts in total. I flew back to Edmonton by the end of April 2022. I was ready to analyze and interpret data. The pandemic situation in Canada was good. Many restrictions had been lifted. Actually, most of activities in the University of Alberta were getting back to normal. It was early September 2022 when I wrote this chapter, and I already got the third shot of vaccine a couple months before. Hopefully, everything keeps getting better and better not only in Canada and Thailand but around the world.

When my supervisor suggested me to write about my difficulties in conducting my research, I was a bit reluctant and unsure if it would be beneficial or relate to my research. However, when I wrote this chapter, I found myself teared up sometimes. I had never thought that I had been through a lot. However, all difficulties that I experienced did not discourage me.

On the other hand, it motivated me to keep working, as I hope that the results of my work could benefit educational settings in some ways, especially to those teachers.

CHAPTER FOUR

DATA ANALYSIS, FINDINGS, and DISCUSSION

Chapter four consists of five main sections. The first four sections are aligned with the four research questions. In each part, I first provide analysis and findings of data from the questionnaire(s) where applicable. Then analysis and findings from interviews follows. Then, I discuss the similarity and divergence of quantitative and qualitative findings together with additional findings. At the end of each section, I provide discussion in relation to other research results, metacognition theory, and Thailand context. The fifth section contains findings other than those that focused in the research questions that emerged from this study.

The research questions for this study, as mentioned earlier, are shown as below.

1. What are Thai lower-secondary science teachers' self-reports of their metacognition?
2. What are Thai lower-secondary science teachers' perceptions of their actual and preferred metacognitively oriented science classroom learning environments?
3. Is there a relationship between Thai lower-secondary science teachers' metacognition and their perceptions of their actual and preferred metacognitive orientations of their science classroom learning environments?
4. How do Thai lower-secondary science teachers explain any similarities and differences between their preferred and actual metacognitively oriented science classrooms?

Research Question 1: What are Thai Lower-Secondary Science Teachers' Self-Reports of Their Metacognition?

As mentioned previously, teachers' metacognition was conceptualized consisting of two categories: Metacognitive Knowledge and Regulation. In exploring teachers' metacognition, data from the Mc questionnaire and interviews were analyzed. The Mc questionnaire consists of three subscales that related to teachers' metacognition. In thematic analysis of interview data, many themes in relation to teachers' metacognition were emerged. A summary of questionnaire subscales and themes from the interviews in relation to teachers' metacognition is shown in Table 4. 1.

Table 4.1

A Summary of Mc Questionnaire Subscales and Themes from Thematic Analysis of Interview data in relation to Teachers' metacognition

Teachers' metacognition	Quantitative Strand: Mc Questionnaire Subscales	Qualitative Strand: Themes
Metacognitive Knowledge		
Declarative Knowledge	Declarative Knowledge	Learning Strengths and Weaknesses Learning Definition
Procedural Knowledge	Learning Process Knowledge (Procedural and Conditional Knowledge)	Learning Processes
Conditional Knowledge		Learning Processes in Different Situations
Metacognitive Regulation		
Monitoring	Regulation (Monitoring, Evaluating, Improving)	Monitoring Their Cognition When Learning Science
Evaluating		Evaluating Their Cognition From Learning Science
Improving		Managing Their Cognition For Learning Science (Improving and Planning)
Planning		

In the following section, questionnaire data and findings of teachers' metacognition in both metacognitive knowledge and regulation categories are shown first. Then interview data and findings of teachers' metacognition are then presented shown. Finally, a summary and discussion of the teachers' metacognition is provided.

Teachers' metacognition: Questionnaire Data and Findings

According to the research framework in Chapter two, teachers' metacognition was organized into two categories: Metacognitive Knowledge and Metacognitive Regulation. Metacognitive Knowledge consists of three elements: Declarative Knowledge, Procedural Knowledge, and Conditional Knowledge. Metacognitive Regulation consists of four elements: Monitoring, Evaluating, Improving, and Planning own cognition. To explore teachers' metacognition, the questionnaire for Assessing Science Teachers' Metacognition was utilized. The questionnaire was validated as outlined in Chapter three. The three subscales of the questionnaire are Declarative Knowledge, Learning Process Knowledge, and Regulation. The first two subscales assess teachers' metacognition in terms of their Metacognitive Knowledge. The third subscale assesses teachers' metacognition in terms of their Metacognitive Regulation. Details about which each subscale assesses teachers' metacognition in which elements was provided in Chapter three.

Prior to exploring findings of the questionnaire data, the quality and reliability of response data was undertaken as follows. From 214 responses of the questionnaire, there were 37 missing data point (from 5778 data points) which is 0.64% missing data. According to Raymond and Roberts (1987), missing data that is less than 2% will not have significant difference in data measurement. Roth (1994) suggested methods such as using mean substitution or pairwise to manage 1-5% missing data. Therefore, missing data in this study did not violate data measurement. Accordingly, mean substitution was applied in the statistics analyses. In addition, Cronbach's Alpha was calculated to check the reliability of the participants' responses to the questionnaire. Then, the descriptive statistics of the questionnaire data were analyzed. The result for each subscale is shown in Table 4.2.

Table 4.2

Cronbach's Alpha results and descriptive statistics of each subscale in the MC questionnaire.

Questionnaire/Subscale	Cronbach's Alpha	Mean score	Std. Deviation	Item mean score range
Declarative Knowledge	0.77	4.24	0.43	4.15 – 4.42
Learning Process Knowledge	0.89	4.23	0.42	4.10 – 4.37
Regulation	0.91	4.10	0.41	4.02 – 4.19

The Cronbach's Alpha of all three subscales is above 0.7. Therefore, the response data of the participants to the questionnaire can be considered reliable. Mean score of subscales Declarative Knowledge (D), Learning Process Knowledge (LP), and Regulation (R) are 4.24, 4.23, and 4.10 respectively. The standard deviation values of each subscale are less than their subscale mean; therefore, the data distribution in each item is considered normal (Livingston, 2004). Many statistics, for example correlation or t-test, make their assumption based on normal distribution (Altman & Bland, 1995; Krithikadatta, 2014). In conclusion the responses from participants are reliable.

Focusing on the mean score of each subscale, all values exceed 4.00, but less than 4.50. As the questionnaire employs the five-point Likert scale, this suggests that the mean score of each subscale is located between *Agree* and *Strongly Agree*, and located closer to *Agree* than *Strongly Agree*. The results suggest that, on the whole, this group of science teachers is likely to agree with all three elements of metacognition represented by the subscales in the metacognition questionnaire.

The mean scores of the subscales were explored further to ascertain if the mean score of each subscale was significantly different from mean scores of other subscales. In this regard, the paired t-test statistic was calculated. The t-test results of each pair of subscales in Mc questionnaire are shown in Table 4.3.

Table 4.3

Paired T- Test Results of Each Subscale Pair in the MC questionnaire at 95% Significant level

Pair	t-test value	df	P-Value (two-tailed)
Mc_D – Mc_LP	0.86	213	0.391
Mc_D – Mc_R	7.76	213	<0.001
Mc_LP – Mc_R	7.71	213	<0.001

Note: Mc_D = Declarative Knowledge, Mc_LP = Learning Process Knowledge, Mc_R= Regulation

In the t-test analysis, for studies with a participant number greater than 120, as in this study, if mean scores of two subscales in a pair are significantly different form each other, the t-test value should be over the range ± 1.96 at 95% significant level, and its p value should be less than 0.05 (Gravetter, & Wallnau, 2017). From Table 4.3, the t-test value between the pair of the subscales Declarative knowledge and Learning Process knowledge is less then 1.96 with p value more than 0.05. This suggests that the mean scores of these two subscales are not significantly different at 95% significant level. For the other two pairs, the pair of subscales Declarative knowledge and Regulation, and the pair of subscales Learning Process Knowledge and Regulation, their t-test values are more than 1.96 and their p values are less than 0.001. The results suggest that, within each of these two pairs, subscale mean scores are significantly different from each other at 95% significant level.

Accordingly, the mean scores of the subscales Declarative Knowledge and Learning Process Knowledge are considered to be no different from each other, and their mean scores are higher than that of the Regulation subscale. Therefore, it is suggested that this group of teachers were more likely to agree with items that concern their Declarative knowledge and Learning Process Knowledge than agree with those that concern their Regulation. For example, they were more agree with items such as *D1 I know what it means to learn science* and items such as *LP2 I know how to learn science* than items such as *R7 I evaluate myself to know if I learn* science. It could be interpreted that the Regulation element was the least endorsed by the participants in terms of their metacognition compared to the Declarative and Learning Process Knowledge elements.

Next, relationships between elements of teachers' metacognition were investigated. Accordingly, teachers' responses of the three subscales of the Mc questionnaire were analyzed. The results of the Pearson correlation between the subscales are shown in Table 4.4, and their correlation graphs are shown in Figure 4.1

Table 4.4

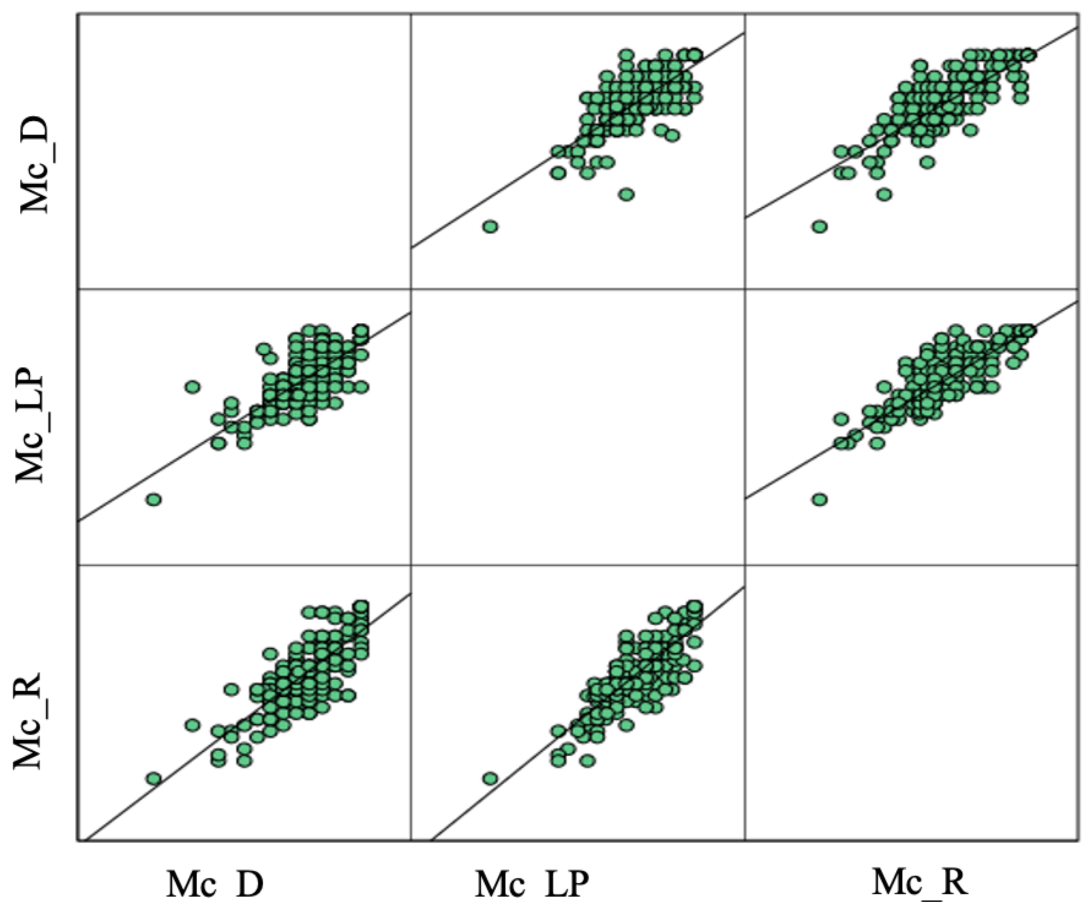
The Pearson Correlation Values Between Subscales of the Mc questionnaire

Subscales	Pearson Correlation	P-Value (two-tailed)
Mc_D – Mc_LP	0.77	<0.001
Mc_D – Mc_R	0.80	<0.001
Mc_LP – Mc_R	0.84	<0.001

Note Mc_D refers to Declarative Knowledge subscale
Mc_LP refers to Learning Process Knowledge subscale
Mc_R refers to Regulation subscale

Figure 4.1

Correlation Graphs Between Three Subscales of Mc questionnaire



The analysis results show that all subscales within the Mc questionnaire are correlated significantly($p<0.001$). Taylor (1990) stated that the correlation coefficients <0.35 are considered weak, 0.36-0.67 are considered moderate, and 0.68-1.0 are considered strong. According to Taylor (1990), the correlation among subscales in Mc questionnaire are considered strong. All correlations are positive. The results suggest that, within this group of teachers, there were relationships between the three elements of teachers' metacognition. Specifically, teachers' metacognition, Declarative Knowledge, Learning Process Knowledge, and Regulation were related to each other. In this group of teachers, science teachers who reported high endorsement of the subscale Declarative Knowledge were likely to report their high endorsement of the subscales Learning Process Knowledge. Teachers who reported their low endorsement of the subscale Learning Process Knowledge were also likely to report their low endorsement of the subscale Regulation.

The correlation values ranging from the highest to the lowest were Learning Process Knowledge and Regulation, the subscales Declarative Knowledge and Regulation, and the subscales Declarative Knowledge and Learning Process Knowledge. The results suggest that within the two elements metacognitive knowledge, teachers' metacognition in relation to the Learning Process Knowledge were more correlated with Regulation than the Declarative Knowledge (with Regulation).

Teachers' Metacognition: Interview Data and Findings

To explore teachers' metacognition, interview data were selected from the thematic analysis of teacher interviews regarding teachers' metacognitive knowledge and metacognitive regulation. To begin with, 23 out of 29 teacher participants reported they had never heard about metacognition before. Six teachers mentioned that they had heard about metacognition, but they were not clear about the concept. Therefore, for this group of teacher participants, metacognition was, at best, a relatively new concept for them. Overall, they were not familiar with it.

Teachers' Metacognitive Knowledge

Teachers' metacognitive knowledge, from the analysis of their interviews, was reflected in four themes: (1) their own definition of science learning, (2) their knowledge about their science learning strengths and weaknesses, (3) their knowledge of their science learning processes, and (4) their knowledge of their science learning processes in different situations. The themes (1) and (2) align with Metacognitive knowledge in relation to Declarative knowledge(dk). The themes (3) and (4) align with metacognitive knowledge in relation to Procedural knowledge (pk), and Conditional knowledge (ck) respectively (see Table 4.1).

Learning Definitions. All teachers could explain their own definition of science learning. Their explanations were, for example,

"Learning, in my own thought [mind], is finding own ways to make myself understand the concept and be able to solve a problem." (Ms. Malee) (dk)

"Learning is that when we have interest to study in a topic, so we could use the knowledge to be beneficial in some ways." (Mr. Wha) (dk)

"Learning, right? Learning has many ways. We have interest or want to study about something. It is like we want to know about something; then we get deep into it. We may study through the internet or we may ask experts about that." (Ms. Khun) (dk)(pk)

Learning Strengths and Weaknesses. When teacher participants were asked about their strengths and weaknesses in learning science, the participants could be categorized into three groups. Twenty-three of 29 participants could identify what their strengths and weaknesses were. For example, these teachers explained that:

"I know, I know my weakness. It is about the subject that is involved with English terms like Biology. I'm not good at memorizing them. If I get to teach this subject, I know automatically that I have to prepare a lot. But if it is about calculation, it is my area. I'm good at numbers and equations." (Mr. Racha) (dk)

"It is my weakness that if I do not like a topic; I do not want to learn about it. On the other hand (on my strengths), if I have interest it, I will study it further." (Ms. Keaw) (dk)

Three teachers needed more explanation about the meaning and examples of strengths and weaknesses of learning, for example, realizing that they have a good memory or good at calculation. However, another three teachers even after having received some explanation could not identify their strengths and weaknesses as science learners. They replied, for example,

"I have never analyzed my strengths and weaknesses." (Ms. Sanho) (dk)

"I'm not really clear about what are my learning strengths and weaknesses." (Ms. Pradu) (dk)

Learning Processes. All teachers could explain processes that they used to learn science. They mentioned processes like, for instance, reading from books or internet, conducting some experiments, and asking experts. They explained, for example,

"I will read it first, then I try to connect with my prior knowledge. It is like I could summarize the information to my own words, and then I try to apply to some examples to make it clearer." (Ms. Chaba) (pk)

"I will read and watch from many sources. Then I will compare them." (Mr. Tawan) (pk)

Learning Processes in Different Situations. When participants were asked if they have different processes in learning in different situations, 18 could explain using different learning processes in different situations. They reported, for example,

> "I study by using the internet, then I record it [information] on my iPad, so I do not forget about it. And if there is a part that I do not understand, I will learn by doing experiments." (Mr. Wan) (ck)

> "There are many ways to learn. I learn from doing experiments, exploring content knowledge, and applying knowledge." "Sometimes, I ask experts." (Ms. Peep) (ck)

In conclusion, teachers' metacognitive knowledge was evident through their interview data. All teachers reported their declarative knowledge in relation to their own individual definition of learning. Twenty-three teachers reported their declarative knowledge about their strengths and weaknesses. All teachers reported procedural knowledge about how they learn science. Eighteen teachers reported their conditional knowledge in relation to how they learn science in different situations.

Teachers' Metacognitive Regulation

Interview data on teachers' metacognition regarding their regulation of their cognition was reflected in three themes: (1) if teachers could monitor their cognition, (2) if teachers could evaluate their cognition, and (3) whether teachers could manage their learning processes to learn based on knowledge of their cognition. Those three themes relate to teachers' regulation in elements of monitoring (mn), evaluating (ev), and improving (im) and planning (pl) respectively.

Monitoring Their Cognition When Learning Science. All teachers reported that they knew when they understood or did not understand science concepts. They reported, for example,

> "There are some science concepts that I know I do not understand them, as there is a lot to be understood. However, for some concepts that need memorizing, I think I know that I understand them." (Ms. Matoom) (mn)

"When I face some situations [in relation to science concepts], or something comes up, then I get like, "okay this is what I already knew". I'm just realizing that I have learned about this concept." (Ms. Ubon) (mn)

Evaluating Their Cognition From Learning Science. When they were asked about how they knew if they actually learned science, their responses were varied. Only 19 teachers could explain how they knew that they had learned science. They explained, for example,

"I could explain it [the science concept]. I could find a reason to support what is the cause and results of it [concept knowledge that they had learned]. And I could explain to other people to understand that knowledge" (Ms. Chaba) (ev)

"I will connect the new knowledge to what I already know, then think about it in a picture, or connect it with some of my experiences. Also, if I could explain it to other people. Until then, I could be confident that I really understand it [the concept]" (Ms. Tawan) (ev)

Ten teachers could not explain about this matter clearly. Eight teachers mentioned that they did not know how they knew that they had learned science; they just learned, and they thought learning was an automatic process for them. Examples of their responses are as follows.

"How do I know that I have learned? Ummm it should be something like …umm… what tells me that I have learned …ummm ummm… I'm not sure. It is difficult to answer" (Mr. Kasalong) (ev)

"Ummm… this is difficult to answer. Sometimes, we just learn it without any process. It is automatic. I think it is by nature that we learn this way. I do not think about how I learn. I have never thought about it. So, I could not explain clearly how I learn." (Mr. Pud) (ev)

Managing Their Cognition for Learning Science. Teachers were asked questions to explore their regulation in terms of improving and planning their own regulation. All teachers mentioned, in general, that they would like to improve their own learning, for example,

> "It is going by the flow, but I like it to be better. I would like to make it better" (Ms. Sanho)
>
> "I like to do it [learning science] my best in everyday, but I like to keep improving it further" (Ms. Jampa)

However, there were only three teachers who explained that they had done something to improve their learning weaknesses. In addition, six more teachers mentioned how they managed to benefit from their learning strengths and/or weaknesses. Their responses were, for example,

> "My weakness is about calculation. When I know that I'm not good in calculation, I try to accumulate experience. I attended a training program, studied techniques from google. I try to prepare it before I get to teach to students" (Ms. Chomjan) (im)
>
> "My weakness, as I told you, is that my thought is not well organized…. I thought that 'How could I have data in my thought for longer time?' I thought that I should organize my thought. "How to organize data/information in my thought", I adopt the Samathi สมาธิ technique. I do meditation for longer time. Samathi is something that we do to make our mind stay still. I have to have Sati สติ before making decision or learning anything. I have to have Samathi and Sati in order to learn better" (Mr. Wan) (Pl)

In conclusion, in relation to their regulation, all teachers reflected that they could monitor if they understood or did not understand science concepts. But in terms of evaluating their own cognition, only 19 could explain how they knew they understood and had any criteria to check it. On the other hand, 10 could not explain how they understand science. Within this group of teachers, eight teachers mentioned learning as an automatic process. Specifically, in terms of managing their own cognition, nine teachers reported that they could manage their own thoughts about learning based on their knowledge of their own cognition.

From the interview data, differentiation between teachers' metacognitive knowledge and regulation was identified. The evidence suggests that more teachers reported on their metacognitive knowledge than on their regulation. Specifically, in relation to metacognitive knowledge, all teachers could explain their science learning definition and their processes for learning science, and 18 could explain different processes in different learning situations. However, in relation to regulation, 19 explained how they checked if they had learned science, and 9 reported how they managed their learning based on their knowledge of their cognition.

Summary and Discussions

In this section, findings about teachers' metacognition from both quantitative and qualitative strands are summarized and discussed as follows.

Thai Lower Secondary Level Science Teachers Reported Their Metacognition in relation to Both Metacognitive Knowledge and Metacognitive Regulation

Findings from both quantitative and qualitative strand suggest similar results. Thai science teachers in this group reported their metacognition. Their reported metacognition relates to both Metacognitive Knowledge and Metacognitive Regulation.

Teachers Reported Their Metacognitive Knowledge in Two Different Elements

Metacognitive knowledge, in the original framework for this study, consists of three elements: Declarative knowledge, Procedural knowledge, and Conditional knowledge. The analyses of interview data indicated that teachers reported their metacognitive knowledge in relation to all three of those elements. However, analysis of questionnaire responses suggests that teachers reported their metacognitive knowledge differently to those in the original framework, that is, as Declarative knowledge and Learning Process knowledge. The Learning Process Knowledge was formed from items related to Procedural and Conditional Knowledge. This suggests that this group of teachers did not differentiate between Procedural and Conditional knowledge. Teachers may view the two parts of metacognitive knowledge as one.

Teachers Reported Their Metacognitive Regulation as One Element

Regulation of cognition, in the original framework, consists of four elements including monitoring, evaluating, improving, and planning. From the qualitative analyses, different elements of teachers' regulation became evident. Teachers reported three elements of regulation; they could monitor, evaluate, and manage their own cognition. Within this group of teachers, references to teachers' improving and planning own cognition were considered as a one theme of managing own cognition. In teachers' interviews, improving and planning own cognition were closely related, and there was less evidence of these two elements of regulation in teachers' interviews. Further, findings from quantitative analysis suggested that they did not differentiate among monitoring, evaluating, improving, and planning. Teachers may view those elements of regulation as the same.

Veenman et al. (2006) suggested the need for more precise taxonomies of metacognition elements. They pointed that out elements of metacognition were considered in different categories by different researchers. Zohar and Ben David (2009) mentioned the similar concerns. In addition, they stated importance of identifying the context within which metacognition of taxonomy was defined as they perceived metacognition as relational concept.

Findings from this study provide supporting evidence for developing a precise metacognition taxonomy as mentioned in Veenman et al. (2006) and Zohar and Ben David, (2009). Firstly, a metacognition taxonomy could be different depending on the context. For example, even at the beginning of this study, three elements of Metacognitive knowledge were used in the framework. Findings from the quantitative analyses, and of teachers' responses in this group, suggest two elements of Metacognitive knowledge. Secondly, findings from quantitative analyses may suggest a metacognition taxonomy for Thai science teachers in this group that consists of Metacognitive knowledge and Metacognitive Regulation. The Metacognitive Knowledge consists of two elements: Declarative and Learning Process knowledge. In the Metacognitive Regulation consist of one element: Regulation.

Teachers Reported their Metacognitive Knowledge and Regulation Differently

Analyses of both quantitative and qualitative data suggest that there was differentiation between teachers' metacognitive knowledge and metacognitive regulation. The mean of the subscale Regulation is significantly different to the means the subscales Declarative knowledge and Learning Process knowledge. The Regulation mean score is lower (see Table 4.2). This suggests that, on average, teachers may endorse items in the subscale Regulation less than other two subscales. Moreover, findings from qualitative strand suggest the same trend. Fewer teachers reported about their regulation than their metacognitive knowledge. The findings are consistent with conclusion of Firth (2012). Firth concluded from many previous studies that, "we have little or no direct conscious access to higher order cognitive processes. We may have access to the outcomes of these processes, but, through introspection, we get very little idea as to how these outcomes are achieved" (p. 2214). Firth suggested that being aware of one's own thoughts is already difficult, and getting to manage one's thoughts is even more difficult. Firth's conclusion could be used to explain why this group of teachers reported about their regulation less than their metacognitive knowledge.

Three Elements of Teachers' Metacognition Were Found Related to Each Other

Findings from correlation analysis suggest that there were correlations between three subscales of Mc questionnaire: Declarative Knowledge, Learning Process Knowledge, and Regulation. All pairs have positive and strong correlation at 95% significance level. The correlation values ranged from high to low as follows: Learning process Knowledge and Regulation (0.84), Declarative Knowledge and Regulation (0.80), and Declarative Knowledge and Learning process Knowledge (0.77). The strong correlation between the subscales suggests strong relationship among those three elements of teachers' metacognition.

Teachers' Metacognition in Relation to Regulation was Found More Related to Learning Process Knowledge than Declarative Knowledge

The subscales Declarative Knowledge and Learning Process Knowledge were considered in this research to be in the same category: Metacognitive Knowledge. Findings from the quantitative analysis suggest that the correlation was higher for the pair of Learning Process Knowledge and Regulation is than the pair of Declarative Knowledge and Regulation. In addition, the correlation value between the subscales Declarative Knowledge and Learning Process Knowledge is lower than that of the pairs of each of the two subscales and the subscale Regulation.

Teachers Reported About their Metacognition Even Though They were not Familiar with the Concept

Although all teachers reported that they were not familiar with metacognition, all teachers could report about their metacognition especially in relation to metacognitive knowledge. Frith (2012) suggested metacognition was not inherited through genetics but developed through social interaction. Firth explained that:

> at the beginning of our life, the content of explicit metacognition is a blank slate on which we learn to write our experiences. And what we learn to write there is determined largely by social interactions: discussions with others, hearing stories and looking at pictures. In this way, humans develop shared views of the world and of themselves, which develop within each lifetime and which evolve across generations to form cultural norms and beliefs. (p. 2220)

Considering Firth's ideas, Thai science teachers in this group could report their metacognition, as they may develop their metacognition through their interaction within the environments within which they were situated. As they were not familiar with the metacognition concept, interaction related to development of their metacognition may be implicit/hidden in their social interaction and educational environments.

There was no Report Regarding Teachers' Metacognition in Other Studies in the Thai Context

The earlier literature review on science teachers' metacognition in Thailand context found that no research papers were evident (no evidence was evident of exploring metacognition in teachers in any subject area in Thailand). The lack of research on teachers' metacognition was also reported by Sanium and Buaraphan (2019, October), as they had reviewed research papers published in Thailand Library Integrated System (ThaiLIS) between 2001-2016. Therefore, there is no information to reference or compare the findings from these science teachers to in the Thailand context. The findings from this study provide initial information about the metacognition of lower secondary science teachers in Thailand.

There Were Reports Regarding Teachers' Metacognition in International Studies

Research exploring teachers' metacognition internationally is rare especially in practicing teachers. Hughes (2017) explored 18 technology and engineering teachers in the USA setting by adopting interview questions based on items from Metacognitive Awareness Inventory, MAI (Schraw & Dennison, 1994). The findings of Hughes (2017) align with the findings from this study in terms of differentiation between teachers' metacognitive knowledge and regulation. Hughes (2017) found that, overall, participants could occasionally explain less than 50% of listed questions about how, why, and what strategies to use in their learning. Hughes concluded that teacher participants showed low to medium levels of knowledge of cognition. In addition, teacher participants were reported less frequently engage in metacognitive regulation. Results from Hughes's are comparable with results from this study, as explained, before as teachers reported their regulation less than their metacognitive knowledge.

Prytula (2012) investigated teachers' metacognition in the context of professional learning community (PLC) in Canada. Three teachers from three separate PLC were interviewed. Prytula reported that all three teachers could explain their metacognition to different degrees in relation to (1) being aware of their own thinking, (2) understanding and managing their learning processes, and (3) using their understanding of their own learning processes to help others with learning. It could be interpreted that the aspects (1) and (2) related to metacognitive knowledge and metacognitive regulation respectively. However, Prytula mentioned only that teachers reported different degrees of metacognition, but did not explain further in how they were different.

Zohar (1999) explored the Declarative Knowledge of teachers who participated in Teaching Thinking Science Courses in Israel. Data of teachers' discussions during two courses, the researcher's course observation, and 39 teachers' written works were analyzed. Zohar concluded that "teachers' intuitive declarative metacognitive knowledge of thinking skills was found to be unsatisfactory for the purpose of teaching higher order thinking in science classrooms" p. 426. The study by Zohar also suggests insufficient level of teachers' metacognition in the context of her study.

In summary, findings of teachers' metacognition from this study could be added in the field of metacognition research to provide understandings of teachers' metacognition especially in context of learning science in practicing teachers.

Research Question 2: What are Thai Lower-Secondary Science Teachers' Perceptions of Their Actual and Preferred Metacognitively Oriented Science Classroom Learning Environments?

The answers to this research question are organized into two sections: teachers' perceptions of their Actual MOLEs and teachers' perceptions of their Preferred MOLEs. Teachers' perceptions of their Actual MOLEs were explored using both questionnaire and interview data. Teachers' perceptions of their preferred MOLEs were explored using interview data. Initially, a questionnaire to assess teachers' perceptions of their preferred MOLEs: the PreferredMOLEs questionnaire was developed. However, based on results of factor analysis in developing process of the PreferredMOLEs questionnaire, the questionnaire could not form congruent subscale(s)/factor(s) with the ActualMOLEs questionnaire and the MOLES-S (the original scale that the PreferredMOLEsquestionnaire was generated from). Consequently, results of teachers' responses of the PreferredMOLEs may not reflect teachers' response of their preferred MOLEs properly. Therefore, the results from the PreferredMOLEs questionnaire were not used in this study. The results of factor analysis of the PreferredMOLEs questionnaire are shown in Appendix L. A summary of questionnaire subscales and themes in relation to teachers' Actual and Preferred MOLEs is shown in Table 4.5.

Table 4.5

A Summary of ActualMOLEs Questionnaire Subscales and Themes from Thematic Analysis of Interview data in Relation to Teachers' Perceptions of Their Actual and Preferred MOLEs

Teachers' Perceptions Of	Quantitative Strand: ActualMOLEs Questionnaire Subscales	Qualitative Strand: Themes
Actual MOLEs	Student-Teacher Negotiation (StN) Teacher Openness (TO) Teacher Value and Support (VS) Metacognition Prompt (MP)	Teachers encouraged students to think about own learning Teachers modeled/shared how they learn to students Students asked/shared teachers about learning Students discussed with other about learning
Preferred MOLEs	–	Whether Teachers were interested in developing MOLEs

Teachers' Perceptions of The Actual Metacognitive Orientation of Their Science Classroom Learning Environments

In this section, findings from the ActualMOLEs questionnaire are provided first. Then findings from interview data follow. Lastly, a summary and discussion of the findings integrated from both quantitative and qualitative strand is presented.

Questionnaire Data and Findings

The Questionnaire to Assess Science Teachers' Perceptions of Their Actual Metacognitively Oriented Learning Environments (ActualMOLEs) contains four subscales: Student-Teacher Negotiation (StN), Teacher Openness (TO), Teacher Value and Support (VS), and Metacognition Prompt (MP). From 214 responses and 4,280 data points, there were 25 missing data point which is 0.58%. Therefore, the missing data does not violate the data quality. The Cronbach's alpha and descriptive statistics of each subscale is shown in Table 4.6.

Table 4.6

Cronbach's Alpha Results and Descriptive Statistics of Each Subscale in ActualMOLEs Questionnaire.

Subscale	Cronbach's Alpha	Mean score	Std. Deviation	Item mean score range
Student Teacher Negotiation	0.90	3.41	0.76	3.19 – 3.62
Teacher Openness	0.85	4.10	0.75	3.98 – 4.20
Teacher Value and Respect	0.86	4.50	0.53	4.41 – 4.63
Metacognitive Prompt	0.76	3.62	0.66	3.33 – 3.85

The results show that all subscales have the value for Cronbach's Alpha above 0.7. Therefore, the participants' responses of the ActualMOLEs questionnaire can be considered reliable. The mean score of subscales Student-Teacher Negotiation, Teacher Openness, Teacher Value and Support, and Metacognition Prompt are 3.41, 4.10, 4.50, and 3.62 respectively. The standard deviation of each subscale is less than its mean score; therefore, the data are considered normal. In conclusion, this data set is considered reliable.

The subscales Teacher Value and Support and Teacher Openness have mean scores located between *Often* and *Always.* Specifically, the mean score of subscale Teacher Openness locates closer to *Often* than *Always*, and the mean score of subscale Teacher Value and Support locates at the middle between *Often* and *Always*. The mean scores of Student-Teachers Negotiation and Metacognition Prompt locate between *Sometimes* and *Often,* and both locate closer to *Often.*

T-test analysis was applied to explore if the mean scores of each subscale pair were different. The results of t-test analysis of each subscale pair in the ActualMOLEs questionnaire is shown in Table 4.7.

All pairs of subscales of ActualMOLEs questionnaire have t-test values greater than the range ±1.96 with p value less than 0.001. Therefore, the results suggest that the mean scores of all subscales are significantly different to each other.

Table 4.7

Paired T- Test Results of Subscales in the ActualMOLEs questionnaire at 95% Significant Level.

Pair	t	df	P-Value (two-tailed)
StN – TO	-12.28	213	<0.001
StN – VS	-19.59	213	<0.001
StN – MP	-4.46	213	<0.001
TO – VS	-10.42	213	<0.001
TO – MP	8.58	213	<0.001
VS – MP	17.88	213	<0.001

The means scores of all subscales ranging from the highest score to the lowest are Teacher Value and Support, Teacher Openness, Metacognition Prompt, and Student-Teacher Negotiation respectively. It could be interpreted that this group of science teachers were likely to agree that their classroom environments were more endorsed with the situations presented in the subscale Teacher Value and support, for example, *VS4 I respect students' individual differences* (VS) than situations presented in the subscale Teacher Openness, for example, *TO4 It is OK for students to speak out to me about activities that are confusing* (T*O).* In addition, they were more likely to agree that their classroom environments were less endorsed with situations presented in the subscale Metacognitive Prompt, for example, *MP1 I ask students to think about how they learn science* (MP) than the two situations mentioned in VS4 and TO4. Further, they were likely to agree that the situations presented in the subscale Student-Teacher Negotiation, for example, *StN3 Students discuss with me about how they can improve their learning of science* (3.55) and *StN6 Students help me decide how much time they spend on activities* were less likely to be evident in their classrooms compared to the situations in other three subscales.

In conclusion, the quantitative findings suggest that teachers perceived that the learning environments in their science classrooms were often such that teachers valued, respected, and were open to their students. However, the reported that their learning environments were sometimes, but less often characterized by teachers encouraging students to think about how they learn science, or teachers and students having discussions about learning science or about learning activities.

Next, relationships between four subscales in the ActualMOLEs questionnaire were analyzed. Results of the Pearson correlation among the subscales are shown in Table 4.8, and their correlation graphs are shown in Figure 4.2.

Table 4.8

The Pearson Correlation Between Subscales of the ActualMOLEs Questionnaire

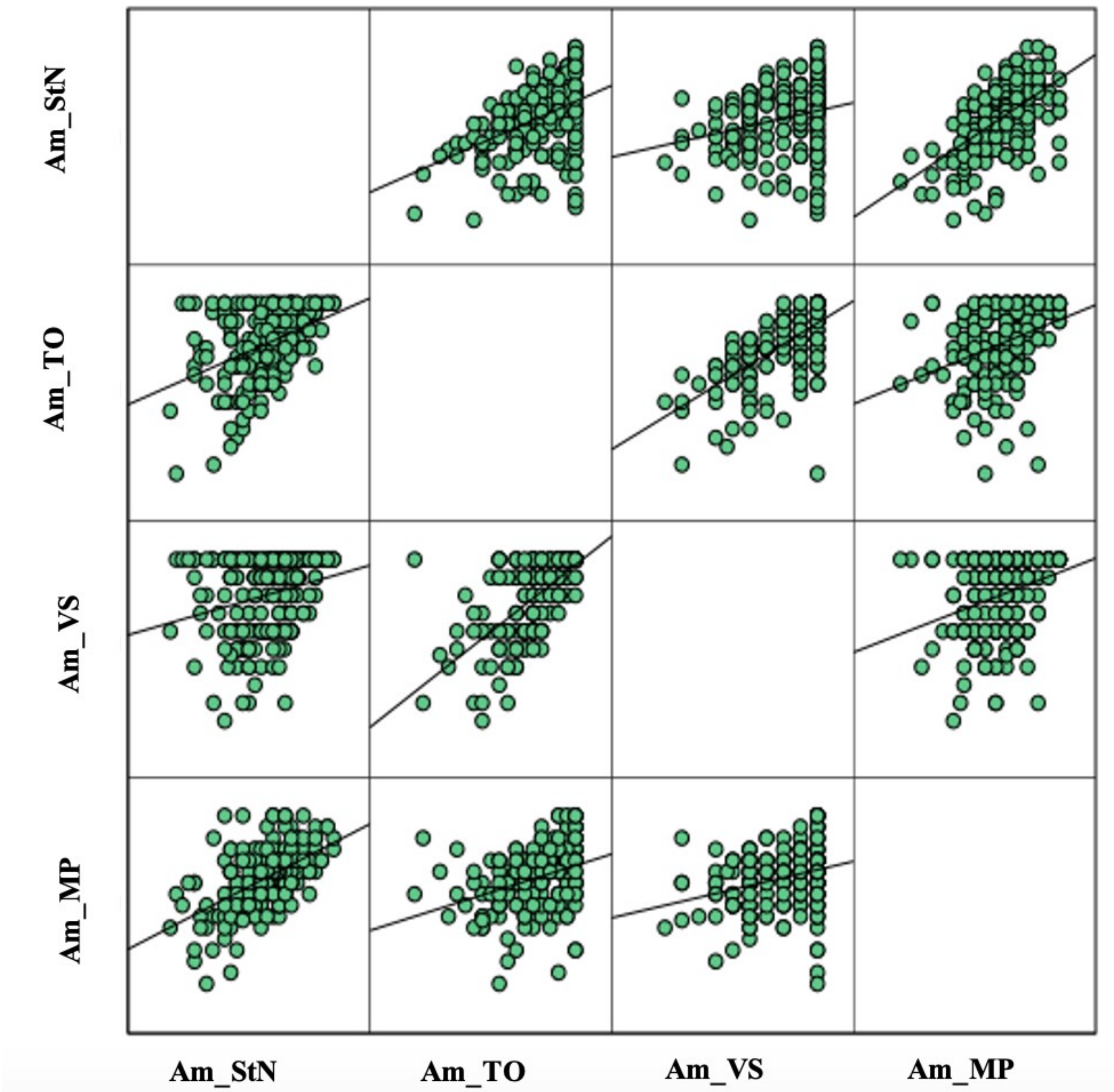
Subscales	Pearson Correlation	P-Value (two- tailed)
Am_StN – Am_TO	0.42	<0.001
Am_StN – Am_VS	0.24	<0.001
Am_StN – Am_MP	0.56	<0.001
Am_TO – Am_VS	0.66	<0.001
Am_TO – Am_MP	0.34	<0.001
Am_VS – Am_MP	0.29	<0.001

Note Am_StN refers to Student-Teacher Negotiation subscale
Am_TO refers to Teacher Openness subscale
Am_VS refers to Teacher Value and Support subscale
Am_MP refers to Metacognition Prompt subscale

The analysis suggests that all pairs among subscales of the ActualMOLEs are correlated significantly ($p<0.001$). Based on suggestions by Tylor (1990), as mentioned before, weak correlations were found between three pairs of subscales: the subscales Student-Teacher Negotiation and Teacher Value and Support (0.241), the subscales Teacher Openness and Metacognition Prompt (0.340), and the subscales Teacher Value and Support and Metacognition Prompt (0.285). Medium correlations were found in other three pairs of subscales: the subscales Student-Teacher Negotiation and Teacher Openness (0.416), the subscales Student-Teacher Negotiation and Metacognition Prompt (0.557), and the subscales Teacher Openness and Teacher Value and Support (0.658).

Figure 4.2

Correlation Graphs between Four Subscales of the ActualMOLES Questionnaire



Note Am_StN refers to Student-Teacher Negotiation subscale
Am_TO refers to Teacher Openness subscale
Am_VS refers to Teacher Value and Support subscale
Am_MP refers to Metacognition Prompt subscale

Specifically, the highest correlation was found between the subscales Teacher Value and Support and Teacher Openness. The two lowest correlations were found between the subscales Teacher Value and Support and Student-Teacher Negotiation, and between the subscales Teacher Value and Support and Metacognition Prompt. This suggests that teachers' who endorsed the subscale Teacher Value and Support may endorsed the subscale Teacher Openness; however, they might not endorse the subscale Student-Teacher Negotiation, or Metacognition Prompt.

The highest correlation with the subscale Metacognition Prompts was found in the subscale Student-Teacher Negotiation. The correlation was considered medium correlation. The correlation between Metacognition Prompt with the other two subscales; Teacher Openness and Teacher Value and Support were considered weak. The findings suggest that teachers who endorsed the subscale Metacognition Prompt may also endorsed the subscale Student-Teacher Negotiation, but may not endorse with the subscales Teacher Openness and Teacher Value and Support.

Interview Data and Findings

From the thematic analysis of the interview data, teachers' perceptions of their Actual MOLEs could be reported in relation to four themes. The first theme related to whether teachers perceived that they discussed with their students and/or encouraged them to think about their learning. The second theme related to whether teachers perceived that they shared or modeled their learning process to their students. The third theme related to whether teachers perceived that students asked or consulted teachers about learning. The fourth theme related to whether teachers perceived that students discussed with each other about learning.

Teachers Variously Encouraged Students to Think About own Learning. Six teachers reported that they often asked students to think about own learning. They reported, for example,

"I asked students [if they cannot answer my questions] if they think there should be something else in their thinking process [in order to answer the questions]?"

"[in some solving problem tasks] If students cannot figure out the answer, they will come to me and ask me themselves if there is something wrong in their problem solving procedure. I will explain to them to check from the beginning step by step"…

"Sometimes, I ask them to ask their friends to help them out [about how to solve the problem that they could not figure the answer]" (Ms. Khun)

"This morning, I just told them that I have my own learning technique, but you may have your own. I asked if they would like to share theirs. Some students shared how they get to learn, for example, one student shared that they learn better when they get to write something" (Ms Jumpee)

Another four teachers reported that occasionally they asked students to think about how they learn; however, 19 teachers reported that they were not likely to ask students to think about how they learn. They reported, for example,

"Sometimes, when my students gave me a really good answer, I asked them why they think that way. I asked them to share their thought to other students, so other could use it as a guideline, and I could use it to teach students in the future" (Ms. Ubon)

"I have never asked students to think about their own thought. Mostly, I asked them about content knowledge" (Ms. Sritrung)

Teachers Variously Modeled/Shared how They Learn to Students. Eleven teachers reported that they were often modeled/shared how they learn to students. They explained, for example,

"I did both sharing and teaching my learning technique. I asked them that if they were not good at calculation, they have to be focused, do an easy problem first to learn how to do it to learn the core method. Then you could go with a difficult one." (Ms Chomjan)

"There was a learning strategy that I used when I was in high school about teaching other friends. I told my students to use this strategy asking questions and teaching to their friends. It could help them learn better." …"Another learning strategy is about using mind map." (Mr. Wha)

Other teachers reported that they were less likely to share how they learn to students. They explained, for example,

"I have never shared about how I learn with students… I have never suggested learning techniques to students." (Mr. Kasalong)

"I rarely share my learning technique to students… and my students have never asked me about how to learn better." (Mr. Racha)

Twenty-six teachers reported that they suggested to students how to learn science. However, from interview data, suggestions from 13 of 26 teachers did not relate to students' learning processes or asking students to think about how to think to learn science. Their suggestions were, for example,

"I suggested to them that in this topic, you should read which content and where to find content to study." (Ms. Yitho)

"I asked students to find answers to questions that I asked. I suggested to them which book or which website they should study. I suggested to them to ask friends or seniors. I suggested to them to complete their homework." (Ms. Nonzee)

Students Asked/Shared to Teachers About Learning. Four teachers reported that their students asked about or shared how to learn with them. They explained, for example,

"Students came to ask me quite often about how they should learn to understand or to be smart students"… "may be because of my personality. I do not reprehend or scold students, so they have courage to talk to me" (Mr. Maha)

However, there was no evidence of students asking or sharing about learning science from the other 25 teachers. They explained, for example,

"My students have never shared ideas about how they like to learn science or do some experiments"… "sometimes, I overheard students asking each other why they are so smart, but they have never asked me about how should they do to learn better" (Ms. Kamfoy)

Students Rarely Discussed With Other Students About Learning. Three teachers reported that they observed that their students discussed with each other about how to learn science better. Their reports are, for example,

"I asked smart students to share their learning techniques to others. Then I asked other students to share their learning techniques. They shared what it works for them. It is like they are okay with their own learning process. They said it did not work if they followed other's learning techniques." (Mr. Maha)

There were no evidences about students sharing or /discussing with each other about learning from other teachers. Their reports are, for example,

"My students do not discuss about learning much. They just like to tease each other about why the other is so smart, but not much about learning process. They are just teasing each other but are not serious about learning." (Mr. Kasalong)

In summary, from the 29 teachers who participated in interview phase, there were three teachers who reported that their classroom learning environments aligned with all four themes that reflect MOLEs. In the classroom learning environments of these three teachers (Ms. Jampee, Ms. Khun, and Ms Lamduan), teachers reported evidence in relation to MOLEs, for example, that they encouraged students to think about how they learn/solve problem, that they shared and suggested how they learn to their students, that their students asked/shared how they learn science to them, and that their students shared/discussed with other students about learning science. Another 10 teachers reported that their classroom learning environments often align with at least one themes in relation to MOLEs (Ms. Chaba, Ms. Mintra, Ms. Tawan, Mr. Maha, Mr. Rak, Mr. Wha, Mr. Wan, Ms. Peep., Ms. Chomjan, and Ms. Ubon). Twenty-five teachers reported that their students were not engaged much in sharing or discussing about the cognition related to learning science.

In addition, the interview data suggest that even though there were not much discussion in learning environments, teachers reported that they valued and supported students, and they were open to students' ideas about learning activities. Some teachers reported that their students did not share ideas about learning much, once students got to share some ideas, they tried to support their students to share ideas more in the future. Some examples of teachers' reports are, for example,

"[when students get to share their ideas] I will check if their ideas are correct. If it is not, I will not scold them, as I do not want them to have negative feelings. I will praise them and suggest them to improve in some area. It is very rare that students have courage to share something. Once they get to share, I will encourage them to share further in the future" (Ms. Tawan)

Eighteen teachers reported that they were open to their students' ideas about science learning activities. They explained that they asked students which learning activities the students liked to do, and what materials students were interested in to examine in experiments. They reported, for example,

"Students always asked me if they could do some experiments. I always said to them do it, let's try. They asked like 'how about this way', 'can I do this way'. I replied to them 'let's try'" (Mr. Kasalong)

However, even though 18 teachers reported they were likely to open to their students, only 8 teachers reported that their students were likely to shared opinions about science learning activities. They explained, for example,

"Most of students were curious to learn. When I get to teach them about content knowledge, they will ask to do experiments. They were enthusiastic to explore and do science experiments" "They have courage to ask how they like to learn" (Mr. Wan)

"Sometimes I let students to teach other students in front of the class. I told them to act like a teacher and I would act like their student. They like it. They like to teach others" (Ms. Khun)

Findings about teachers valued, support, and were open to students, based on teachers' perceptions, could provide context of teaching and learning in science classrooms of the teachers' participants.

Summary and Discussion

Findings from survey and interview data were integrated. A summary and discussion of teachers' perceptions of their actual MOLEs are as follows.

Teachers Valued and Supported Students. Based on the quantitative analyses, teachers tended to value, respect, and support their students. Specifically, the mean scores of each item in this subscale were located at around the same level of the Likert scale between *Often* to *Always* (4.41-4.63). The interview data suggest similar findings that teachers respected students' ideas about learning activities and tried to create environments that encourage students to be confident in sharing ideas about learning activities in science classrooms.

The learning environments related to the Teacher Value and Support dimension was highly reported in teachers. There was no evidence in the interview data to explain this situation (as it was not in the research foci). However, the high level of Teachers Value and Support dimension might be explained as follows. Teachers have been emphasized to create learning environments that value and support students. Such learning environments are indicated in code of teaching professional for teachers in Thailand educational context (e.g., Office of the Teacher Civil Service and Educational Personnel Commission (OTEPC) of Thailand, 2022).

Teachers Were Open to Their Students' Opinions on Science and Learning Activities. Data from the questionnaire suggest that teachers were often open to their students' opinion about learning activities. The mean scores of each item in this subscale ranged from 3.98-4.20 which is located in the edge of *Often* and *Always* in Likert scales. The Teacher Openness dimension was found to have the second highest mean score in the ActualMOLEs questionnaire. In addition, evidence from interview data support the high mean score in this subscale. There was much evidence that teachers were open to students' ideas about science learning activities as mentioned before. As there was no evidence in the interview data to explain the high level of teachers being open to students' ideas, the findings might be explained as follows. Teachers' behaviors, such as opening to their students' opinion are found emphasized in ethical guidelines for teachers and educators in Thailand (e.g., OTEPC, 2022).

However, there are two considerations about the findings. First, the findings are based on data from teachers' perceptions. Perceptions may reflect actuality, and also be potentially different from actuality (Pronin, 2007). Second, teachers may report that they were open to their students, but at the same time, students may not be likely to engage in sharing their ideas about science learning activities.

Although the first two subscales/dimensions are not directly related to developing students' metacognition, the two dimensions could establish foundations for developing MOLEs in science classrooms. For example, the learning environments that teachers were likely to open to their students' ideas about learning activities may suggest that teachers were likely to open discussion in the learning environments. That type of learning environments has a good foundation to be develop to be metacognitive orientation that teachers and students discuss with each other about how to learn science or learning processes of learning science.

In addition, the findings about the two dimensions could provide context of teaching and learning in science classrooms in Thailand. Specifically, high mean scores and substantial evidence from interview data suggest that, in the learning environments of their science classrooms, teachers in general valued, respected, supported, and were open to their students on same matters.

Teachers Sometimes Encouraged Students to Think about How to Learn Science. The mean score of the Metacognition Prompt subscale at 3.62 located between the Likert scale

Sometimes and *Often*. It suggests that teachers sometimes encouraged students to think about how to think about how to learn science. Similar findings were found in interview data. Ten teachers reported that they encouraged students to think about their own learning, and 11 teachers reported that they modeled/ shared how they learned science to their students.

Findings from both quantitative and qualitative strands suggest similarly that, in the whole picture, teachers were not engaged much in encouraging students to think about how they (the students) learn science.

There was not Much Discussion Between Students and Teachers about Learning Processes or Strategies in Their Learning Environments. The subscale Student-Teacher Negotiation held the lowest mean score (3.41) among the four subscales in the ActualMOLEs questionnaire. The mean score of this subscale locates between *Sometimes* and *Often*.

Findings from interview data suggested similar trend. As mentioned before, eight teachers reported that their students always shared their opinion about learning activities in science classrooms. Further, only four teachers reported that their students shared/discussed with them about processes of learning science. Further, only three teachers reported that they observed their students discussing with each other about the processes of learning science.

The data from survey and interview suggest that there were not many occasions that students discussed about science learning processes with teachers or with other students in their science learning environments.

Learning Environments in relation to the Dimensions Teacher Value and Support and Teacher Openness Were Found Related. The quantitative analysis suggests medium correlation between the subscales Teacher Value and Support and Teacher Openness (0.67). An explanation for this might be that teachers who value and support students may also be open to their students' opinion. Therefore, teachers who reported that they valued and support their students might also be open to students' opinion about science learning activities.

Learning Environments in relation to the Dimensions Student-Teacher Negotiation and Teacher Openness Were Found Related. The subscales Student-Teacher Negotiation and Teacher Openness were found medium correlated (0.42). A reasonable explanation could be that teachers who are open to their students' opinions might create learning environments that encourage discussion between students and teachers. Therefore, teachers who reported that they trended to open to their students could be found reported that they discussed with their students about learning or learning activities.

Learning Environments in relation to the Dimensions Student-Teacher Negotiation and Metacognition Prompt Were Found Related. A medium correlation was found in the pair (0.56), and it might be explained as follows. When teachers reported high/low dimension of student-teacher discussion (related to Students-Teacher Negotiation) may create high/low opportunity of discussion about learning that teachers encourage students to think about learning science (related to Metacognition Prompt). Therefore, teachers who reported high or low dimension of Students-Teacher Negotiation in their learning environments could be found reported high or low dimension of Metacognition Prompt in their learning environments. In addition, further studies should be conducted to seek accurate/more explanations of the relationship.

Learning Environments in relation to the Dimensions Teacher Value and Support and Teacher Openness may not Indicate Discussion Between Teachers and Students. Weak correlations were between in three pairs including Teacher Value and Support and Student-Teacher Negotiation (0.24), Teacher Value and Support and Metacognition Prompt (0.29), and

Teacher Openness and Metacognition Prompt (0.34). The weak correlations suggest that in learning environments that teachers reported that they highly value, support, and open to students could possibly found that teachers reported low engagement in discussion about learning, or learning activities. The findings suggest that although learning environments that teachers value, support, and open to their students may establish good foundation of teaching and learning in the learning environments, it could not be considered as the main indicator to determine if the learning environments establish deep learning that teachers and students discuss about learning or how to learn.

There was Similar Finding on Students' Low Engagement of Discussion about Learning in Thai Context: Based on Students' Perception. The findings about teachers' perceptions of students' low engagement in discussing about learning science in this study conform with research results from Chantharanuwong et al. (2012b). Chantharanuwong et al. (2012b) conducted a study in schools across northeastern part of Thailand to explore the MOLEs in science classrooms based on high school students' perceptions. Students reported low engagement in making decisions for learning activities in their classrooms. Similar findings reported by Thomas and Chantharanuwong (2022). They conducted a study in 5,418 Thai science students in grades 10-12 across Thailand to explore students' perception of their MOLEs in their science classrooms. Students reported low endorsement to items in relation to discussion between students and teachers and discussion among students in their science classroom learning environments. Similar findings from both teachers' and students' perceptions provide some pictures of learning environments in classroom in Thailand. This issue should be explored more in further studies. However, some initial explanation about this issue is discussed in the following section.

The Thailand Cultural Context may Affect How Students Engaged in Classrooms. Not only teachers reported that students had low engagement in discussion about learning, but teachers also reported that students had low participation in classroom activities. Specifically, in the interview phase, only 8 teachers reported that their students always shared opinion about learning science and learning activities in classrooms. One of factors that could be used to explain this situation could be about culture norm in the Thailand educational context.

Deveney (2005) studied the impact of Thai culture on Thai students in an international school in Thailand, and found that teachers reported difficulty in challenging Thai students. The study concluded that there were two factors from Thai culture that impact how Thai students behaved in responding to teachers in classrooms. First, students paid respect to their teachers as the teachers held higher status, and second, students were afraid to lose their face regarding their responses to teachers' questions. In addition, Raktham (2012) found similar results in observing a Thai classroom at the university level; such as being quiet and less participation in the class, and "a ready acceptance of the teachers' authority" (p. 88). Raktham (2012) explained that the students' behaviors were influenced from Thai culture. Specifically, Nicholls and Apiwattanakorn (2015) explained different roles in different hierarchy in Thai culture which could be evident in the educational context that, "Thais are highly sensitive to any form of criticism and have a strong but often suppressed response to perceived insults" (p.7) and "a person lower in the social hierarchy will generally remain silent rather than make a suggestion which could be interpreted as critical" (p.7). In could be concluded that Thai culture could be one of factors that influences student low participation in classroom.

In addition, similar findings were found in Hong Kong context. Thomas (2006) explored students' perceptions of metacognitive orientation in their science classrooms. The study took place in 16 classes of local Hong Kong schools and 27 classes of international schools in Hong Kong. The findings suggested different levels of metacognitive orientation between local and international schools. In this case, in students' perceptions, learning environments in international school held higher level in terms of accountability of students' opinion than in local school. Thomas (2006) suggested the differences may generate based on different culture context even those schools located in the same geography.

Situations about culture norms might influence how students participate in classrooms should be focused and explored for more in future study. Specifically, students' low participation in classrooms could affect how and the extent to which students discuss about learning with teachers and other students. Further, it could influence teachers' creating MOLEs in their science classroom, and affect developing students' metacognition eventually.

Situations of MOLEs in Thai Science Classrooms Based on Evidences from Teachers' Perceptions. According to developing MOLEs in classrooms, Thomas (2003) suggested three characteristics of MOLEs, as mentioned in Chapter two. Those characteristics are teachers should discuss about learning with students, a language of learning should be employed in the discussion, and the interaction between teachers and students should occur regularly. In addition, similarly to Thomas (2003), Veenman et al. (2006) explained three essential keys for effective instruction to develop students' metacognition. Firstly, the instruction should be blended into content knowledge learning. Secondly, explicitly explaining about the benefits of metacognition should be explained to students, and third continuous implementation of instruction for metacognition and sufficient time for the development are necessary.

According to suggestions from Thomas (2003) and Veenman et al. (2006), the situations of MOLEs in science classrooms of teacher participants in Thailand based on evidence from their perceptions are as follows. Evidence from teachers' report on actual MOLEs in their classrooms suggest that, overall, activities in those learning environments are insufficient in terms of developing MOLEs in science classrooms. There was low evidence of discussion about learning processes and cognition between teachers and students, and among students and students. There was low evidence of language of learning that emphasized learning about own learning, and little evidence of explaining the importance of learning to learn or developing learning processes. There was little evidence of prolonged and simultaneous activities in relation to developing students' metacognition.

Teachers' Perceptions of their Preferred Metacognitively Oriented Science Classroom Learning Environments

To answer research question about teachers' perceptions of their Preferred MOLEs, interview data were explored. Findings of teachers' perceptions of their Preferred MOLEs are as follows.

Interview Data and Findings

From the thematic analysis of the interview data, there was one theme that emerged in relation to teachers' perceptions of their Preferred MOLEs. The theme is about whether teachers were interested in developing MOLEs in their science classrooms.

Were Teachers Interested in Developing MOLEs in their science Classrooms. Teachers were asked if they were interested in developing MOLEs in their science classrooms in order to support their students to be learn science better. Based on their responses, their interests could be categorized into three levels: high, medium, and low.

Six teachers reported high interest in supporting their students to be metacognitive. The teachers who reported high interest were teachers who gave responses about the ways that they would certainly try to develop MOLEs in their classrooms. In addition, they explained the importance of developing such learning environments for their students. Some of their interview data are,

> "Excellent, I think it [MOLEs] is great. Should we start it the next semester? I think it is great. If we start it late, it will be too late. Some students may lose their chance to learn. I do not know if they will teach about this in university level." (Ms. Tiwa)
>
> "Umm in my opinion, I think it [MOLEs] is great. In learning science, there has to have some learning processes about how to get to learn science knowledge." "If there is a workshop, I'm willing to learn and implement it for students" (Ms. Jampee)

The majority of teachers (16) reported that they were interested in supporting students to be metacognitive in medium level meaning that they had medium interest. This group of teachers gave responses about the ways that they were interested in implementing instruction to support students. In addition, metacognition for them was great for students, but it was not seen to be that necessary. Examples of their responses are as follows.

> "I think it [MOLEs] is very good, so students could know their own strengths and weaknesses in learning.""I think it is good, but it has to be in the classrooms where students hold perform at a medium level or higher. Those students could be able to analyze and improve their own learning process." (Ms. Malee)
>
> "If we can do it, it will be great, so students could know themselves, and know what to improve. Like earlier that I got to ask about myself, I have no idea about what I'm good at. I have never analyzed myself like that."…"If I have a chance to be trained about it, I would love to. I think I could implement them [instruction for metacognition] into my classrooms" (Ms. Kamfoy)

There were seven teachers who reported low interest in implementing instruction for metacognition into their classrooms. Those teachers gave responses about the ways that they were interested in metacognition, but that there may be some problems/obstacles in implementing these ideas into their classrooms. They reported that even though they were interested, they may not have a chance to develop MOLEs in all of their classrooms. Their responses are, for example,

> "I think it is great. I'm kind of interested. But I do not know if I could implement it into my classrooms. Is it necessary to be at lower secondary level? Can we use it with other levels? I think it is interesting, but I do not understand about the concept and the process."… "I think asking students to assess their own learning is a bit difficult for them" (Ms. Pradu)

Findings from the interview data suggest that all teachers were interested in developing learning environments that support the development of students' metacognition, but to varying extents. Seven teachers reported low levels of interest. Sixteen teachers reported medium interest in MOLEs. Those teachers also explained the importance of metacognition for students. Six teachers reported high interest to develop MOLEs in their classrooms. Those teachers explained the necessity of students being metacognitive.

All teachers considered that metacognition is good for their students' learning. This could be taken as a positive response of teachers to the idea of metacognition. It suggests a good sign supporting the idea of developing MOLEs in science classrooms in the Thailand context. The differentiation between their perceptions on MOLEs may relate to their knowledge and understanding of metacognition, and obstacles they perceive in their contexts. Further findings about how teachers explained about their challenges in developing MOLEs in their science classrooms are explored and discussed under the findings for the fourth research question in this thesis.

Research Question 3: Is There a Relationship Between Thai Lower-Secondary Science Teachers' Metacognition and Their Perceptions of Their Actual and Preferred Metacognitive Orientations of Their Science Classroom Learning Environments?

To answer this research question, there are two sections. Firstly, relationships among teachers' metacognition and their perceptions of their actual MOLEs are analyzed using questionnaire data (quantitative strand). Secondly, relationship of teachers' metacognition, their perceptions of actual MOLEs, and their perceptions of preferred MOLEs are explored using four case studies (qualitative strand). Finally, a summary and discussion of relationships of teachers' metacognition, their perceptions in actual and preferred MOLEs are provided. A summary of quantitative and qualitative analysis in relation to this research question as mentioned in the two sections is shown in Table 4.9. Details of each analysis are provided in following sections.

Table 4.9

A Summary of Quantitative and Qualitative Analysis in relation to the Third Research Question

Relationships	Quantitative Strand	Qualitative Strand
Relationships among teachers' metacognition and teachers' perception of their Actual MOLEs	Correlation among subscales in Mc and ActualMOLEs questionnaires	–
Relationships among teachers' metacognition and their perception of their Actual and Preferred MOLEs	–	Four case studies

Relationship Between Teachers' Metacognition and Perceptions of Their Actual MOLEs: Questionnaire Analysis

The relationships were explored by analyzing correlations between the three subscales of the MC questionnaire and the four subscales of the ActualMOLEs questionnaire. The Pearson correlation analysis in the SPSS program version 28 was employed. To clarify, analyzing correlation between any two subscales means to explore if the two subscales are correlated to each other, but the findings does not suggest causal influence between the two. The results of the Pearson correlation among the subscales of the Mc and ActualMOLEs questionnaire are shown in Table 4.10, and correlation graphs are shown as Figure 4.3.

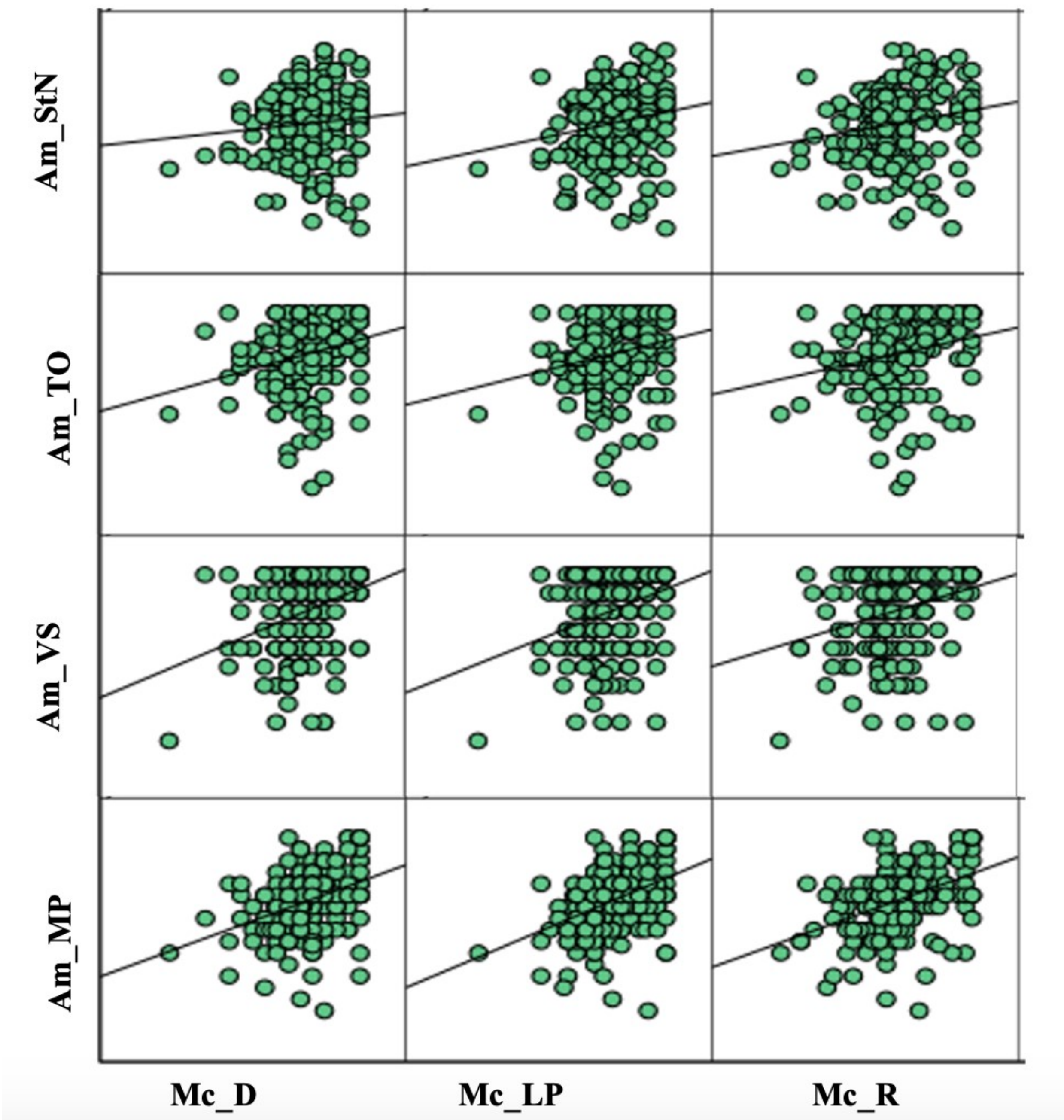
Table 4.10

The Pearson Correlation Among Subscales and all Items Between the Mc and ActualMOLEs Questionnaire

Subscales	Pearson Correlation	P-Value (two-tailed)
Mc_D - AM		
Mc_D – Am_StN	0.09	0.174
Mc_D – Am_TO	0.24	<0.001
Mc_D – Am_VS	0.33	<0.001
Mc_D – Am_MP	0.37	<0.001
Mc_LP - AM		
Mc_LP – Am_StN	0.18	0.008
Mc_LP – Am_TO	0.21	0.002
Mc_LP – Am_VS	0.30	<0.001
Mc_LP – Am_MP	0.41	<0.001
Mc_R - AM		
Mc_R – Am_StN	0.18	0.009
Mc_R – Am_TO	0.22	0.001
Mc_R – Am_VS	0.27	<0.001
Mc_R – Am_MP	0.41	<0.001

Figure 4.3

Correlation Graphs Between Subscales of Teachers' Mc and Teachers' ActualMOLEs Questionnaire



The results suggest that among 12 pairs of the subscales of MC and the Actual MOLEs questionnaire, 11 pairs are significantly correlated at 95% confident ($p<0.05$). The subscales Declarative Knowledge and Student-Teacher Negotiation were not found to be significantly correlated ($p=0.174$). Specifically, within the 11 pairs, medium correlations were found for the all pairs of each of three subscales of the Mc questionnaire and the subscale Metacognition Prompt of the ActualMOLEs questionnaire. The other pairs showed weak correlations (between each of three subscales of the Mc questionnaire and other subscales of the ActualMOLEs questionnaire).

From the results, it can be suggested that teachers who reported high endorsement of either of the subscales Declarative Knowledge, Learning Process Knowledge, and Regulation endorsed the subscale Metacognitive Prompt. Teachers who reported a high endorsement of either the subscales Declarative Knowledge, Learning Process Knowledge, and Regulation might or might not endorse the subscales Student-Teacher Negotiation, Teacher Value and Support, and Teacher Openness.

Summary and Discussion

Correlations among subscales in Mc and ActualMOLEs questionnaire were analyzed. The findings could be summarized and discussed as follows.

Three Elements of Teachers' Metacognition Were Found Related to Teachers' Perceptions of Actual MOLEs in the Metacognition Prompt Dimension. Correlation values of the pairs of each subscale in the Mc questionnaire: Declarative Knowledge, Learning Process Knowledge, and Regulation and the subscale Metacognition Prompt were 0.37, 0.41, and 0.41 respectively. Those correlation values suggest medium correlations. It could be suggested that teachers who reported a high level of metacognition in relation to each of the three elements also reported that their learning environments endorsed the subscale Metacognitive Prompt. Similarly, teachers who reported low levels of metacognition also reported low endorsement of Metacognitive Prompt in learning environments.

There were no data in this study to explain the correlation. Further study should be conducted to seek the explanation. However, these correlations might be explained as follows. Teachers who reported high endorsement for the subscales of Mc questionnaire may have knowledge about their own cognition (Declarative and Learning Process Knowledge) and could manage they own cognition (Regulation). Those teachers may encourage their students to think about their learning processes (Metacognition Prompt) as the way they know and manage their own cognition. This finding suggests the influence and importance of teachers' metacognition as a possible factor in developing MOLEs in science classrooms.

The Three Elements of Teachers' Metacognition may Relate to Teachers' Perceptions of Their Actual MOLEs Regarding the Dimension Metacognition Prompt Differently. All subscales of the Mc questionnaire held medium correlation with the subscale Metacognition Prompt of ActualMOLEs, but there were some variations of those correlation values. The subscale Declarative knowledge had a lower correlation value with Metacognition Prompt compared to the other two subscales: Learning Process Knowledge and Regulation.

These findings might suggest that encouraging students to think about how they learn (Metacognition Prompt) may be related to teachers knowing about their own learning process (Learning Process knowledge) and managing their own cognition (Regulation) more than teachers knowing about the quality of their own learning (Declarative Knowledge).

There Were Weak Relationships Between Each of Three Subscale of Mc Questionnaire and the Dimensions Teacher Value and Support, and Teacher Openness.

Weak yet significant correlations were found among all three subscale of Mc questionnaire and the subscales Teacher Value and Support, and Teacher Openness. It might be that the weak correlation Teacher Value and Support, and Teacher Openness are considered as essential foundations in any learning environment. Teachers may hold these two dimensions and attempt to establish learning environments that teachers value, respect, and are open to their students. Therefore, weak correlations could be found between all three subscales of Mc questionnaire and the subscales Teacher Value and Support, and Teacher Openness.

Different Relationship between Three Elements of Teachers' Metacognition and the Dimension Student-Teacher Negotiation. The dimension Student-Teacher Negotiation was found to be weakly correlated with the subscales Learning Process Knowledge and Regulation, and not significantly correlated with the subscale Declarative Knowledge. The dimension Student-teacher Negotiation refers to learning environments that students, as doers, discuss with teachers about learning science and help teachers making decision about learning activities.

Weak correlation could be explained. Teachers who reported high endorsed with the subscales Learning Process Knowledge and Regulation may trend to create learning environments that provide opportunities of discussion about own learning to students. Therefore, students may be familiar with and courage to discuss about how to learn with teachers. The relationship is not direct, therefore weak correlation between those subscales could be found. However, teachers' declarative knowledge could be found insignificantly correlated with the dimension Student-Teacher Negotiation. The explanation could be as follows. The subscale Declarative Knowledge refers to knowledge about state, quality, or nature of own learning. Teachers' declarative knowledge may not directly relate to having students discussing about how to learn or discussing about learning activities.

Relationship Among Teachers' Metacognition, Their Actual MOLEs, and Their Preferred MOLES: Case Studies

Four case studies were explored to provide deeper understandings regarding teachers' metacognition, and their actual and preferred MOLEs. Teachers' interview data were analyzed to their levels of metacognition, their actual MOLEs, and their Preferred MOLEs. The following sections explain how levels of teachers' metacognition, their perceptions of Actual MOLEs, and their perceptions of Preferred MOLEs were identified.

Levels of Metacognition

Swartz and Perkins (1990) suggested four levels of metacognition as follows.

First, 'Tacit' use, people use their cognition to explore the world (e.g., analyzing evidence without awareness about their cognition). This level is not aligned with metacognition.

Second, 'Aware' use, people are aware of their thinking (cognition). But at this level, they are just aware or barely notice the state of their cognition.

Third, 'Strategic' use, at this level, not only are people aware of their cognition, they also use that awareness to direct their further thoughts and actions.

Fourth, 'Reflective' use, people are thinking about their cognition in order to evaluate, control, and create their thinking.

Using these criteria, it could be suggested that teachers who reported only their metacognitive knowledge could be considered in level two, teachers who reported their metacognitive knowledge and some regulation could be considered in level three, and teachers who reported metacognitive knowledge and clear regulation could be considered in level four. For the purpose of this study, level two, three, and four will be considered as low, medium, and high levels respectively.

Level of Teachers' Perceptions of Their Actual and Preferred MOLEs

When considering the MOLEs, the learning environments that involve activities where teachers modeled/shared how they learn, encouraged discussion about learning, and where students discussed and shared how they learn can be considered as regarding a high level of Actual MOLEs. The learning environments that involve only teachers' activities as mentioned before, but no students' activities can be considered as medium level. The learning environments that involve none or low activities about learning in both teachers and students as mentioned can be considered as low level. These levels where used for the selection of teachers for the case studies.

For the Preferred MOLEs, as in Thai culture (especially in formal context) direct rejection of anything is considered inappropriate. People may have a low interest in instruction for metacognition by reporting even if they were interested, and if they had a chance, they would try to implement the instruction into their classrooms. Therefore, teachers who reported as mentioned were considered as low level of Preferred MOLEs. Teachers were considered as having reported a medium level of Preferred MOLEs if they expressed their intention to learn about instruction for metacognition, and reported their intention to implement the instruction into their classrooms. Teachers were considered having reported a high level of Preferred MOLEs when they reported that they were really interested to learn about metacognition and implement instruction for metacognition in all of their classrooms, and they also explained the importance of metacognition for their students and the necessity of students being metacognitive. A summary of the differentiation of teachers' metacognition, their actual MOLEs, and their preferred MOLEs is shown as in Table 4.11

Table 4.11

The Differentiation of Teachers' Metacognition, Actual MOLEs, and Preferred MOLEs

	Low	Medium	High
Metacognition	Evidence of only their metacognitive knowledge	Evidence of their metacognitive knowledge and some evidence of regulation e.g., aware of their own understanding with some criteria	Evidence of their metacognitive knowledge and clear evidence of regulation e.g., aware of their own understanding with many criteria and mange to benefit from their metacognition
Actual MOLEs	None or low evidence of teacher's discussing, encouraging, and modeling about own science learning process e.g., I rarely discussed with my students about how to learn science	Evidences of teacher's discussing, encouraging, and modeling about own science learning process e.g., I shared how I learn science to my students	Evidences of teacher's discussing, encouraging, and modeling about own science learning process, And, Evidence of students' discussing and sharing own learning process e.g., I always shared how I learn science to my students, and asked them to share theirs
Preferred MOLEs	Showing interest in metacognition as a concept and little, if any interest in implementing instruction related to metacognition into their classrooms e.g., I love to try it, if I have time	Showing interest in learning about and implementing instruction related to metacognition into their classrooms e.g., I will implement it into my classroom	Showing interest in learning about and implementing instruction related to metacognition into their classrooms with some further expression e.g., I would love to implement it for all of my students. We should start it as soon as possible.

Case Studies

As mentioned before, four case studies of teacher participants in this research are presented. In each case, I discuss their metacognition, their perception on their actual and preferred MOLEs, and challenges in implementing metacognition into their classrooms. I provide possible explanations of relationship in the cases. However, the focus of this study was on findings of teachers self-reported about their metacognition and perceptions of their MOLEs. Further studies should be conducted to seek for explanations of the findings that teachers have reported.

A summary of level of teachers' metacognition, their Actual MOLEs, and their Preferred MOLEs in each case study is as follows.

Case 1 (Ms. Lamduan): A teacher who reported a high level of metacognition, a high level of Actual MOLEs, and a high level of Preferred MOLEs

Case 2 (Ms. Raya): A teacher who reported a medium level of metacognition, a medium level of Actual MOLEs, and a medium level of Preferred MOLEs

Case 3 (Ms.Pubpleng) : A teacher who reported a low level of metacognition, a low level of Actual MOLEs, and a low level of Preferred MOLEs

Case 4 (Ms. Mintra): A teacher who reported a high level of metacognition and a high level of preferred MOLEs, but a medium level of their Actual MOLEs

In addition, a summary of information of teachers in the four case studies in terms of their levels of teachers' metacognition, and teachers' perceptions of Actual MOLEs and Preferred MOLEs based on analyses of their questionnaire data, and their interview data is shown in Table 4.12.

Table 4.12

A Summary of Information of Teachers in the Four Case Studies in relation to Level of Their Metacognition, Actual Moles, And Preferred Moles

Case	Quantitative interpretation: Mean score of their			Qualitative interpretation: Level of their		
	Metacognitive* Knowledge	Regulation	ActualMOLEs**	Metacognition	Actual MOLEs	Preferred MOLEs
Case 1	4.15	4.31	4.36 (4.67)	high	high	high
Case 2	4.00	4.00	3.86 (3.80)	medium	medium	medium
Case 3	3.62	3.31	1.73 (2.50)	low	low	low
Case 4	3.85	3.92	3.54 (4.20)	high	medium	high

Note: *Metacognitive knowledge mean score is mean score of Declarative and Learning Process knowledge
**ActualMOLEs mean score is mean score of the subscales Student-Teacher Negotiation and Metacognitive Prompt and the number in () is the mean score of all subscales in the ActualMOLEs questionnaire

Case 1: A Teacher who Reported High Level of Metacognition, Actual MOLEs, And Preferred MOLEs: Ms. Lamduan

Ms. Lamduan had been teaching science for 28 years at the lower secondary level. She reported her interest in teaching science stating that science is a subject that can be learned endlessly. She mentioned that teaching and learning science help create clear learning processes. She said systematic thinking processes in learning science helps with relating science to everyday life, as people can (use that systematic thinking to) explain situations that they face. In terms of learning science, she explained that learning is finding an answer in a topic that she interested by using appropriate processes to find the answer. From her interviews, Ms. Lamduan related learning science with processes of learning, and she were interested in science in terms of having systematic thinking process that can also be used in everyday life. It could be suggested that, in her mind, she already conferred importance to processes of learning. In terms of metacognition, she mentioned that she had never heard about the term before.

Metacognition. The evidence from Ms. Lamduan's interview data suggested that she holds a high level of metacognition. She could explain clearly her own definition of learning and her processes of learning clearly. In addition, she mentioned different processes of learning in different situations. She explained her weakness and strengths in learning, and she also reported how she could learn better based on her knowledge of her learning weakness.

Ms. Lamduan explained about her own science learning processes as follows.

"Mostly, I learn from the internet. I explored knowledge additionally from what I had learned. Sometimes, I attained some workshops." (Procedural knowledge, pk)

"I read or study from many sources, then I process and summarize what the knowledge about."…"I organize what I learn until I get to (see) the concept. Then, I can explain how it [science concept] works or where it comes from." (pk)

"I will ask if in any situation how should I learn to get the best results." "I can ask what should I think or do to learn better?" "I think that there are always some new techniques that could help us learn better. At some point, we should change [our learning processes] in order to fit with situations." (Conditional knowledge, ck)

"My learning strength is that I always want to learn something new. I tried to read more and attained workshops. About my weakness, sometimes in some topics that I had learned, if I haven't used the knowledge, I will forget about it. So, when I have time, I will try to reread or explore the knowledge again. As I'm getting old, my memory is getting lost, so I have to revisit the knowledge or search for more information continually." (Declarative knowledge, dk; Planning, pl)

From Ms. Lamduan's interview data, it can be suggested that she possessed Declarative knowledge (dk), Procedural Knowledge (pk), and Conditional Knowledge (ck). In relation to Regulation, in Ms. Lamduan's interview, she suggested she could regulate her cognition as well. She recognized her weaknesses, and she used more than one strategy to improve her learning. Therefore, Ms. Lamduan could be considered as one with a high level of metacognition.

Actual MOLEs. Ms. Lamduan explained her learning environments in relation to the Actual MOLEs in a variety of ways. For examples, she encouraged her students to think about students' ideas in learning science. She modeled how she learned to students. She suggested to students how to learn and how to improve their' own learning. She gave students opportunities to share and discuss about learning or how to learn better. In addition, she mentioned that students discussed with her how they could learn better. Her statements were, for example,

"Before learning a new topic, I will revisit prior knowledge. I will show them how prior knowledge could connect to new knowledge." (modeling how to learn)

"I used to ask students to evaluate if they have learned, or how they can improve their learning." "When students presented me their thoughts, I asked them that if you think this way how could you improve it further." (encouraging students to think about how to learn)

"Sometimes, I ask them to write it down and present it to other students" "In some learning activities, I asked them to work as a group. Then, I asked them to share what they have learned and how they could learn together." (giving opportunities to students to discuss with each other about learning)

"I told students that if they do not understand a concept, they should try to connect it with situations in real life. I would show them how I could connect some everyday life situations to knowledge, then I asked them to do the same." (suggesting how to learn)

“Sometimes, students asked me, ‘Teacher if I like to learn this topic what should I do’ or ‘if I like to understand this what should I do?’” (student asking how to learn)

“I suggested to them to consider, ‘what is the topic about?’ I told them that they could search for more information from the internet and look for virtual experiments. I told them to watch video clips repeatedly until they could see techniques. I told them that it [learning like this] could apply in doing a test as well. I told them that they can learn strategies or techniques that people from internet explain then they could adjust to fit with them. Then they could try to apply [these processes] in learning other topics.” (suggesting and modeling how to learn)

“I shared [with students] that they should take notes in the way they understand [in their own words] then they could summarize together about the concept knowledge. Sometimes, I told them to use mind maps. Before that, I had first taught them how to do mind map. Next time, they would know how to do it automatically.” (suggesting how to learn)

“I suggested to them that they could search for knowledge from internet, but they should read from many sources. Then they should process and summarize how they understand the knowledge.” (suggesting how to learn)

Based on Ms. Lamduan’s interview data, she reported many activities in her learning environments that related to Actual MOLEs as mentioned. It could be interpreted that her Actual classroom learning environments reflected a high level of metacognitive orientation.

Preferred MOLEs. Ms. Lamduan explained how she could see benefit of learning processes, and she mentioned that she would love to learn about instruction for metacognition, so she could implement it into her classrooms. Her statements were as follows.

“If we have good learning processes, it [learning processes] could be used in real life. It could benefit a learner a great deal.” “I love to learn about it [instruction for metacognition], so I could see if it is different from what I thought, and I could adjust to implement [the ideas] into my classrooms."

From her interviews, it could be interpreted that Ms. Lamduan reported a high-level preference for MOLEs.

Ms. Lamduan mentioned some challenges in supporting MOLEs. Those related to expectations in students' learning such as to getting in to university, lacking of time as there was too much curriculum to follow, and policy that not support student learning.

"If we think about teaching and learning in Thailand in the whole picture, there is not much that we could train students to learn by themselves. The purpose of students' learning is to finish the degree, so they could get into university." (Expectation in learning: students)

"Parents could not see importance of student learning processes. They expect that their children should get into university." (Expectation in learning: parents)

"In addition, it requires extra time for teaching that kind of learning. We have really tight curriculum to teach." (Tight Curriculum)

"If we want to improve students' learning, it should be fixed from the policy makers' perspective. There is no clear picture abut managing teaching and learning in the way that supports their own capacity in learning." (Policy)

Summary and Discussion of Case 1: A Teacher who Reported High Metacognition, Actual MOLEs, and Preferred MOLEs. Based on data from Ms. Lamduan's interview, Ms. Lamduan could be considered as a teacher with high metacognition, a high level of MOLEs in her learning environments, and high interest in implementing MOLEs into her classrooms. In Ms. Lamduan's case, a relationship between her metacognition and her Actual MOLEs could be observed. From her interviews, Ms. Lamduan suggested how she learned to her students. For example, she reported that she learned by searching knowledge from many sources and organizing the content knowledge in her own terms. Then, she reported that she also suggested those processes of learning to her students. In addition, she was aware of her cognition and managed her cognition to learn better, and she encouraged her students to improve their own learning just as she did. It could be suggested that Ms. Lamduan may be familiar with her learning processes and perceived benefits from her learning processes and from managing her learning. Therefore, she attended to improving student learning, so she modeled and suggested those learning processes to her students.

In relation to her high level of Preferred MOLEs, Ms. Lamduan was familiar with her own learning processes and perceived them as importance. Therefore, even though she had never heard the terms ‘metacognition’ before, once she was introduced to the term, she could report her understanding of the importance and interest in implement metacognition into her learning environments. In this respect, she reported her high level of Preferred MOLEs.

Case 2: A Teacher who Reported Medium Level of Metacognition, Actual MOLEs, and Preferred MOLEs: Ms. Raya

Ms. Raya has been teaching science for about 11 years in both private and public schools. She had various teaching experience in junior high school and high school, or medium and high-performance classes. She mentioned that teaching science is important, so that students could apply content knowledge in their real lives. She also indicated a focus on teaching science as that students get to share their ideas about what they learn. Ms. Raya reported that she was not familiar with the concept of metacognition.

Metacognition. Ms. Raya reported some characteristics related to her metacognitive knowledge. From her interview, she suggested that she had her own definition of learning, and she knew her learning processes, and learning strengths and weaknesses.

"I read something, then I come back to summarize in my own thoughts. It is like coming back to do it by myself. That will be learning to me. When we just listen to something, we won't be able to understand. It is when we get to do it; to make it is understandable within oneself. That is learning." "It is like I have to use that knowledge first, then I will get to learn." (dk)

"Mostly, I learn from video clips. I will explore how they do experiments both from Thailand and international. Sometimes, I attend some training programs." (pk)

"I read from books. If there is anything that I do not understand, I will ask my peers or my senior. In my school, we always share like this. In my school setting, if we do not know about anything, we can discuss with others, those who have experience." (ck)

"My learning weakness is about calculation. If learning involved calculation, I will ask my peer to explain it to me." "My strength is about explanation. If I get to write on a black board or explain through drawing, my students will love it." "When I get to write, I will understand, and I can teach students further." (dk, pk)

In terms of Regulation, she did not report much, she just indicated a sign that she could plan to learn based on her learning weakness.

"I know that I do not have good memory, so I have to write something down." (pl)

Therefore, based on her interview data, Ms. Raya could be considered as a teacher who reported medium metacognition.

Actual MOLEs. Learning environments in Ms. Raya classrooms, according to her reports, focused largely on content knowledge. There was no evidence about encouraging students to think about or improve their own learning.

"Mostly, I ask students to discuss about the experiments' results, but I had never asked them if they think their friends answer it correctly, or how should it be." (cognitive processes)

"I told students all the time that if they want to pass the exam [this is what they should do]. I told them about the content knowledge that I will use in the exam. The content knowledge would be just this and that, no more than what I told them. I tried to ask them which part they do not understand, and then I would teach them again." (cognitive processes)

However, Ms. Raya reported that she suggested to students how they could learn better. She mentioned some strategies that she suggested to her students.

"I only suggested to them that there are many YouTube clips to teach them about that topic. If they want to understand more, they should watch those clips."

"I told my students that in this line [in the text], this is the core concept. 'We should write it down or highlight like this, so we could come back to read them later.'"

When asked if her students were curious about how to learn better or if her students discussed about learning with each other, she reported as follows.

"Mostly, my students did not ask me about learning. They just asked me about content knowledge, and I would explain it to them." "Some students may ask me outside classroom period. I suggest to them to learn from some video clips."

"I have never heard my students discuss with each other about learning, but I know that they may exchange their notebooks to read summarized content before a midterm exam."

Data from Ms. Raya's interview suggest that, in her learning environments, she encouraged students to learn, but mostly focused in what to do to learn science rather than students' thinking processes. She suggested her own learning activities to students, for example, watching from video clips or writing some notes and rereading it. Some of her students talked with her about learning, but most of them did not. It could be considered Ms. Raya's classroom learning environment had as medium (to low) level of MOLEs

Preferred MOLEs. When asked about supporting students to learn about learning, Ms. Raya reported medium interest. She explained her understanding of how metacognition is important to students' learning. She reported that she would like to implement the instruction into her classrooms. She was interested to improve MOLEs in her classrooms, but it may not be necessary for her students.

"It[metacognition] is good, so students will get to assess themselves [about learning]. Sometimes, they did not know what they were learning, or why they learned. They learned as their teachers told them to. They did not ask me like, "if I like to learn about this, what should I do?"

"I'm kind of interested. If I get to be trained, I may have a chance to try it for my students."

Ms. Raya mentioned the challenges in developing MOLEs in her classrooms in two ways: lack of teaching time and lack of knowledge.

"It is good to support them about thinking, but sometimes it is like 'I cannot wait'. There is so much content knowledge that I have to teach. Sometimes, I tried to add[teach] some thinking skills in my instruction, but there was not much time to focus on that thing. If today's activity was about doing an experiment, I would like to focus on a process that encourages students to think to share. Sometimes, it works, but it is not always like that. 'I cannot wait'. It's like I tried to encourage students to answer or do some activities, but they did not. They did not have that much motivation. I do not know how to explain this."

"Sometimes, I like to teach focusing on some thinking processes, but I do not have examples or guidelines to teach like that."

Summary and Discussion of Case 2: A Teacher who Reported Medium Level of Metacognition, Actual MOLEs, and Preferred MOLEs. Ms. Raya is an example of teachers who reported a medium level of her metacognition, a medium level of MOLEs in her classroom learning environments, and a medium level of interest in supporting MOLEs in her classrooms. Although Ms. Raya could report her learning in terms of processes of learning, the quality of her learning, and some possible adjustments in learning processes based on her learning weakness, she reported her focus in the classroom in terms of content knowledge and not learning processes. She reported that her classroom instruction emphasized content knowledge, and what her students should do to achieve. However, she mentioned briefly that she shared her learning processes with her students. From her interview, it could be suggested that Ms. Raya may not recognize learning or learning processes as a concrete concept. Her focus in learning may be about possessing content knowledge. Therefore, learning processes that she suggested to her students may be focused in terms of helping students to learn knowledge not to improve students' learning processes.

In relation to her Preferred MOLEs, Ms. Raya explained her understanding of the importance of metacognition and reported her interest in MOLEs. However, she reported that her main concerns in her classrooms about a lack of time and a tight curriculum. She also indicated that she did not have guidelines for how to support MOLEs.

In Ms. Raya's case, a relationship between her metacognition, Actual MOLEs, and Preferred MOLEs could be evident. Ms. Raya may hold a certain level of metacognition, but not perceived a learning process as an important element in learning. In addition, she may have not much knowledge about metacognition. Therefore, there were less evidence of MOLEs in her classrooms, as her focus was on students' possessing content knowledge and her covering content in the curriculum. Still, she reported her medium Preferred MOLEs as she may understand the importance of MOLEs, but at the same time may prioritize creating learning environments that support students to learn content knowledge and not to learn about learning.

Case 3: A Teacher who Reported Their Low Level of Metacognition, Actual MOLEs, And Preferred MOLEs: Ms. Plubpleng

Ms. Punpleng had been teaching science at lower secondary level for three years. She mentioned that learning science is important, so that students could use it as foundation knowledge to learn at higher levels. She explained her foci in teaching science as trying to encourage students to first like the subject. She mentioned that she was not familiar with metacognition. Ms. Pubpleng is a case study of a teacher who reported a low level of metacognition, low Actual MOLEs, and low Preferred MOLEs. Statements from her interview data in relation to metacognition and MOLEs are as follows.

Metacognition. In Ms. Pubpleng's interviews, she reported some evidence of her metacognitive knowledge. She could explain her own definition of learning which was related to her interest. She could explain processes of how she learned and how she used different processes in different learning situations. However, she could not explain much about her learning strengths and weaknesses. She reported her metacognitive knowledge as follows.

“Learning is that we want to learn about content knowledge. It starts with, if we are interested to learn about something.” (dk)

“[explaining about how she learns some topic] I search for information from the internet from many sources, then I summarize them.” (pk)

“For some topic that I’m not familiar with, I will try to understand it by myself first, then I may ask my seniors who are experts in this topic to explain them to me.” (ck)

“About my strengths and weakness in learning, I know what topics I understand and what topic I do not understand.” “I just have a medium level of learning. I cannot tell what I’m good at or not good at.” (dk)

In relation to Regulation, there were no evidence reported by Ms. Pubpleng about how she regulated her cognition. When asked about how she know if she understands any content knowledge, Ms. Pubpleng explained as follows.

“Ummm this question is a bit difficult. How do I know that I understand the knowledge” “I think I will test myself if I understand by doing some task/test.” “Maybe I could test my knowledge with other teachers. I will summarize knowledge and ask other teachers if I understand it correctly.” “I do not usually do something like that [evaluate own knowledge by asking other teachers].”

It could be suggested that Ms. Reported a low level of metacognition, as there was only limited evidence in relation to her metacognitive knowledge and little evidence of regulation.

Actual MOLEs. There was little evidence of MOLEs in Ms. Pubpleng’s learning environments. She reported that she suggested learning techniques to students. However, she indicated that she had never asked students to think about how students learn, and that she rarely asked students to share ideas or evaluate other students’ ideas.

"I have a remembering technique that I use to help me remember some technical terms. I suggested my students about the technique too."

"I suggest students to learn. Mostly I suggest this to students at a higher level, for example, grade nine. I have suggested them to summarize concepts and use colored pens to capture our intention to read the summarized concept."

When asked if she had ever asked students about their thoughts during learning a science concept, she replied "not really."

When asked if she had ever asked students to evaluated their peer's answer, she answered "I use that question [asking students to evaluated their peers] in some classrooms."

"I have never asked students about their own thinking or learning."

She reported no evidence about students asking her about how to learn or about students discussing this with each other.

"I have never heard students talking to each other about learning."

Ms. Pubpleng's focus in science teaching was on concept knowledge.

"My focus in teaching science is that I will use language that they could understand. I use a lot of pictures to help them understand what I teach. Then, I summarize the concepts for them. It is very important that I use keyword for them to understand."

From the interview, it could be interpreted that Ms. Pubpleng reported a low level of her MOLEs in her learning environments.

Preferred MOLEs. Ms. Pubpleng reported some interest, but not much, in learning about and implementing instruction for metacognition into some of her classrooms. It suggests that she might think that metacognition is more appropriate for 'high performance' students, but not for all students.

When asked if she was interested in learning about instruction for metacognition, she replied:

"Umm I'm interested, but I have to check if I have time."

"I would love to try [to use instruction for metacognition in my classroom]. However, I may try in a classroom with high performance students first. If it works, I may try in other classrooms."

Ms. Pubpleng mentioned various obstacles to supporting MOLEs in classrooms including tight curriculum, students' readiness in learning, and teachers' knowledge.

"The first thing is about the curriculum, there are too many indicators to learn in a limited time." "The important thing is time, there are so much content to be taught the in science curriculum." (tight curriculum and lacking of time)

"Students in each year are different." "sometimes, students are not ready to learn. Especially, during a Covid pandemic like this." (students' readiness in learning)

"Teachers should be prepared about how to implement the instruction to improve students." (teachers' knowledge)

Summary and Discussion of Case 3: A Teacher who Reported low Level of Metacognition, Actual MOLEs, and Preferred MOLEs. Ms. Pubpleng was interviewed twice in this study. However, she did not report much about her learning processes, how to learn, how students learn, or discuss about learning in each interview. In Ms. Pupleang's case, a low level of metacognition, a low level of Actual MOLEs, and a low level of Preferred MOLEs could be evident in her interviews. Possible explanations of a low level in those dimensions could be as follows.

Ms. Pubpleng shared her learning techniques to her students. However, she did not report learning processes as her focus in learning, and she did not report clearly about her metacognitive knowledge or regulation. It could be suggested that she may not be familiar with recognizing her own learning processes. From her interview, there was little evidence in relation to MOLEs in her learning environments, as she did not focus or think or discuss about learning with students. Ms. Pubpleng may not experience any benefit from her metacognitive knowledge, as she did not report her Regulation. Therefore, she may not perceive any importance of metacognition in learning. Consequently, she reported her low level of Preferred MOLEs.

In the first three case studies, evidence of the relationship of teachers' metacognition, their perceptions of their Actual MOLEs, and Preferred MOLEs reflect a similar trend to the earlier findings. Specifically, a teacher who reported high level of metacognition reported a high level of Actual and Preferred MOLEs, a teacher who reported medium level of metacognition also reported their medium level of Actual and Preferred MOLEs, and a teacher who reported low level of metacognition reported the same respect. However, not all interviewed teachers reported followed that trend. The next section is a case study of a teacher who reported a high level of metacognition and a high level of Preferred MOLEd, but a medium level of Actual MOLEs.

Case 4: A Teacher who Reported High Level of Metacognition and Preferred MOLEs, But Medium Level of Their Actual MOLEs: Ms. Mintra

Mis. Mintra had two years of experience in the setting. She had graduated with a bachelor's degree in another faculty (Engineer), but her passion for being a teacher led her to pursue a degree in education for another 5 years. She mentioned that she was really happy as a teacher to teach her students. Her class size was about 40-50 students per classroom. However, she mentioned her difficulty in being a teacher being that there was too much paper work.

Metacognition. Ms. Mintra reported a clear picture of what learning is, how she learns, how she gets to understand science knowledge, and what about her learning and strengths and weaknesses are.

"What is learning? It is that we develop ourselves to be better in the area that we would like to improve. It is not only content knowledge, but also skills." (dk)

"My weakness is that I do not like reading books. I prefer video clips. My strength is that I like to remember things in pictures." (dk)

"Personally, if I'm interested in what topic, I will explore it. I will search for information from different sources. If the information from many sources aligns to each other, that information could be correct. I won't believe [information] from one source." (pk)

Ms. Mintra reported different ways to learn each subject. Also, she knew what she should do if she did not understand a concept.

"If it is biology, I will study from summarized diagrams, then I make my own [diagram]. If it is physics, I will study through activity video clip, I try to explain what I see by myself. But if it is biology, which I do not like, I will study from summarized diagrams." "If it is physics, I will watch and re-watch activity video clip until I get my own concept." (ck)

From her interview, Ms. Mintra suggested she regulated her learning. She reported that she had criteria to check if she learned science, and she could plan to learn in a way appropriate with her way to learn.

"If it could be summarized in my own word, that means I have learned the concept already. If I have that concept in my head, it is that [I knew] I understand it." (Evaluating, ev)

“I realize when I understand science knowledge. If I understand, I could keep continue [to learn further]. I could connect from one point of that knowledge to explain other points. But If I read and I do not understand, I will be like..”what?.. thing like that, then what?” I cannot connect to summary and then I won’t understand. If I do not understand, I will ask my senior teachers in my department.” (Monitoring, mn; ev)

“I do not like reading. In some cases, it is a must to read a lot of things. But I’m like “oh I cannot read a lot of sentences”. If it is inevitable, I have to make up my mind. I will carry them around and read it a page at a time when I’m available.” (pl)

Based on Ms. Mintra’s reports, it could be interpreted that she hold a high level of metacognition, as she reported evidence of her metacognitive knowledge and regulation of her cognition.

Actual MOLEs. There was not much evidence reported by her of her instruction that related to MOLEs. In her teaching, she focused largely in content knowledge and skills. She reported that she always gave her students chances to share ideas or direct classroom activities. In her classroom leaning environments, she reported that there was a lot of doing experiments and sharing ideas in terms of knowledge and skills.

“(in teaching science) I follow science textbooks. Do I do all the experiments? (in textbook), no, I do not. Sometimes, I cluster them together, and do those experiments in the same day.” “I got them to learn by doing experiments more than listening to my lecture. I would like them to learn from doing”

“Sometimes, I asked my students to choose what they wanted to study, what they wanted to explore.”

However, there were some occasions in her teaching, mostly when involving with calculation, that she reported that she modeled how she learn or encourage students to think about how they learn.

“If the learning topic is about calculation, sometimes it is like they think [about it] in their mind. Sometimes, I tell them to write it down, and not to calculate it in their mind so much. “Think and write it down”. I tell them to write it down, so they could see which part they may do wrong.”

“I try to give my students some examples (about how to learn) that you have to look for its concept. “If were you, I would picture it. This equation, I will do like this”. “[she told her students that] You do not have to do like the way I do. You could create your way to remember it.’”

Ms. Mintra reported that sometimes she heard her students explain to each other about content knowledge, but not about how to learn. When asked if she had ever discussed with students how to learn better, she reported that she may discuss with some students who came to ask her privately. However, she explained that she discussed with those students about content knowledge that they did not understand.

From Ms. Mintra’s interview, it could be considered that her learning environment held medium level of MOLEs. There was some evidence about sharing and modeling how to learn to students. However, there was little evidence about discussing about learning between the teacher and students or between students and students.

Preferred MOLEs. Ms. Mintra indicated that she had never heard about metacognition. However, when got the explanation, she showed high interest in implementing instruction for metacognition into her classrooms. Also, she mentioned that she wanted all students to get to learn with the instruction for metacognition not only the high-performing students.

"Ummm I like that. I'm thinking that they may have learnt like this in a high-performance class. But in a regular classroom, they do not learn like this. I want it to be more spread [to all classrooms]. I want every student get to learn that way [learn with instruction for metacognition]."

"If I get to learn about it [MOLEs], I will definitely implement it into my classrooms."

In regards to supporting MOLEs, Ms. Mintra mentioned about her obstacles in implementing the instruction. She explained about the need of instructional knowledge. Further, she explained how her setting, which included too much paper work and complication in her school society, might influence how she teaches.

"This type of instruction needs experts to train us." "I used to face the situation like, as I'm from a new era [she tried to explain that she was a teacher who always had a new idea for teaching]. Sometimes, I implemented a new way of teaching in my class. I did research about it. However, I got critics from the upper [her senior or other experience teachers]. Sometimes, we have to open [teachers should open their mind for new teaching strategies/ideas], and let experts to be the one who lead us in what to do. In addition, it should be in a policy. If it is not in a policy, the one who has been teaching for a long time won't be interested to do that. [They may say] I will do this way [the same as they used to do]. I teach this way for a long time"

"I'm so happy when I'm in a classroom, but you may know that there is a lot of paper work. I'm not happy about that. I feel that they need only numbers. They do not really care about students"

Summary and Discussion of Case 4: A Teacher who Reported High Level of Metacognition and Preferred MOLEs, but Medium Level of Actual MOLEs. Ms. Mintra is an example of a teacher who reported high level of metacognition. She could report how she learns, what about quality of her learning, and when she understands. Also, she could regulate her own learning based on knowledge of her cognition. She also reported highly positive regarding supporting students to think about their own learning. However, based on her reports, her actual classroom did not reflect such instruction to any extent. She shared how she learns from time to time, and she encouraged students to think about their thinking process occasionally in a topic involving math problems. An explanation for her high metacognition and her medium MOLEs could be possibly found in the obstacles she reported.

First, she might hold some characteristics related to metacognition, but she lacks knowledge about the metacognition concept and instruction for metacognition. She mentioned that she needed experts to train her to develop those learning environments. Second, her teaching experience was only two years, most of it during the Covid-19 pandemic. She may not have developed her own concept of how she should teach, or what her instruction to support her students to learn should be. Third, as a teacher of only a few years of experience, she may be adjusting to school life. There are hierarchies in school systems. Opportunities for implementing any new way of instruction may not be accepted too much. That is why she mentioned about putting in a policy. Fourth, there were too much extra work in her school setting. She mentioned that extra paperwork took so much time and energy away from focusing on her effective teaching.

Within the interviewed teachers, most who reported a high level of metacognition and highly positive opinions on MOLEs, reported low to medium MOLEs. They reported similar obstacles to Ms. Mintra. They lacked of knowledge about metacognition concept and guidelines of how to develop MOLEs and reported problems regarding teaching time, the tight curriculum, and too much extra work. They also reported obstacles, for example, resistance of the teachers and their school systems, and students' motivation to learn.

Discussion at the Relationships Between Teachers' Metacognition and Perceptions of Their Actual and Preferred MOLEs: Integration of Quantitative and Qualitative Findings

In this section, the findings of relationship between teachers' metacognition and perceptions of their Actual and Preferred MOLEs from quantitative strand (questionnaire analysis) and qualitative strand (case studies) are discussed.

There were Relationship between Teachers' Metacognition and Their Actual MOLEs

Findings from both the quantitative (questionnaire analysis) and qualitative strands (case studies) suggest relationship between teachers' metacognition and their Actual MOLEs. The quantitative findings suggest medium and significant correlation between teachers' metacognition and their actual MOLEs (in the Metacognitive Prompts dimension). Qualitative Findings from four case studies suggest that teachers who reported their metacognition as being at a high level also reported their Actual MOLEs at a high or medium level. Teachers who reported a medium level of their metacognition also reported a medium level of Actual MOLEs. A teacher who reported low level of their metacognition also reported low level of their Actual MOLEs.

The qualitative findings may explain the medium correlation in the quantitative findings. Even though there were relationship between teachers' metacognition and their Actual MOLEs, there were some variations. For example, not all teachers who reported high metacognition reported high Actual MOLEs. There were some teachers who reported high metacognition who reported a medium level of their Actual MOLEs. This could be a reason why the quantitative analysis found the medium correlation and not a strong one.

Quantitative and Qualitative data may Suggest Variation of Relationship Between Three Elements of Teachers' Metacognition and Teachers' Perceptions of Actual MOLEs Differently

As mentioned before, the quantitative findings suggest that between the two elements of Metacognitive Knowledge, the teachers' metacognition in relation to Learning Process Knowledge held stronger relationship to their perceptions of their Actual MOLEs than teachers' metacognition in relation to Declarative Knowledge.

However, findings from the qualitative strand may not suggest which element between the two of Metacognitive Knowledge held closer relationship their perceptions of Actual MOLEs clearly. Available information in the case studied may not be interpreted in the way that teachers who reported Learning Process Knowledge reported higher level of Actual MOLEs than teachers who reported only Declarative Knowledge, as all teachers in the case studies could report their metacognition in relation to both Declarative and Learning Process Knowledge. Findings in this respect could be explored in further studies.

Focusing on the Regulation, as mentioned before, the quantitative findings suggest relationship between teachers' metacognition in relation to Regulation and their perceptions of Actual MOLEs. Findings from the qualitative strand were congruent with the quantitative one, as it supports the relationship between teachers' Regulation and their perceptions of MOLEs. In the case studies, teachers who reported their metacognition in relation to Regulation also reported their perceptions of Actual MOLEs in medium or high levels.

There Were Relationships between Teachers' Metacognition and their Perceptions of Preferred MOLEs

The case studies suggest that teachers who reported high level of metacognition reported high level of Preferred MOLEs. In addition, teachers who reported medium level of metacognition reported medium or high level of Preferred MOLEs. A teacher who reported low level of metacognition also reported low level of Preferred MOLEs. The findings suggest a direct relationship between teachers' metacognition and their Preferred MOLEs. It could be explained that teachers who reported high level of metacognition could perceive positive experience of being metacognitive. Therefore, when they were introduced to instruction for metacognition, they reported high level of Preferred MOLEs. Similar explanations could be applied to teachers who reported medium or low level of metacognition accordingly.

There Were Some Differentiation Between Teachers' Perceptions of Actual and Preferred MOLEs

Based on the case study four, a teacher who reported high level of Preferred MOLEs may reported medium level of Actual MOLES. Differentiations between Actual MOLEs and Preferred MOLEs could also be evidenced in interview data as mentioned before. Explanations will be discussed under the Research Question Four in the following section.

There Was Congruence and Incongruence Between Quantitative and Qualitative Data Regarding Teachers' Reports of Their Metacognition and Actual MOLEs

Teachers reported their metacognition or their Actual MOLEs by giving response to questionnaires (quantitative data) and interviews (qualitative data). Interpretations of both quantitative and qualitative data suggest congruence between the two strands. For example, teachers who reported high mean score on Mc questionnaire reported high level of their metacognition in their interview. Or teachers who reported low mean score on the subscale Metacognitive Prompt also reported low level of Actual MOLEs in their interviews.

However, incongruence between quantitative and qualitative data could be found when comparing between two individuals. For example, comparing information between two teachers in the Case 2: Ms. Raya and Case 4 Ms. Mintra, in the quantitative strand, Ms. Raya's mean score of metacognition from Mc questionnaire was 4.00 which is higher than Ms. Mintra at 3.85. However, in qualitative strand, Ms. Raya reported lower level of metacognition than Ms. Mintra.

This incongruence could be explained in three aspects which mentioned in the limitations of this study. Firstly, in Thai culture, people may give responses in to questionnaire items or interview questions differently than their perceptions of their actual situations. They may give higher scores than the reality for them to save their face. Or they may give responses in lower score than their perceptions because they are humble. Secondly teachers' perceptions could be different from their actuality. Teachers may think that they endorsed with items in Mc questionnaire, but their actual situations, based on their reports, may not reflect their endorsement. Thirdly, as the study was conducted during the Covid-19 pandemic, interview data were collected using telecommunication. Although most teachers were interviewed twice, and they got to check their interview data in a member checking process, the interview data may not explain all of teachers' perceptions of their metacognition and Actual MOLEs. The researcher may have missed some opportunities to ask some follow up questions, and teacher participants may not give responses to cover all of their elements of metacognition and their Actual MOLEs. These three possible reasons could influence the incongruence of quantitative and qualitative analyses/findings.

There Have Been Findings About Relationship Between Teachers' Metacognition and Developing MOLEs in International Context

As mentioned before, there was no research from Thailand exploring science teachers' metacognition and their perceptions of MOLEs in science classrooms. Therefore, information about these relationships between science teachers' metacognition and their MOLEs in Thailand are not evident as well. However, in the international context, two studies regarding relationship between teachers' metacognition and their MOLEs are evident.

Ozturk (2017) explored the relationship between teachers' self-reported of their metacognition (using MAI questionnaire, an instrument for assessing metacognition which was mentioned in Chapter two) and teachers' self-reports of their competencies in instruction for metacognition (using lesson-plan think aloud). The participants were 30 English language teachers in university level in Turkey. Ozturk (2017) reported that only teachers who had high (≥237) and medium score (226-236) in MAI that their lesson plan transcript showed evidence of developing instruction for metacognition. In teachers who had MAI scores lower than ≤225, their transcript did not show evidence of instruction for metacognition. Ozturk (2017) also mentioned that in teachers who had a high score in MAI, their lesson plans showed more evidence of instruction for metacognition compared to teachers with the medium scores. The study from Ozturk (2017) suggested a direct relationship of teachers' metacognition and their instruction for metacognition (based on their lesson plans). Results from Ozturk (2017) suggest the same direction as results from this study; that there are relationships between teachers' metacognition and their Actual MOLEs. Specifically, teachers who reported high level of Actual MOLEs reported high level of metacognition, teachers who reported medium level of Actual MOLEs or reported medium or high level of metacognition, and teachers who reported low level of Actual MOLEs reported low level of metacognition.

In another study, as mentioned before, Karlen et al. (2023) explored how teachers' self-regulated learning (SRL) skills related to their promotion of metacognition into their classrooms. The participants were 185 teachers at lower secondary school level in Switzerland, and the participant were mixed from teachers who taught German, mathematics, science, and foreign language. SRL skills in this study referred to four aspects combined together including metacognitive awareness, metacognitive regulation skills, cognitive regulation skills, and motivational regulation skills. The study employed teachers' self -reported methods to collect all data. Karlen et al. (2023) concluded that there were relationships between teachers' SRL skills and their promotion of metacognition. Although SRL skills in the study by Karlen et al. (2023) combined four aspects, two of them relate to metacognition framework of this study: metacognitive awareness and metacognitive regulation. Therefore, it could be suggested that findings from the study by Karlen et al. (2023) are congruent with the findings in this study, that is, based on teachers' reports, teachers' SRL skills (teachers' metacognition) relate to promotion of metacognition in classrooms (Actual MOLEs).

Findings From This Study Provide Information about the Relationship of Specific Elements of Teachers' Metacognition and MOLEs

Karlen et al. (2023) reported that the correlation value between teachers SRL skills and teachers' self-reported promotion of metacognition was 0.17 ($p<0.05$). Based on the guidelines used in this study, this could be considered as a weak but significant correlation between Teachers' SRL skills and Teachers' promotion of metacognition. Specifically, quantitative findings from this study add more specific information about teachers' metacognition and promotion of metacognition. Karlen et al. (2023) studied SRL skills which combined two aspects related to metacognition with other two aspects, but this study explored teachers' metacognition specifically, in addition to its three elements. Karlen et al. (2023) found a weak relationship between teachers' SRL skills and their promotion of metacognition. Findings from this study, based on teachers' reports, suggest a medium correlation between teachers' metacognition and promotion of metacognition in classrooms (Actual MOLEs). Specifically, this study provides further support regarding the relationships between each element of teachers' metacognition and their Actual MOLEs.

Research Question 4: How do Thai Lower-Secondary Science Teachers Explain any Similarities and Differences Between Their Preferred and Actual Metacognitively Oriented Science Classrooms?

Findings and Discussion

To answer this research question, themes from thematic analysis of interview data were employed. To begin with, as mentioned before, all teachers reported that they were interested to different extents, in implementing MOLEs in order to support their students. However, there were only 13 teachers who reported that they often identified at least one of the four focused dimensions of MOLEs in their science classrooms. Those dimensions of MOLEs included teachers encouraging students to think about own learning, teachers sharing how they learn to students, students discussing with teachers about learning, and students discussing with each other about learning. In brief, differences between teachers' reports of their Preferred and Actual MOLEs were evident. The differentiation could be explained partly by teachers' reports on their obstacles in supporting MOLEs and lack of knowledge about metacognition. Four themes about obstacles that teachers identified for developing MOLEs in science classroom are discussed as follows.

Lack of Teaching Time

Twenty-five teachers reported that they were concerned about teaching time in their classrooms. They mentioned about not having enough time for classroom teaching. They explained further that if they were to implement instruction to support MOLEs in their classrooms, they would not know if they have enough time. In relation to lack of teaching time, 15 teachers mentioned about too much content knowledge in curriculum to be followed.

> "It [time] is a problem in teaching and learning. Time and content are not consistent. There is not enough time to teach all content and support students to learn… I have to teach only content knowledge and cut all learning activities out." "and yes there is no time to support anything else." (Ms. Sritrung)

In addition to the lack of teaching time as results of too much content knowledge, 13 teachers mentioned about too much extra work. Those teachers reported that they did not have time to prepare for their teaching. Sometimes, they had to leave their class to manage their school work.

> "Sometimes, when I teach students in my class, I have to leave them there as there is an urgent task. Sometimes I have to leave my class for a meeting." "I do not have time to prepare for my teaching. Tonight, I have to prepare for extra work for school." "I do not have time to think about how to improve students." (Ms. Yitho)
>
> "The first thing is about too much teachers' workload. Teachers' main duty is supposed to be teaching, but nowadays it is not. There is too much workload, and it is not teaching work" (Ms. Matoom)

The situations of that Thai teachers reported challenging in implementing curriculum into their classrooms are not new in Thailand's educational context. OECD/UNESCO (2016) mentioned about similar situations in their book *Education in Thailand: An OECD-UNESCO Perspective.* OECD/UNESCO (2016) indicated that, "They [teachers] reported feeling confined by the standards to plan and teach in a methodical way to ensure they covered all of them" (p. 114). In addition, in the same book, situations about teachers' extra works were mentioned as a teachers' burden as well. OECD/UNESCO (2016) stated that, "their [teachers'] administrative tasks are encroaching on their teaching time" p. 215. In summary, situations about tight curriculum and teachers' extra works seem to be challenges in Thai education context which can affect supporting MOLEs in science classrooms.

Students' Learning Motivation and Readiness

Seventeen teachers reported about their students' lack of motivation for learning. They explained that a lot of students did not have interest in learning, and students just followed teachers' instruction. Within this group, seven teachers mentioned that their school was located in rural area, and most of the students who were interested in learning chose to study in schools in urban areas. Therefore, those teachers explained that most of their students were students who just come to school to finish the degree. However, 10 teachers who reported about students lack of motivation for learning did not mention about or relate any situation about their school's location.

In addition, four teachers mentioned that student families' economic status could affect students' intention for learning. The teachers further explained that those students had other duties beside studying in school, but also had to work to support their family. Teachers indicated that those students did not have time to think about learning.

Another crucial issue was about students' readiness in learning. Two teachers mentioned that some students could not read or write properly even though they were in lower secondary level. (There was a policy in Thailand that all student had to pass their grade level to higher one. Even though those students may not be capable enough. Therefore, some students in lower secondary level may not be able to read and write properly).

Examples of teacher interviews related to students' intention and readiness in learning are as follows.

> "High performance students choose to study in schools in urban area, and low performance students are in my school. Some student cannot even read. Therefore, it is really difficult for me to find a way to support them to learn" (Ms. Nonzee)
>
> "If it is about doing an experiment, students will be enthusiastic. But in general, mostly, they do not share ideas or ask for anything different" (Ms. Matoom)
>
> "Some of my students can read, but cannot write. So, learning science is something that is not important for them [compared to reading and writing]" (Mr. Wha)
>
> "Poverty will affect students' quality of life and their intention for learning a great deal. Students who need to help their family may have low intention and their time in learning. Family factors affect students a lot" (Ms. Jampa)

One other possible explanation could relate to Thai culture as mentioned in Deveney (2005) and Nicholls and Apiwattanakorn (2015) which was already discussed in the section about Students-teacher negotiation. Specifically, Thai culture may impact how students and teachers interact in classrooms. Students may perceive teachers as 'higher' persons, so students are comfortable in learning by following teachers' instruction, and they may not be confident to share their opinion in classrooms. These two possible explanations could provide some understandings about the situation on students' low learning intention and readiness in Thailand context.

Teachers' Metacognition Knowledge and Attitudes

Eleven teachers mentioned about the need for knowledge about metacognition. Five teachers mentioned about teachers' attitude for learning and adjusting to new instruction.

"I need mentor to support me… I do need deep feedback" (Ms. Keaw)

"I think at the very beginning, there will be some struggles as we are not familiar with (this form of instruction)" (Ms. Jampee)

"I think the first thing is about teachers. Teachers may not want to change, so it will be difficult to change. It [implementing this form of instruction] has to change many things including thinking process and teaching process" (Ms. Malee)

"I think it is about teachers. If teachers think that it is important and can be used in classroom, it won't be very difficult. I think it will be possible" (Mr. Pud)

"If I get to support students about their learning processes, it will be just a tiny part of their time. If we want it [instruction for metacognition] to be effective, we should all agree to do that together [all teachers in schools should implement instruction for metacognition]. Changing other teachers [for them to agree with instruction for metacognition] to agree with enhancing students' metacognition is a bit difficult" (Mr. Pud)

The finding that teachers in this group reported the need of metacognition knowledge is similar to suggestions by Veenman et al. (2006). Specifically, Veenman et al. (2006) reported that teachers were found to be willing to implement instruction for metacognition into their classrooms; however, teachers needed knowledge and methods to do so. Similarly, Zohar and

Barzilai (2013) stated that teachers need knowledge of instruction for metacognition. Therefore, teachers' knowledge about how to support students to be metacognitive is essential in order to support developing Actual MOLEs in classrooms. Teachers should not be perceived to already have enough knowledge to implement instruction for metacognition.

Also, teachers' attitude toward instruction for metacognition should be considered as important. The findings suggest that teachers' attitude to metacognition could influence instruction for metacognition in at least two ways: firstly, to an individual teacher who is responsible to classroom instruction, and secondly, to other teachers in the same educational setting. The second factor is crucial in the Thailand educational context, as the whole society, including school settings, is considered a collective. Hallinger and Kantamara (2001) explained high collectivism in Thailand educational context that "people look for social acceptance and sanctions to direct their behavior during the change" and "actions which make one stand out from the group are avoided" p. 395. Consequently, in the Thai context including for teachers in school settings, being part of the society is important, and being different to others of social norms could cause negative consequences. A teacher may have knowledge and be interested in instruction for metacognition, but may not implement the instruction into their classrooms if they are influenced by other teachers who do not agree with instruction for metacognition. Therefore, teachers' attitudes could impact supporting instruction for metacognition in Thailand context.

In addition, it should be acknowledged that implementing instruction for metacognition requires time for adjusting and practicing especially with new teachers. Teachers may have knowledge about instruction for metacognition and positive attitude to create MOLEs in their learning environment, but they may require time and practices to adjust the instruction with complex situations in their classrooms. Couteret et al. (2018) reported some challenges from their experience as science teachers who had learned about metacognition in their preservice program, and tried to implement instruction for metacognition in their science classrooms. They described that, “I think it takes new teachers a little while to settle in before being ready to use some ideas” (p. 45), and they had to manage with “what to do or what to deal with situation in classrooms than focusing on student thinking and learning” (p.45). They stated that, “[U]nderstanding the theory and how it can be useful only comes when we’ve had some experience” (p. 48).

Policy and Learning Expectations

Six teachers mentioned about policy from the top that should be open to support instruction for learning.

> “It is about policy too. If they need to assess student quality by their grade level, it [supporting students to be metacognitive] won’t be possible” (Ms. Chaba)
>
> “I think most teachers and students focus on testing and content knowledge. If we could decrease the amount of content knowledge and focus on the processes of learning, it [the situation for supporting metacognition in classrooms] could be better” (Mr. Wan)
>
> “The most important thing is about assessment and evaluation. It makes everything impossible to change. In Thailand, assessment and evaluation are still focused on testing” (Mr. Wha)

Teachers reported that policy and learning expectations are considered as obstacles in enhancing MOLEs. The identified pressure on policy and learning expectation resonated with what Fry (2008) indicated in his book *Education in Thailand: an old elephant in search a new Mahout.* Fry (2008) mentioned that “assessment and testing are powerful forces in the Thai system. There is still too much teaching to the test. Teachers are often discouraged from using innovative genuinely student-centered approaches because this may not improve students' test performance" p. 702. The book was released in 2008, but the pressure on testing culture was still reported within this group of teachers.

Findings from this Study Other Than Those Related the Four Research Questions

Besides findings related to the research questions, three interesting findings in relation to metacognition were found in the interview data. Those findings are, (1) teachers reported their learning strengths and weaknesses in terms of affection not cognition, (2) teachers reported their metacognition in terms of knowing cognition capability of others which was not in the framework of this study, and (3) teachers mentioned a relationship between metacognition and Buddhism practice. Findings and discussion of those topics are as follows.

Teachers Reported Their Learning Strengths and Weaknesses in Terms of Affection Not Cognition

Learning strengths and weaknesses are must often considered categorized in relation to cognition. However, 10 teachers in this group mentioned their weaknesses and strengths in terms of affection not cognition. Examples of their interview are as follows.

> "About my strengths, I love to learn, I love learning especially new knowledge."
>
> Ms. Tiwa
>
> "About my weakness, I know that I do not like to get to do thing by myself. I like to read other people's works. I do not want to prove what they said if it is correct. I just want to read to understand topic knowledge." "my strength is that I like to learn. I like to study and understand new knowledge continually. But I do not like to do it by my own."
>
> Ms. Kasalong
>
> "It is my weakness that if I do not like a topic, I do not want to learn about it [science

topic]. On the other hand (on my strengths), if I am interest it [science topic], I will study it further." Ms. Keaw

Although, this finding may not relate to the study in terms of metacognition, it is noteworthy, as it may add benefit to metacognition research in Thailand context in the future. Affection (feeling) and cognition (thought) have been considered different classifications (Hilgard, 1980). However, affection and cognition are inseparable and have reciprocal relationship (Forgas, 2008). Eisenberg (2104) summarized that many theorists suggested affection could structure cognition, and in the same regard, many theorists suggested cognition could shape affection. Forgas (2008) mentioned that affection influences people's cognition in many ways, for example, remembering, perceiving, and interpreting. Bower (1992) explained how motivation (affection) structures learning (cognition) and that motivation leads attention which encourages practices and actions that finally lead to learning in that area of motivation. Many studies that focused on relation between affection/motivation and cognition/learning in diverse areas could be found, for example, writing, language learning, decision making, or behavior (e.g. Hayes, 2000; Jiang et al., 2006; Kyro, 2008; MacIntyre & Gregersen, 2012; Meyer & Turner, 2002; Schwarz, 2000).

The finding that Thai science teachers included affection as a representation of cognition suggests that they did not differentiate between affection from cognition. Further studies about any relationship between affection and cognition may be beneficial in exploring how to improve cognition or metacognition. Research questions of further studies could be, for example, "How are teachers' cognition or metacognition influenced by their affection for particular topics or task?" or "How can teachers' metacognition be improved by addressing their affection?"

Teachers Reported Their Metacognition in Terms of Knowing the Quality of Students' Cognition

There is one element of metacognition that was not employed in the framework of this study, but was mentioned in Flavell's framework of metacognitive knowledge (Flavell, 1979), and was evident in participant interviews. The element of metacognition is about knowing about how others learn. In this study, there was no question related to this element in both Mc questionnaire and semi-structure interview.

However, 10 teachers mentioned that they knew about how their students learn. They explained, for example,

> "Every student has their own ways in learning. I know which students can learn fast or slow. So, when I teach, I will pay attention on some students (who learn slow)." (Mr. Rak)
>
> "Students improved. They were more careful about the mistakes that they have done. They could know about it by themselves when they got something wrong again for the same mistake. They realized it and they could fix the mistake." (Ms. Khun)
>
> "Sometimes students were just too scared to ask me questions even they did not understand. They may be afraid if they make their friends or a teacher uncomfortable. I tried to create a learning environment (to encourage students to ask). I told students to come to ask me on their free time if they do not understand; they could use online chat to ask me directly." (Ms. Chomjan)

The findings suggest that teacher participants may hold another element of metacognition that had not been explored/focused in this study. In addition, in terms of metacognition research, findings about various elements of metacognition could be beneficial. The findings could provide more precise information about ones' metacognition, and it could be used as foundation knowledge of metacognition to be improved.

Teachers Mentioned Relationship between Metacognition and Buddhism Discourse

In the interviews in this study, there were no question or questions leading teachers to themes about Buddhism discourse. However, there were three teachers who related metacognition to Buddhism discourse specifically 'Sati'. They stated, for example,

> "Is it [metacognition] similar to that in Buddhism, Sati (สติ) or know your thought thing like that?" "We have Sati knowing what we are doing, what we are thinking, thing like this, is it similar to metacognition?" (Ms. Pradu)
>
> "We should know about this (metacognition), know how we learn. I am not talking about science, but I am talking about it [metacognition] in terms of Buddhism. In order to be enlightened, we have to know the learning processes to get there" (Ms. Pud)

From those teachers who mentioned about Buddhism practice, only one teacher reported that he practiced meditation regularly. In addition, he reported that he had implemented Samathi (สมาธิ) and Sati (สติ) when he engaged with his thoughts. It should be noted that from his interview, he reported high level of metacognition. He mentioned that he noticed quality of his thought, and tried to regulate this thought as well. Some parts of his interview are shown as follows.

> "Before, I felt like my life was something like doing thing too fast, and I thought fast but not correctly. When I got to learn with a monk, my thinking process got slower and more thorough. I have made decisions reasonably." "I have learned from that monk about Samathi (สมาธิ). That is making our mind stay still. But before that, we have to have

Samathi (สมาธิ) and have Sati (สติ) before making any decision or learn about that thing. We have to have Samathi (สมาธิ) and Sati (สติ), then we will learn better" (Mr. Wan)

Sati (สติ) is a term using in Thailand, and maybe in other countries, which generally refers to consciousness or mindfulness. In Buddha' discourses, there is a specific term called 'Satipatthana' (สติปัฏฐาน) which refers to mindfulness or consciousness in four foundations: body (กาย), feeling (เวทนา), mind (จิต), and dhammas (ธรรม) (Analayo, 2006; Intarawong, 2020). Specifically, Analayo (2006) and Intarawong (2020) explained that, there are many levels in each foundation. Satipatthana in the body, feeling, mind, and dhammas foundation are, for example, being conscious when we are breathing or acting, being conscious how we feel about something, being conscious how we think, and being conscious about nature of dhammas, for example, hindrance or noble truths, respectively (Analayo, 2006; Intarawong, 2020). Accordingly, there are some overlaps between Satipatthana and metacognition definition. While Satipatthana focuses on being conscious in four foundations as mention earlier, metacognition focuses on cognition. Available information showed that Sati and metacognition have been connected in terms of mindfulness in psychology studies, for example, hypnosis or mental states intervention (e.g., Lush & Dienes, 2019; Lovell & Dienes, 2021). However, there is no available information/published articles about connection of Satipatthana/Sati and metacognition in area of learning. More than 90% of Thai population are Buddhist. Most Thai students have a chance to learn Buddhism discourses in their schools including Sati or Satipatthana that may lead them to have foundation in being conscious on their feeling or mind. As a researcher about metacognition, I could also connect metacognition with Sati as mentioned in Chapter one. The findings about teachers relating metacognition to Sati could lead their ways to develop MOLEs in Thailand context.

CHAPTER FIVE

SUMMARY and CONCLUSIONS

The research centers on a foundation of issue of how to enhance Thai students' science learning. The literature review suggested that Thai students' metacognition may be problematic for learning science. The literature review also suggested that there were countless reports on positive influences of metacognition on students' learning including in relation to science learning. Specifically, Georghiades (2004a) stated that, "[W]orking towards 'metacognitively enhanced science learning' could therefore be a promising future direction for science education" (p. 378). Metacognitive science learners could be developed so that they would be more be aware of, and able to manage, and control their learning. Therefore, based on the literature, learners could learn better in school systems and could continue to be productive lifelong learners. However, there is little research regarding the metacognitive orientation of science classroom learning environments and contributing factors to develop such learning environments in either Thailand or international contexts. Within the little research that is available, findings suggest a relationship between teachers' metacognition and their capacity to develop students' metacognition and their perceptions of metacognitive orientation of learning environments. However, the findings were situated in learning other subjects, not in science and not in Thailand context. In addition, from available literature, there was no information of how each element of metacognition relates to MOLEs in their learning environments or how each element of metacognition relates to each other. The information is worthy to both in the field of metacognition research and in developing MOLEs.

Therefore, for this researcher, it was necessary to fill in a gap to understand state of and contributing factors to metacognitively oriented learning environments (MOLEs) in science classrooms in Thailand. This research to explore Thai science teachers' metacognition, their perceptions of their actual science classroom in relation to MOLEs (Actual MOLEs), and their perceptions of MOLEs (Preferred MOLEs). In addition, possible relationships between those three aspects were investigated. The four research questions of this study were as follows.

1. What are Thai lower-secondary science teachers' self-reports of their metacognition?
2. What are Thai lower-secondary science teachers' perceptions of their actual and preferred metacognitively oriented science classroom learning environments?
3. Is there a relationship between Thai lower-secondary science teachers' metacognition and their perceptions of their actual and preferred metacognitive orientations of their science classroom learning environments?
4. How do Thai lower- secondary science teachers explain any similarities and differences between their preferred metacognitively oriented science classroom and the actual?

The study was conducted using a mixed methods approach. Survey and interview methods were employed to collect research data. Two questionnaires were developed for use in this research: the Questionnaire for Assessing Science Teachers' Metacognition (Mc questionnaire) and the Questionnaire for Assessing Teachers' Perceptions of the Metacognitive Orientation of Their Actual Science Classroom Learning Environments (ActualMOLEs questionnaire). Statistics, for example, Cronbach's Alpha, t-test, Pearson correlation were adopted to analyze data in the quantitative strand. Thematic analysis and instrumental case studies were adopted to analyze data in the qualitative strand. There were 214 teacher participants who gave responses to questionnaires, and 29 teacher participants in the interviews.

Findings integrated from both quantitative and qualitative strands suggest that all science teacher participants reported their metacognition, but their response and reports varied. In the quantitative strand, findings from the teachers' responses to the Mc questionnaire suggested that they endorsed questionnaire items more in relation to Metacognitive Knowledge than Metacognitive Regulation. In the qualitative strand, in relation to Metacognitive Knowledge, all teachers could describe processes they adopted in science learning, and 23 teachers could explain their strengths and weaknesses in their science learning. In relation to Regulation, 19 teachers could explain how they established if they knew or if they understood a science concept. Nine teachers reported how they manage their own cognition. In summary, science teachers in this group were likely to report their metacognition in relation to Metacognitive Knowledge more than Metacognitive Regulation.

Findings from teachers' responses to the ActualMOLEs questionnaire suggested that teachers considered that their classroom learning environments were sometimes related to MOLEs for the dimensions of Metacognitive Prompt and Student-Teacher Negotiation. From the interview data, six teachers reported that they often encouraged their students to think about own learning. Eleven teachers reported that they often modeled or shared how they learn science to students. Four teachers reported that their students engaged in sharing and discussing about how they learn with other students. Findings from both quantitative and qualitative strands suggested that, for this sample of teachers, there was insufficient metacognitive orientation in their science classroom learning environments.

However, in terms of Preferred MOLEs, all teachers reported that they were interested to varying extents in developing MOLEs in their science classrooms. Specifically, six teachers reported high interest, 16 teachers reported medium interest, and seven teachers reported low interest.

Findings from the quantitative strand suggested that there were medium correlations between all three elements of teachers' metacognition and their perceptions of the Actual MOLEs for their classrooms. Findings from four case studies suggested, similarly, that the teachers' metacognition might relate to their perceptions of their Actual MOLEs. For example, a teacher who reported their metacognition to be at a high level also reported their science classroom learning environments at a high level of MOLEs. A teacher who reported their metacognition at a medium level also reported their science classroom learning environments at a medium level of MOLEs.

However, some variation of relationship between teachers' metacognition and their perceptions of MOLEs was evident. From the case studies, it was learned that not all teachers who reported their metacognition at a high level also reported their learning environments at a high level of MOLEs. This finding could be used to explain the medium correlation of teachers' metacognition and their perceptions of Actual MOLEs in the quantitative strand. In addition, the variation could be explained through challenges in developing MOLEs from teachers' reports.

Further, findings from the four case studies suggested some trends in relation to teachers' metacognition and their perceptions of their Preferred MOLEs. Information from the case studies indicated that teachers who reported a high level of Preferred MOLEs also reported a high level of metacognition. Teachers who reported medium and low level of preferred MOLEs reported medium and low level of their metacognition respectively.

The difference between teachers' perceptions of their Actual MOLEs and their Preferred MOLEs was evident. While all teachers mentioned that they interested in MOLEs, only 13 teachers reported at least one dimension of MOLEs in their actual learning environments. Teachers reported challenges in developing MOLEs in their classrooms for the four main reasons: teaching time, students' learning intention and readiness, teachers' knowledge of metacognition and their attitude, and policy and learning expectations.

Future Research Implication

Findings from the research could be employed to develop MOLEs in science classrooms in Thailand (and other countries) to improve student learning. There are four agencies in educational context that may involve in the development including, policy makers, teachers, students, and researchers. Those agencies could consider these research findings to develop MOLEs as follows.

Policy makers in this respect cover all agencies that have authorities to support and manage teaching and learning in educational settings, for example, school principals, institutions, educational bureaucracies. The findings suggest possible influences to developing MOLEs including teachers' metacognition, teachers' metacognition knowledge, teachers' attitude, teaching time, students' learning readiness, and learning expectations. Accordingly, policy makers should support teachers to learn about and develop their own metacognition including develop knowledge about the concept of metacognition and instruction for metacognition. The supports could be implemented since preservice course, then in professional developments, and further in mentorship programs. The importance of supporting teachers to learn about metacognition also was suggested by researchers. De Jager et al. (2005) emphasized that, "teachers have to be trained to implement the instructional models in their classrooms successfully" (p. 194). Similarly, Thomas (2012b) stated that, "teachers' as well as students' metacognition needs to be given more prominence in teacher education and teacher development" (p.48). Thomas (2011) suggested that metacognition should be placed in educational programs for prospective teachers, so they could learn about metacognition, instruction for metacognition, and develop to be metacognitive learners themselves.

Metacognition should be indicated in curriculum documents to manifest its important and encourage implementations. Thomas (2023) pointed that metacognition has been placed in science curriculum in some contexts, for example, F-10 Australian science national curriculum. He mentioned that, "[I]t is possible to give explicit attention to metacognition in science curricular frameworks with implicit expectations that it will addresses in teachers' practices" (p. 259).

The supports should include supporting teachers to have positive attitude to metacognition. Importantly, the supports should be concerned with the nature of collective society in Thailand's educational settings, and acknowledge the influences of teachers on each other in the same educational settings. Policy makers should be concerned about and finding ways to support all students to learn. Moreover, many educational challenges were identified in this study, such as tight curriculum, teachers' heavy workloads, or teaching for testing culture. Those challenges have been identified in Thailand's educational settings for more than 15 years (e.g. Fry, 2008). The challenges work against developing MOLEs, but also overall teaching and learning. The policy makers should express concern about these issues and create new strategies to attend to these limiting factors.

Teachers are the crucial part of learning environments. Even in the Thailand educational context, teachers may seem to be at the lower hierarchy as they have to follow curriculum and bureaucratic policies. Teachers should consider themselves as main actors who have authority to direct activities in their learning environments. Thomas (2012) mentioned that "metacognition development requires that science teachers are themselves metacognitive and able to communicate with students regarding the benefits of particular ways of thinking about learning science and how it might best be facilitated" (p. 141-142). Therefore, in order to develop MOLEs, teachers should be aware of their own perceptions of metacognition, their own metacognition, and their own knowledge of instruction for metacognition. In addition, teachers should be aware that their interactions with students act as formative factors in learning environments. The important interactions are not only being open or leading discussions between teacher and students, but also encouraging discussion among students and students, and being role models of metacognitive learners for students. As learned in the study, some teachers have concerns that metacognition may be appropriate to high performance students rather than those with low performance. Teachers should consider the appropriateness of their own context as a priority, but should be aware that much research has identified the positive influence of instruction for metacognition for students at young ages as in elementary school level (e.g., Georghiades, 2004b; Roebers et al., 2009; Thomas & Mee, 2005) and in students with low academic performance (e.g., Cardelle-Elawar, 1992; Dang et al., 2018; Händel & Fritzsche, 2016; Miller & Geraci, 2011). In addition, teachers should be aware of the influences of Thai culture norms on their learning environments. To encourage discussion about learning, teachers should be aware of their own behavior in their classroom learning environments if it is open opportunities of discussing and sharing about how to learn science.

In this study, teachers reported their perceptions of students' learning readiness. Students should be supported and encouraged to know that they are the ones who should take responsibility of their own learning. Students should be informed about metacognition in terms of its benefits to their learning in classroom settings and in real-world settings. They should be taught explicitly strategies for developing metacognition.

Although the study took place in the Thailand educational context, some findings might be considered in other countries' contexts as well. The questionnaire instruments developed in the study could be adopted for assessing teachers' metacognition and MOLEs in science classrooms. Researchers could use the findings as foundations to explore further knowledge of instruction for metacognition. Findings about relationships between the three elements of teachers' metacognition and their perceptions of Actual MOLEs may be used to provide understanding of possible contributing factors in developing MOLEs. Challenges in developing MOLEs in science classrooms learning environments from Thai science teachers' perceptions may be adopted as foundation knowledge for other contexts.

Recommendations for Further Studies

Based on findings from this research, further studies are suggested as follows.

Firstly, teacher participants mentioned that they needed guidelines on instruction for metacognition. Future studies may be conducted to explore appropriate guidelines for teachers for developing MOLEs in their science classrooms. Research questions for those studies are, for example:

- How should MOLEs in science classroom be considered?
- What dimensions of learning environments should be included in MOLEs?
- How should teachers share, model, and encourage students in order to develop MOLEs?

- Should there be any difference between MOLEs in classrooms of high and low academic performance students?
- What challenges of students are in developing metacognitive students in Thailand context?

Secondly, there were no clear evidence in this study between experienced and inexperienced teachers in terms of their metacognition. Specifically, the foci of this study were not related to experienced or inexperienced teachers. However, teachers who reported their metacognition at a high level and their learning environments in relation to MOLEs at a high level also reported more than 10 years of teaching experience. Teachers who reported low level of those metacognition elements reported less than five years of teaching experience. Exploring on this topic may be beneficial in terms of understanding possible contributing factors to teachers' metacognition and their MOLEs.

Thirdly, as mentioned before, there were studies of students' perceptions of their Actual MOLEs. Further information about students' perceptions of their Preferred MOLEs is required. Information about how students view instruction for metacognition could provide understandings of teaching and learning in metacognitively oriented science classrooms from students' perspectives which could be used for developing MOLEs.

Fourthly, findings from this study might suggest relation between Sati (สติ) and metacognition. Future research might study this aspect deeper, for example, relation between participants who practice Sati and their metacognition.

Fifthly, this study focused on teachers' metacognition in relation to Metacognitive Knowledge and Metacognitive Regulation. Future research may study teachers' metacognition in relation to other categories, for example, Metacognitive Experience.

One final thought: Teaching and learning in this information rich era will require profound change as follows. We must prepare learners to be autonomous in their own learning. Specifically, learning to learn should be highlighted equally or highly than learning to possess content knowledge or skills. Findings from this study could hopefully be part of fulfillment to the fundamental knowledge for developing metacognitive orientation in learning environments which could lead to enhance students to be metacognitive and to be autonomous learners eventually.

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APPENDIX A

A Summary of Inventories for Assessing Metacognition

Inventory	Domain	Aspects of Metacognition
	Inventories using with Adults	
Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994)	General domain	knowledge of cognition: declarative, procedural, and conditional knowledge, and regulation of cognition: planning, information management, monitoring, debugging, and evaluation.
Metacognitive Awareness of Reading Strategies Inventory (MARSI) (Mokhtari & Reichard, 2002)	Reading for Adults	Global Reading Strategies, Problem-Solving Strategies, and Support Reading Strategies.
	Inventories using with Teachers	
Metacomprehension behaviors (Schmitt & Baumann, 1990)	Teachers' behavior for promoting students' meta-comprehension	Preview material, activate prior knowledge, text characteristics, purpose for reading, generate questions, predict, verify prediction, summarise, answer generate quest, return to purpose, comprehend. Breakdown, and fix-up strategies

Inventory	Domain	Aspects of Metacognition
teaching reflection inventory for English teachers (Akbari et al., 2010)	English teachers	practical, cognitive, metacognitive, affective, critical, and moral reflection metacognitive component consists of teachers' knowledge of their personality, definition of learning and teaching, and view of their profession.
Teachers' metacognition scale (Wilson & Bai, 2010).	self-perceptions regarding his/her understanding of metacognition and pedagogical knowledge of the metacognition.	Pedagogical knowledge, conditional knowledge, procedural knowledge, declarative knowledge
Metacognitive Awareness Inventory for Teachers (MAIT) (Balcikanli, 2011)	General domain for teachers	declarative knowledge, procedural knowledge, conditional knowledge, planning, monitoring, and evaluating.
Teacher Metacognition Inventory (TMI) (Jiang, Ma, & Gao, 2016)	General domain for teachers	1) Teacher metacognitive experience (2) Metacognitive knowledge about pedagogy (3) Teacher metacognitive reflection (4) Metacognitive knowledge about self

Inventory	Domain	Aspects of Metacognition
		(5) Teacher metacognitive planning and (6) Teacher metacognitive monitoring
	Inventories using with Students	
Physics Metacognition Inventory (Taasoobshirazi et al., 2015)	Physics problem for students	Knowledge of cognition (declarative, procedural, and conditional) Information management Regulation of cognition: (monitoring, evaluation, debugging, and planning)
Index of Reading Awareness (Jacob & Paris, 1987)	Metacognition in reading	evaluation, planning, regulation, and conditional knowledge.
Metacognition Strategy Index (Schmitt, 1990)	Students' knowledge of strategic reading	Predicting and verifying, Previewing, Purpose setting, Self-questioning, drawing from background knowledge, Summarizing and applying fix-up strategies.
The Metacognitive Statements (Fortunato et al., 1991)	Problem solving for learners	Interpreting and planning, monitoring, evaluating, ways of working out the problem
Metacognitive reading awareness inventory (Miholic, 1994)	Students' awareness on reading	Regulation, conditional knowledge, planning, evaluation

Inventory	Domain	Aspects of Metacognition
State metacognitive inventory (O'Neil & Abedi, 1996)	Assessing higher level of metacognition in college students	planning, self-checking, cognitive strategy and awareness
Reading Strategy Use scale (Pereira-Laird & Deane, 1997)	Cognitive and metacognitive strategy use in reading for students	13 metacognitive items and 12 cognitive items of strategy use
Junior Metacognitive Awareness Inventory (Jr. MAI) (Sperling et al., 2002)	Version A for grade 3-5 students Version B for grade 6-9 students	Knowledge of cognition and regulation of cognition
Taxonomy of Metacognitive Activities (Meijer et al., 2006)	History text-studying and problem solving in physics	orientation, planning, execution, monitoring, evaluation, and reflection
Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) (Thomas et al., 2008)	students' metacognition, self-efficacy and constructivist science learning processes	(1) Constructivist Connectivity (2) Monitoring, Evaluation & Planning (3) Science Learning Self-efficacy (4) Learning Risks Awareness; and (5) Control of Concentration

Inventory	Domain	Aspects of Metacognition
Metacognitive Reading Awareness (Chen et al., 2009)	Reading awareness for college students	Phonemic Awareness, Phonics, Reading Fluency, Vocabulary Development, and Reading Comprehension.
Metacognitive Activities Inventory (MCAI) (Cooper & Sandi-Urena, 2009).	chemistry problem solving for students	Regulation of cognition (metacognitive skillfulness): planning, evaluating, and monitoring
Metacognition Scale (MS) (Yildiz et al., 2009)	General domain for elementary students	Knowledge of cognition (declarative knowledge, procedural knowledge and conditional knowledge) . and knowledge of regulation (planning, self-control, cognitive strategies, self-evaluation and self-monitoring factors)
Metacognition Applied to Physical Activity Scale (MAPAS) (Settanni et al., 2012)	Physical activity for students	metacognitive processes specifically declarative and procedural knowledge

APPENDIX B

The Questionnaire for Assessing Science Teachers' Metacognition Used in the Main Study

ที่ No.	ข้อความ item	ไม่เห็นด้วยอย่างยิ่ง Strongly Disagree	ไม่เห็นด้วย Disagree	ไม่แน่ใจ Neither Disagree or Agree	เห็นด้วย agree	เห็นด้วยอย่างยิ่ง Strongly agree
1	ฉันรู้ว่าการเรียนรู้วิทยาศาสตร์หมายความว่าอย่างไร I know what it means to learn science.	1	2	3	4	5
2	ฉันรู้วิธีการเรียนรู้วิทยาศาสตร์ I know how to learn science.	1	2	3	4	5
3	ฉันรู้วิธีการเรียนรู้หลากหลายวิธีเพื่อใช้ในการเรียนรู้วิทยาศาสตร์ในสถานการณ์ต่างๆ I know various strategies to learn science in different situations.	1	2	3	4	5
4	ฉันรู้ตัว ตอนที่ฉันกำลังเข้าใจองค์ความรู้วิทยาศาสตร์หนึ่งๆ I know when I am understanding science knowledge.	1	2	3	4	5
5	ฉันมีวิธีการที่จะตรวจสอบว่าฉันเข้าใจองค์ความรู้วิทยาศาสตร์หนึ่งๆถูกต้อง I have ways to check if I understand science correctly.	1	2	3	4	5
6	ฉันพยายามที่จะปรับแก้จุดอ่อนในกระบวนการเรียนรู้วิทยาศาสตร์ของฉัน I try to fix the weaknesses of my science learning processes.	1	2	3	4	5
7	ฉันวางแผนที่จะปรับปรุงการเรียนรู้วิทยาศาสตร์ของฉันให้มีประสิทธิภาพยิ่งขึ้น I plan to improve my science learning to be more efficient.	1	2	3	4	5
8	ฉันรู้ว่าการเรียนรู้วิทยาศาสตร์แตกต่างจากการเรียนรู้วิชาอื่นอย่างไร I know how learning science is different from learning other subjects.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เห็นด้วยอย่างยิ่ง Strongly Disagree	ไม่เห็นด้วย Disagree	ไม่แน่ใจ Neither Disagree or Agree	เห็นด้วย agree	เห็นด้วยอย่างยิ่ง Strongly agree
9	ฉันรู้ว่าฉันเรียนรู้วิทยาศาสตร์อย่างไร I know how I learn science.	1	2	3	4	5
10	ฉันรู้ว่าควรจะใช้วิธีการเรียนรู้แบบใดในการเรียนรู้วิทยาศาสตร์ในสถานการณ์ต่างๆ I know which learning strategies to use to learn science in different situations.	1	2	3	4	5
11	ฉันรู้ตัว ตอนที่ฉันกำลังไม่เข้าใจองค์ความรู้วิทยาศาสตร์หนึ่งๆ I know when I am not understanding science knowledge.	1	2	3	4	5
12	ฉันประเมินว่าฉันได้เรียนรู้วิทยาศาสตร์แล้วหรือไม่ I evaluate myself to know if I learn science.	1	2	3	4	5
13	ฉันพยายามที่จะพัฒนาจุดแข็งในกระบวนการเรียนรู้วิทยาศาสตร์ของฉันให้มีประสิทธิภาพดียิ่งขึ้น I try to improve the strengths of my science learning process to be more efficient.	1	2	3	4	5
14	ฉันวางแผนที่จะหลีกเลี่ยงการใช้จุดอ่อนในการเรียนรู้วิทยาศาสตร์ของฉันในการเรียนรู้วิทยาศาสตร์ I plan to avoid using the weaknesses of my science learning to learn science.	1	2	3	4	5
15	ตอนที่ฉันเรียนรู้วิทยาศาสตร์ ฉันรู้ตัวว่าฉันกำลังคิดอะไรอยู่ When I learn science, I am aware of what I am thinking.	1	2	3	4	5
16	ฉันรู้จุดแข็งของฉันในการเรียนรู้วิทยาศาสตร์ I know my strength(s) in learning science.	1	2	3	4	5
17	ฉันรู้ว่าวิธีการเรียนรู้วิทยาศาสตร์ของฉันแตกต่างจากวิธีการเรียนรู้วิชาอื่นของฉันอย่างไร I know how I learn science is different from how I learn other subjects.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เห็นด้วยอย่างยิ่ง Strongly Disagree	ไม่เห็นด้วย Disagree	ไม่แน่ใจ Neither Disagree or Agree	เห็นด้วย agree	เห็นด้วยอย่างยิ่ง Strongly agree
18	ตอนที่ฉันเรียนรู้วิทยาศาสตร์ ฉันรู้ตัวถึงความเป็นเหตุเป็นผลของกระบวนการคิดของฉัน When I learn science, I am aware of how rationale of my thinking.	1	2	3	4	5
19	ฉันประเมินว่าฉันบรรลุวัตถุประสงค์ของฉันในการเรียนรู้แล้วหรือไม่ I evaluate if I meet my science learning goals.	1	2	3	4	5
20	ฉันวางแผนที่จะใช้จุดแข็งในการเรียนรู้วิทยาศาสตร์ของฉันในการเรียนรู้วิทยาศาสตร์ I plan to use the strengths of my science learning to learn science.	1	2	3	4	5
21	ฉันพยายามที่จะเรียนรู้วิทยาศาสตร์ให้ดียิ่งขึ้น I try to learn science better.	1	2	3	4	5
22	ในการเรียนรู้วิทยาศาสตร์ ฉันประเมินว่ากระบวนการเรียนรู้ของฉันมีประสิทธิภาพหรือไม่ In learning science, I evaluate the effectiveness of my science learning process.	1	2	3	4	5
23	ตอนที่ฉันเรียนรู้วิทยาศาสตร์ ฉันรู้ตัวว่าฉันกำลังคิดอย่างไร When I learn science, I am aware of how I am thinking.	1	2	3	4	5
24	ตอนที่ฉันเรียนรู้วิทยาศาสตร์ ฉันรู้ตัวว่าลำดับถัดไปในกระบวนการเรียนรู้วิทยาศาสตร์นี้ คืออะไร When I learn science, I am aware of what step to take in the learning process.	1	2	3	4	5
25	ฉันรู้จุดอ่อนของฉันในการเรียนรู้วิทยาศาสตร์ I know my weakness(es) in learning science.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เห็นด้วยอย่างยิ่ง Strongly Disagree	ไม่เห็นด้วย Disagree	ไม่แน่ใจ Neither Disagree or Agree	เห็นด้วย agree	เห็นด้วยอย่างยิ่ง Strongly agree
26	ฉันรู้ว่าเมื่อใดที่ควรใช้วิธีการเรียนรู้แบบใดในการเรียนวิทยาศาสตร์ I know when to use a specific learning strategy to learn science.	1	2	3	4	5
27	ฉันรู้จุดอ่อนในกระบวนการเรียนรู้วิทยาศาสตร์ของฉัน I know pitfall(s) of my science learning processes.	1	2	3	4	5
28	ฉันวางแผนที่จะใช้วิธีการเรียนรู้วิทยาศาสตร์ที่เคยใช้แล้วได้ผลสำเร็จ ในการเรียนวิทยาศาสตร์ต่อไป I plan to use my previous successful strategies of learning science to learn science in future.	1	2	3	4	5
29	ฉันรู้ว่าส่วนไหนในการเรียนรู้วิทยาศาสตร์นั้นยากสำหรับฉัน I know which part of learning science is difficult for me.	1	2	3	4	5
30	ฉันรู้วิธีการเรียนรู้วิทยาศาสตร์หลากหลายวิธี I know various strategies to learn science.	1	2	3	4	5
31	ฉันรู้ว่าเมื่อใดที่วิธีการเรียนรู้แบบใดจะใช้ได้ผลดีเยี่ยม I know when my science learning strategy works best.	1	2	3	4	5
32	ตอนที่ฉันเรียนรู้วิทยาศาสตร์ ฉันรู้ตัวถึงอุปสรรคความยากลำบากในการเรียนรู้ของฉัน When I learn science, I am aware of my learning difficulties.	1	2	3	4	5
33	เมื่อฉันไม่เข้าใจองค์ความรู้วิทยาศาสตร์หนึ่งๆ ฉันรู้ว่าฉันควรทำอะไรเพื่อช่วยให้ฉันเข้าใจองค์ความรู้นั้น When I do not understand science, I know what I should do to help me understand science.	1	2	3	4	5
34	ฉันรู้ว่าส่วนไหนในการเรียนรู้วิทยาศาสตร์นั้นง่ายสำหรับฉัน I know which part of learning science is easy for me.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เห็นด้วยอย่างยิ่ง Strongly Disagree	ไม่เห็นด้วย Disagree	ไม่แน่ใจ Neither Disagree or Agree	เห็นด้วย agree	เห็นด้วยอย่างยิ่ง Strongly agree
35	ฉันรู้ตัวว่าวิธีการเรียนใดที่ฉันใช้ในการเรียนรู้วิทยาศาสตร์ I am aware of learning strategies that I use to learn science.	1	2	3	4	5
36	ตอนที่ฉันเรียนรู้วิทยาศาสตร์ ฉันรู้ตัวว่าสิ่งที่ฉันกำลังคิดสอดคล้องกับกระบวนการเรียนรู้วิทยาศาสตร์หรือไม่ When I learn science, I am aware if what I am thinking aligns with a process of learning science.	1	2	3	4	5
37	ฉันรู้จุดแข็งในกระบวนการเรียนรู้วิทยาศาสตร์ของฉัน I know the strength(s) of my science learning processes.	1	2	3	4	5
38	เมื่อฉันไม่เข้าใจองค์ความรู้วิทยาศาสตร์หนึ่งๆ ฉันจะเปลี่ยนวิธีการเรียนรู้ของฉัน When I do not understand a science concept, I change my learning strategy.	1	2	3	4	5

APPENDIX C

The Questionnaire for Assessing Science Teachers' Perceptions of Their Actual MOLEs Used in the Main Study

ที่ No.	ข้อความ item	ไม่เคย Never	น้อยครั้ง Rarely	บางครั้ง Sometime	บ่อยครั้ง Often	เป็นประจำ Always
	ในห้องเรียนวิทยาศาสตร์ของฉัน In my science classrooms					
1	นักเรียนช่วยฉันวางแผนว่าควรจะเรียนรู้อะไร Students help me plan what needs to be learned.	1	2	3	4	5
2	ฉันให้นักเรียนนึกถึงความยากลำบากในการเรียนรู้วิทยาศาสตร์ของพวกเขา I ask students to think about their difficulties in learning science.	1	2	3	4	5
3	ฉันให้นักเรียนคิดว่าพวกเขาจะเป็นผู้ที่เรียนรู้วิทยาศาสตร์ที่ดีกว่าเดิมได้อย่างไร I ask students to think about how they could become better learners of science.	1	2	3	4	5
4	นักเรียนของฉันปรึกษาหารือกันว่าพวกเขาจะปรับปรุงการเรียนรู้วิทยาศาสตร์ให้ดีขึ้นได้อย่างไร My students discuss with each other about how they can improve their learning of science.	1	2	3	4	5
5	นักเรียนช่วยฉันวางแผนว่าควรจะใช้เวลาเท่าไหร่ในการทำกิจกรรมต่างๆ Students help me decide how much time they spend on activities.	1	2	3	4	5
6	นักเรียนปรึกษาหารือกับฉันว่าพวกเขาเรียนรู้วิทยาศาสตร์อย่างไร Students discuss with me about how they learn science.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เคย Never	น้อยครั้ง Rarely	บางครั้ง Sometime	บ่อยครั้ง Often	เป็นประจำ Always
7	ฉันให้นักเรียนลองใช้วิธีใหม่ๆในการเรียนรู้วิทยาศาสตร์ I ask students to try new ways of learning science.	1	2	3	4	5
8	ฉันให้นักเรียนนึกว่าพวกเขาเรียนรู้วิทยาศาสตร์อย่างไร I ask students to think about how they learn science.	1	2	3	4	5
9	นักเรียนของฉันปรึกษาหารือกันว่าพวกเขาเรียนรู้วิทยาศาสตร์ได้ดีระดับไหน My students discuss with each other about how well they are learning science.	1	2	3	4	5
10	ไม่มีปัญหานะ ถ้านักเรียนแนะนำให้ใช้กิจกรรมการเรียนรู้วิทยาศาสตร์ ที่ต่างไปจากที่ฉันเสนอ It is OK for students to suggest alternative science learning activities to those proposed by me.	1	2	3	4	5
11	นักเรียนช่วยฉันเลือกว่ากิจกรรมอันไหนที่ดีที่สุดสำหรับพวกเขา Students help me to decide which activities are best for them.	1	2	3	4	5
12	ฉันเคารพแนวคิดของนักเรียน I respect students' ideas.	1	2	3	4	5
13	นักเรียนของฉันปรึกษาหารือกันถึงแนวทางการเรียนรู้วิทยาศาสตร์แบบต่างๆ My students discuss with each other about different ways of learning science.	1	2	3	4	5
14	ไม่มีปัญหานะ ถ้านักเรียนบอกฉันเกี่ยวกับอะไรก็ตามที่ขัดขวางไม่ให้พวกเขาเรียนรู้ It is OK for students to speak out to me about anything that prevents them from learning.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เคย Never	น้อยครั้ง Rarely	บางครั้ง Sometime	บ่อยครั้ง Often	เป็นประจำ Always
15	ฉันมองเห็นคุณค่าในความพยายามของนักเรียน I value students' efforts.	1	2	3	4	5
16	ฉันเคารพความแตกต่างส่วนบุคคลของนักเรียน I respect students' individual differences.	1	2	3	4	5
17	ฉันช่วยเหลือสนันสนุนนักเรียนที่ลองแนวทางการเรียนรู้วิทยาศาสตร์แบบใหม่ๆ I support students who try new ways of learning science.	1	2	3	4	5
18	ฉันกระตุ้นให้นักเรียนลองปรับปรุงวิธีการเรียนรู้วิทยาศาสตร์ของพวกเขา I encourage students to try to improve how they learn science.	1	2	3	4	5
19	ไม่มีปัญหานะ ถ้านักเรียนบอกฉันว่ากิจกรรมอันไหนทำให้เขางง It is OK for students to speak out to me about activities that are confusing.	1	2	3	4	5
20	นักเรียนของฉันปรึกษาหารือกันว่าพวกเขามีการคิดอย่างไร ตอนที่เรียนรู้วิทยาศาสตร์ My students discuss with each other about how they think when they learn science.	1	2	3	4	5
21	ฉันช่วยเหลือสนับสนุนนักเรียนที่พยายามจะปรับปรุงการเรียนรู้วิทยาศาสตร์ของตนเอง I support students who try to improve their science learning.	1	2	3	4	5
22	ไม่มีปัญหานะ ถ้านักเรียนถามฉันว่าทำไมพวกเขาต้องทำกิจกรรมอันใดอันหนึ่ง It is OK for students to ask me why they have to do a certain activity.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เคย Never	น้อยครั้ง Rarely	บางครั้ง Sometime	บ่อยครั้ง Often	เป็นประจำ Always
23	นักเรียนช่วยฉันวางแผนว่าเมื่อไหร่ควรจะเริ่มเรียนรู้หัวข้อใหม่ Students help me decide when it is time to begin a new topic.	1	2	3	4	5
24	นักเรียนปรึกษาหารือกับฉันถึงแนวทางการเรียนรู้วิทยาศาสตร์แบบต่างๆ Students discuss with me about different ways of learning science.	1	2	3	4	5
25	นักเรียนช่วยฉันเลือกว่าพวกเขาจะทำกิจกรรมอันไหน Students help me decide which activities they do.	1	2	3	4	5
26	ไม่มีปัญหานะ ถ้านักเรียนบอกฉันว่าพวกเขาไม่เข้าใจวิทยาศาสตร์ It is OK for students to tell me when they don't understand science.	1	2	3	4	5
27	นักเรียนของฉันปรึกษาหารือกันว่าพวกเขาเรียนรู้วิทยาศาสตร์อย่างไร My students discuss with each other about how they learn science.	1	2	3	4	5
28	นักเรียนปรึกษาหารือกับฉันว่าพวกเขาจะปรับปรุงการเรียนรู้วิทยาศาสตร์ให้ดีขึ้นได้อย่างไร Students discuss with me about how they can improve their learning of science.	1	2	3	4	5
29	ฉันให้นักเรียนอธิบายว่าพวกเขาแก้ปัญหาทางวิทยาศาสตร์อย่างไร I ask students to explain how they solve science problems.	1	2	3	4	5

ที่ No.	ข้อความ item	ไม่เคย Never	น้อยครั้ง Rarely	บางครั้ง Sometime	บ่อยครั้ง Often	เป็นประจำ Always
30	ฉันกระตุ้นให้นักเรียนลองเรียนรู้วิทยาศาสตร์ด้วยวิธีการต่างๆ I encourage students to try different ways to learn science.	1	2	3	4	5
31	ฉันกระตุ้นให้นักเรียนพูดคุยกันว่าพวกเขาเรียนรู้วิทยาศาสตร์อย่างไร I encourage students to talk with each other about how they learn science.	1	2	3	4	5
32	นักเรียนปรึกษาหารือกับฉันว่าพวกเขาเรียนรู้วิทยาศาสตร์ได้ดีระดับไหน Students discuss with me about how well they are learning science.	1	2	3	4	5
33	ฉันปฏิบัติกับนักเรียนอย่างเป็นธรรม I treat students fairly.	1	2	3	4	5
34	ฉันเชื่อใจนักเรียน และนักเรียนเชื่อใจฉัน I trust the students, and I think they trust me.	1	2	3	4	5
35	นักเรียนปรึกษาหารือกับฉันว่าพวกเขามีการคิดอย่างไรตอนที่เรียนรู้วิทยาศาสตร์ Students discuss with me about how they think when they learn science.	1	2	3	4	5

APPENDIX D

Interview Questions 1

1. How do you learn science? Explain.
2. Do you think learning science is different from learning other subjects? Explain.
3. Do you know your own strengths and weaknesses in learning science? Explain.
4. Can you explain your processes in learning science?
5. Do you have any strategies for learning science? Explain.
6. Do you know when to use those learning and thinking strategies? Explain.
7. Do you know when you understand or not understand science concept?
8. How do you improve your science learning strategies? Explain.
9. What kind of questions that you often use in your classrooms to encourage students to learn science?
10. Have you ever discussed with students about learning?
11. Do your students like to participate in science classrooms? Explain.
12. Do you agree with situation in science classrooms that support students to think about their own learning processes? Explain.
13. Have you ever supported students to think about their own learning process? Explain.
14. Are you interested to learn more about how to support students to be better learners/ learn about learning?
15. What could be challenges of implement that kind of instruction into your classrooms/ in science classrooms in Thailand?

Interview Questions 2

1. Can you explain what learning is?
2. How do you process information that you receive?
3. How do you learn science?
4. Do you have different process in learning science in different situations?
5. Do you have any plan to improve how you learn? Explain.
6. How do you know if you have learned a science concept?
7. Do you discuss with your students about how to learn science? Explain.
8. How do you know if your students have learned what you expect them to learn?
9. Do you have any teaching process to help students to learn?
10. Have you ever discussed with students about how to improve their learning?
11. Have you ever shared your learning strategies to your students?
12. Have you students ever discussed to each other about learning science/their learning?
13. What is your dream instruction?
14. Do you want to support students to be better learners or learn about learning?
15. Do you think what could be obstacles to support students to learn about their own learning/ be better learners?

APPENDIX E

Information Letter and Consent Form: Survey and Interview Elements

(English and Thai Language Versions)

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INFORMATION LETTER and CONSENT FORM

Study Title: Exploring the Relationship between Thai Science Teachers' Metacognition and Their

Perceptions of the Metacognitively Oriented Learning Environments

(SURVEY ELEMENT)

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Background

Nowadays ‘Learning to Learn’ is an important initiative component that could assist people to be prepared for challenging situations in the present and in the future. Metacognition is an essential component for learning to learn. Educational experts around the world and in world educational organizations, for example, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the National Research Council of USA, and the Organisation for Economic Co-operation and Development (OECD) suggest that teachers should learn about and support teaching and learning that enhances students’ metacognition. This study aims to gain information for support development of metacognitively oriented learning environment in science classrooms in Thailand.

We would like to invite you to participate in this research study as you are one of science teachers who teach at lower secondary level in Thailand. This Information Letter and Consent Form is part of the process of seeking your informed consent. It explains this research study, and what will happen to you if you choose to be in this study. Before you make a decision, read this form carefully to make sure you understand all the information provided. You are encouraged to ask questions if you feel anything needs to be made clearer. You can make a copy of this form for your records.

Purposes of the Study

From this research, we aim to learn about Thai science teachers’ metacognition and perceptions on their preferred and actual metacognitively oriented science classroom learning environments together with any relationships among those aspects. The knowledge could be used to develop and enhance metacognitively oriented learning environments in science classrooms in Thailand.

Study Procedures

Around 400 Thai science teachers at lower secondary level will take part in this part of the study. If you agree to participate in this study, please complete the attached questionnaires. The questionnaires should take you approximately 15-20 minutes to complete. You do not have to answer any questions that you do not want to answer. Once you have completed the questionnaires, please choose the “submit” button. We would appreciate receiving it before January 15, 2022.

Benefits

There are no direct benefits to you. However, by completing the questionnaires you may reflect and receive information about your own metacognition and your perceptions regarding your preferred and actual metacognitively oriented learning environments in your science classrooms. The research findings will be used as foundation information to develop metacognitively oriented learning environments in science classrooms especially in the Thailand educational context.

Risks

There are no risks or foreseeable discomforts in participating this study. However, there may be risks to being in this study that are not known. If we learn anything during the research that may affect your willingness to continue being in the study, we will tell you right away.

Compensation (or Reimbursement)

There is no compensation or reimbursement in this study

Voluntary Participation

You are under no obligation to participate, and if you choose to participate, you may refuse to answer questions that you do not want to answer. Should you choose to withdraw midway through the electronic questionnaires simply close the link and no responses will be included. You may withdraw from the study within one month after submitting the questionnaires by informing the researcher by phone or email. Your data will be removed from the database within two days after you inform the researcher.

Confidentiality and Anonymity

The information that you will share will remain strictly confidential and will be used solely for the purposes of this research. The only person who will have access to the research data is the researcher. Your information will be assigned a code that is unique to this study. The list connecting your name to this code will be kept in a locked file in the researcher's computer. When the study is completed and the data have been analyzed, the list linking participant's names to study codes will be eliminated. Study findings will be presented only in summary form and your name would not be used in any report. In order to minimize the risk of security breaches and to help ensure your confidentiality we recommend that you use standard safety measures such as signing out of your account, closing your browser and locking your screen or device when you have completed the questionnaires.

Data Storage

The study database will be created in the REDCap system which is certified by the University of Alberta. The database software and hardware are maintained by the Women & Children's Health Research Institute (WCHRI) in collaboration with the Faculty of Medicine and the Northern Alberta Clinical Trials and Research Centre (NACTRC), University of Alberta. The data will be stored in the electronic database for maximum of two years after the data is collected. The electronic data will be transferred, encrypted, and stored in a password protected hard drive that will be kept in a locked cabinet in the researcher's office. Electronic copies will be kept in a password protected computer in the department of Secondary Education at the University of Alberta for five years after the research is completed, then it will be eliminated.

Information about the Study Results

The research results will be used to support the researcher's dissertation, and it will be published in scholarly journals as well as presented in conferences related to teaching and learning science. If you are interested, you can inform the researcher to ask for the research results; the researcher will send you summary of the research findings once the research is completed.

Contact Information

If you have any questions or require more information about the study itself, you may contact the researcher or her supervisor at the contact information mentioned herein. The plan for this study has been reviewed by a Research Ethics Board at the University of Alberta. If you have questions about your rights or how research should be conducted, you can call +1 (780) 492-2615. This office is independent of the researchers.

Please print or save a copy of this form for your records.

Completion and submission of the questionnaires means that you consent to participate.

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เอกสารคำชี้แจงข้อมูลและหนังสือแสดงความยินยอม

หัวข้อวิจัย:
ศึกษาความสัมพันธ์ระหว่างเมตาคอกนิชันของครูวิทยาศาสตร์ไทยและความเห็นเกี่ยวกับสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชัน (ในส่วนของแบบสอบถาม)

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ข้อมูลเบื้องต้น

ในยุคปัจจุบันการเรียนรู้เกี่ยวกับกระบวนการเรียนรู้ “Learning to Learn” นับว่าเป็นส่วนสำคัญที่จะทำให้คนเตรียมพร้อมรับมือกับสถานการณ์ที่ท้าทายในปัจจุบันและอนาคต เมตาคอกนิชัน “Metacognition” เป็นองค์ประกอบสำคัญที่ช่วยให้เกิดการเรียนรู้เกี่ยวกับกระบวนการเรียนรู้ของตนเองนักการศึกษาจำนวนมากทั่วโลกรวมทั้งหน่วยงานที่เกี่ยวกับการศึกษาระดับโลกหลายหน่วยงาน เช่น องค์การการศึกษาวิทยาศาสตร์และวัฒนธรรมแห่งสหประชาชาติ (UNESCO) สภาวิจัยแห่งสหรัฐอเมริกา (National Research Council of USA) หรือองค์การเพื่อความร่วมมือและการพัฒนาทางเศรษฐกิจ (OECD) ต่างก็สนับสนุนให้คุณครูเรียนรู้และจัดการเรียนการสอนที่ส่งเสริมให้นักเรียนเกิดการพัฒนาเมตาคอกนิชันโดยการวิจัยนี้มุ่งหวังที่จะได้รับข้อมูลเพื่อนำไปใช้ในการส่งเสริมการพัฒนาเมตาคอกนิชันในห้องเรียนวิทยาศาสตร์ของประเทศไทย

ผู้วิจัยขอเชิญท่านเข้าร่วมโครงการวิจัยนี้เนื่องจากท่านหนึ่งในเป็นคุณครูวิทยาศาสตร์ที่สอนในระดับมัธยมศึกษาตอนต้นในประเทศไทยเอกสารคำชี้แจงข้อมูลและหนังสือแสดงความยินยอมนี้เป็นส่วนหนึ่งในกระบวนการขอความยินยอมจากท่านในการเข้าร่วมการวิจัยโดยในเอกสารจะมีข้อมูลเบื้องต้นเกี่ยวกับการวิจัยนี้และกิจกรรมที่ท่านจะปฏิบัติหากท่านมีความประสงค์จะเข้าร่วม

โครงการวิจัยก่อนที่ท่านจะตัดสินใจเข้าร่วมโครงการกรุณาอ่านและทำความเข้าใจข้อมูลในเอกสารนี้โดยละเอียด หากท่านมีข้อสงสัยประการใด โปรดสอบถามข้อมูลเพิ่มเติมได้ทุกประการ ท่านสามารถทำสำเนาเอกสารฉบับนี้เพื่อเก็บเป็นหลักฐานได้

วัตถุประสงค์ของการวิจัย

ในการวิจัยนี้ผู้วิจัยมีความมุ่งหวังจะได้รับองค์ความรู้เกี่ยวกับสภาพเมตาคอกนิชันของครูวิทยาศาสตร์ไทยและความเห็นของครูวิทยาศาสตร์เกี่ยวกับสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชันที่คุณครูพึงพอใจและในสภาพจริงรวมทั้งความสัมพันธ์ขององค์ประกอบดังกล่าวโดยองค์ความรู้นี้สามารถนำไปใช้ในการพัฒนาสภาพแวดล้อมการเรียนรู้ในห้องเรียนวิทยาศาสตร์ในประเทศไทยต่อไป

ขั้นตอนการวิจัย

การวิจัยนี้จะมีครูวิทยาศาสตร์ระดับมัธยมศึกษาตอนต้นเข้าร่วมประมาณ 400 คน หากท่านมีความสนใจจะเข้าร่วมโครงการ ท่านสามารถทำได้โดยทำแบบสอบถามที่แนบมาด้วย ในการทำแบบสอบถามจะใช้เวลาประมาณ 15-20 นาที ท่านสามารถข้ามข้อที่ท่านไม่สะดวกจะตอบคำถามได้ หากท่านทำแบบสอบถามเสร็จแล้วกรุณากดปุ่ม “Submit” เพื่อส่งข้อมูล หากท่านส่งข้อมูลกลับมาก่อนวันที่ 15 มกราคม 2565 จะเป็นพระคุณยิ่ง

ประโยชน์ที่คาดว่าจะได้รับ

ท่านอาจจะไม่ได้รับประโยชน์โดยตรงจากการเข้าร่วมโครงการวิจัยนี้แต่จากการทำแบบสอบถาม ท่านอาจจะได้รับข้อมูลสะท้อนกลับเกี่ยวกับสภาพเมตาคอกนิชันของท่านเอง รวมทั้งข้อมูลเกี่ยวกับสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชันที่ท่านพึงพอใจและในสภาพจริงในห้องเรียนวิทยาศาสตร์ของท่านองค์ความรู้ที่ได้จากการวิจัยนี้สามารถนำไปใช้ในการพัฒนาสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชันในห้องเรียนวิทยาศาสตร์ โดยเฉพาะอย่างยิ่งในบริบทของการศึกษาไทย

ความเสี่ยง

การเข้าร่วมโครงการวิจัยนี้ไม่มีความเสี่ยง หรือสิ่งที่อาจก่อให้เกิดอันตรายใดใด อย่างไรก็ตามอาจจะมีปัจจัยเสี่ยงบางประการที่อยู่นอกเหนือความคาดหมายของผู้วิจัย ซึ่งหากผู้วิจัยตรวจสอบพบปัจจัยดังกล่าวที่ ผู้วิจัยจะแจ้งให้ท่านทราบโดยทันที

ค่าตอบแทน หรือ ของกำนัล

การวิจัยครั้งนี้ไม่มีค่าตอบแทน หรือของกำนัลใดใด แก่ผู้เข้าร่วมโครงการ

การเข้าร่วมโครงการเป็นไปตามความสมัครใจ

ท่านไม่ได้อยู่ภายใต้ข้อบังคับใดใดในการเข้าร่วมการวิจัยนี้ และหากท่านสมัครใจเข้าร่วม ท่านสามารถปฏิเสธการตอบคำถามใดใดที่ท่านไม่ต้องการท่านอาจจะขอถอนตัวจากการเข้าร่วมการวิจัยภายในหนึ่งเดือนหลังจากที่ท่านส่งแบบสอบถามกลับมายังผู้วิจัยโดยท่านสามารถทำได้โดยการแจ้งผู้วิจัยผ่านทางโทรศัพท์ หรือทางอีเมล์ ข้อมูลของท่านจะถูกลบออกไปภายใน สองวันหลังจากผู้วิจัยได้รับแจ้งจากท่าน

การปกปิดข้อมูลเป็นความลับและไม่เปิดเผยชื่อของผู้เข้าร่วมโครงการวิจัย

ข้อมูลที่ท่านส่งกลับมาจะถูกปกปิดเป็นความลับและจะถูกนำไปใช้เพื่อการวิจัยนี้เท่านั้น มีเพียงผู้วิจัยเท่านั้นที่สามารถเข้าถึงข้อมูลดังกล่าวได้โดยข้อมูลจะถูกเข้ารหัสเฉพาะสำหรับการวิจัยนี้รายชื่อของท่านที่ผูกกับรหัสดังกล่าวจะถูกเก็บไว้ในไฟล์ข้อมูลซึ่งจัดเก็บในคอมพิวเตอร์ที่มีรหัสผ่านของผู้วิจัย เมื่อการศึกษาวิจัยเสร็จสมบูรณ์ไฟล์ดังกล่าวจะถูกลบออกไป

ผลการศึกษาจะถูกทำเสนอในรูปแบบข้อสรุปโดยไม่ปรากฏชื่อหรือข้อมูลเฉพาะของท่านในรายงานใดใดเพื่อเป็นการลดความผิดพลาดที่อาจจะเกิดจากระบบความปลอดภัยทางอินเทอร์เน็ตและเพื่อเป็นการรักษาความปลอดภัยของข้อมูลของท่านผู้วิจัยแนะนำให้ท่านปฏิบัติตามข้อกำหนดมาตรฐานในการรักษาความปลอดภัยของข้อมูล เช่น การลงชื่อออก การปิดโปรแกรม หรือการล็อกหน้าจอหรืออุปกรณ์ เมื่อท่านทำแบบสอบถามเรียบร้อยแล้ว

การเก็บรักษาข้อมูล

ฐานข้อมูลนี้อยู่ในระบบ REDCap system ซึ่ง University of Alberta ให้การรับรองโปรแกรมและฮาร์ดแวร์ของระบบได้รับการดูแลรักษาโดย the Women & Children's Health Research Institute (WCHRI) ร่วมกับ the Faculty of Medicine and the Northern Alberta Clinical Trials and Research Centre (NACTRC), University of Alberta หลังจากได้รับข้อมูลแล้วข้อมูลจะถูกจัดเก็บในฐานข้อมูลเป็นเวลาสองปีเป็นอย่างมากจากนั้นไฟล์ข้อมูลจะถูกเข้ารหัสและย้ายไปเก็บในฮาร์ดไดรฟ์ซึ่งนำไปเก็บไว้ในตู้ที่มีกุญแจล็อกภายในห้องทำงานของผู้วิจัย อีกทั้งไฟล์สำเนาข้อมูลจะถูกจัดเก็บในคอมพิวเตอร์ที่มีรหัสผ่านใน Department of Secondary Education, University of Alberta โดยไฟล์ข้อมูลจะถูกเก็บรักษาไว้เป็นเวลาห้าปีจากนั้นข้อมูลทั้งหมดจะถูกลบออกจากระบบ

ข้อมูลเกี่ยวกับผลการวิจัย

ผลการวิจัยจะถูกนำไปใช้เป็นข้อมูลในวิทยานิพนธ์ของผู้วิจัยและนำไปตีพิมพ์ในวารสารวิชาการรวมทั้งถูกเอาไปนำเสนอในการประชุมวิชาการต่างๆที่เกี่ยวกับการเรียนและการสอนวิทยาศาสตร์ หากท่านสนใจ ท่านสามารถติดต่อผู้วิจัยเพื่อขอข้อมูลผลการวิจัยได้ โดยผู้วิจัยจะส่งสรุปโดยย่อของผลการวิจัยมายังท่านเมื่อการทำวิจัยเสร็จสมบูรณ์แล้ว

ข้อมูลติดต่อ

หากท่านมีข้อสงสัยประการใด หรือต้องการข้อมูลเพิ่มเติมเกี่ยวกับงานวิจัยนี้ ท่านสามารถติดต่อมายังผู้วิจัยหรืออาจารย์ที่ปรึกษาตามที่อยู่ที่ปรากฏในเอกสารนี้

แผนการวิจัยนี้ได้ถูกตรวจสอบโดย Research Ethics Board, University of Alberta หากท่านมีคำถามเกี่ยวกับสิทธิของท่านหรือ การจัดการการศึกษาวิจัยนี้ ท่านสามารถติดต่อผ่านโทรศัพท์ (+1) 780-492-2615 หน่วยงานนี้เป็นอิสระจากผู้วิจัย

กรุณาพิมพ์ หรือบันทึกเอกสารนี้ไว้เป็นหลักฐาน
หากท่านทำแบบสอบถามและส่งข้อมูลกลับมาในระบบ
แสดงว่าท่านให้ความยินยอมเข้าร่วมการวิจัยนี้

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INFORMATION LETTER and CONSENT FORM

Study Title: Exploring the Relationship between Thai Science Teachers' Metacognition and Their

Perceptions of the Metacognitively Oriented Learning Environments

(INTERVIEW ELEMENT)

Research Investigator

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Background

Nowadays 'Learning to Learn' is an important initiative component that could assist people to be prepared for challenging situations in the present and in the future. Metacognition is an essential component for learning to learn. Educational experts around the world and in world educational organizations, for example, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the National Research Council of USA, and the Organisation for Economic Co-operation and Development (OECD) suggest that teachers should learn about and support teaching and learning that enhances students' metacognition. This study aims to gain information for support development of metacognitively oriented learning environment in science classrooms in Thailand.

We would like to invite you to participate in this research study as you are one of science teachers who teach at lower secondary level in Thailand, and you have informed through the questionnaire form related to this study that you allow the researcher to interview you for further information. This Information Letter and Consent Form is part of the process of seeking your informed consent. It explains this research study, and what will happen to you if you choose to be in this study. Before you make a decision, read this form carefully to make sure you understand all the information provided. You are encouraged to ask questions if you feel anything needs to be made clearer. You can make a copy of this form for your records.

Purposes of the Study

From this research, we aim to learn about Thai science teachers' metacognition and perceptions on their preferred and actual metacognitively oriented science classroom learning environments together with any relationships among those aspects. The knowledge could be used to develop and enhance metacognitively oriented learning environments in science classrooms in Thailand.

Study Procedures

Around 20 Thai science teachers at lower secondary level will take part in this part of the study. If you agree to participate in this study, you will be interviewed by the researcher through telecommunication, for example, by phone or program computer. The interview questions will be about your basic information (name, teaching level, experience, etc.), your learning process, and your perceptions about learning environments in your science classrooms. The interview will take you approximately 30 minutes to one hour to be complete. You do not have to answer any questions that you do not want to answer, and you can terminate the interview at any time. Once the interview is complete, if necessary, there may be some follow up questions. The interview will be recorded, and the interview transcript will be sent back to you in order to confirm your responses.

Benefits

There are no direct benefits to you. However, by participating the interview, you may reflect and receive information about your own metacognition and your perceptions regarding your preferred and actual metacognitively oriented learning environments in your science classrooms. The research findings will be used as foundation information to develop metacognitively oriented learning environments in science classrooms especially in the Thailand educational context.

Risks

There are no risks or foreseeable discomforts in participating this study. However, there may be risks to being in this study that are not known. If we learn anything during the research that may affect your willingness to continue being in the study, we will tell you right away.

Compensation (or Reimbursement)

There is no compensation or reimbursement in this study

Voluntary Participation

You are under no obligation to participate, and if you choose to participate, you may refuse to answer questions that you do not want to answer. You may withdraw from the study within one month after receiving the interview transcript by informing the researcher by phone or email. Your data will be removed within two days after you inform the researcher.

Confidentiality and Anonymity

The information that you will share will remain strictly confidential and will be used solely for the purposes of this research. The only person who will have access to the data is the researcher. Your information will be assigned a code that is unique to this study. The list connecting your name to this code will be kept in a locked file in the researcher's computer. The interview transcript will be printed out for using as a working document which your name and your identifiers will be replaced using pseudonym. When the study is completed and the data have been analyzed, the list linking participant's names to study codes will be eliminated. Study findings will be presented only in summary form and your name would not be used in any report.

Data Storage

The interview record and the transcript file will be encrypted and stored in a password protected hard drive that will be kept in a locked cabinet in the researcher's office. Electronic copies will be kept in a password protected computer in the department of Secondary Education at the University of Alberta. The data will be kept for five years after the research is completed, then will be eliminated.

Information about the Study Results

The research results will be used to support the researcher's dissertation, and it will be published in scholarly journals as well as presented in conferences related to teaching and learning science. If you are interested, you can inform the researcher to ask for the research results; the researcher will send you summary of the research findings once the research is completed.

Contact Information

If you have any questions or require more information about the study itself, you may contact the researcher or her supervisor at the contact information mentioned herein. The plan for this study has been reviewed by a Research Ethics Board at the University of Alberta. If you have questions about your rights or how research should be conducted, you can call + 1(780) 492-2615. This office is independent of the researchers.

Consent Statement

I have read this form and the research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told whom to contact. I agree to participate in the research study described above and will receive a copy of this consent form. I will receive a copy of this consent form after I sign it.

______________________________ ________________________________ _____________

Participant' s Signature Participant's Name (Printed) Date

______________________________ ________________________________ ___________

Signature of Person Obtaining Consent Name of Person Obtaining Consent Date

551 Education South, 11210 - 87 Ave
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เอกสารคำชี้แจงข้อมูลและหนังสือแสดงความยินยอม

หัวข้อวิจัย:
ศึกษาความสัมพันธ์ระหว่างเมตาคอกนิชันของครูวิทยาศาสตร์ไทยและความเห็นเกี่ยวกับสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชัน (ในส่วนของการสัมภาษณ์)

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ข้อมูลเบื้องต้น

ในยุคปัจจุบันการเรียนรู้เกี่ยวกับกระบวนการเรียนรู้ “Learning to Learn” นับว่าเป็นส่วนสำคัญที่จะทำให้คนเตรียมพร้อมรับมือกับสถานการณ์ที่ท้าทายในปัจจุบันและอนาคต เมตาคอกนิชัน “Metacognition” เป็นองค์ประกอบสำคัญที่ช่วยให้เกิดการเรียนรู้เกี่ยวกับกระบวนการเรียนรู้ของตนเองนักการศึกษาจำนวนมากทั่วโลกรวมทั้งหน่วยงานที่เกี่ยวกับการศึกษาระดับโลกหลายหน่วยงาน เช่น องค์การการศึกษาวิทยาศาสตร์และวัฒนธรรมแห่งสหประชาชาติ (UNESCO) สภาวิจัยแห่งสหรัฐอเมริกา (National Research Council of USA) หรือ องค์การเพื่อความร่วมมือและการพัฒนาทางเศรษฐกิจ (OECD) ต่างก็สนับสนุนให้คุณครูเรียนรู้และจัดการเรียนการสอนที่ส่งเสริมให้นักเรียนเกิดการพัฒนาเมตาคอกนิชันโดยการวิจัยนี้มุ่งหวังที่จะได้รับข้อมูลเพื่อนำไปใช้ในการส่งเสริมการพัฒนาเมตาคอกนิชันในห้องเรียนวิทยาศาสตร์ของประเทศไทย

ผู้วิจัยขอเชิญท่านเข้าร่วมโครงการวิจัยนี้เนื่องจากท่านหนึ่งในเป็นคุณครูวิทยาศาสตร์ที่สอนในระดับมัธยมศึกษาตอนต้นในประเทศไทยและท่านได้แจ้งผ่านแบบสอบถามที่เกี่ยวกับการวิจัยนี้ว่าท่านยินดีให้ผู้วิจัยสัมภาษณ์เพื่อสอบถามข้อมูลเพิ่มเติมได้เอกสารคำชี้แจงข้อมูลและหนังสือแสดงความยินยอมนี้เป็นส่วนหนึ่งในกระบวนการขอความยินยอมจากท่านในการเข้าร่วมการวิจัย

โดยในเอกสารจะมีข้อมูลเบื้องต้นเกี่ยวกับการวิจัยนี้และกิจกรรมที่ท่านจะปฏิบัติหากท่านมีความประสงค์จะเข้าร่วมโครงการวิจัย ก่อนที่ท่านจะตัดสินใจเข้าร่วมโครงการกรุณาอ่านและทำความเข้าใจข้อมูลในเอกสารนี้โดยละเอียด หากท่านมีข้อสงสัยประการใดโปรดสอบถามข้อมูลเพิ่มเติมได้ทุกประการ และท่านจะได้รับสำเนาเอกสารชุดนี้ด้วย

วัตถุประสงค์ของการวิจัย

ในการวิจัยนี้ผู้วิจัยมีความมุ่งหวังจะได้รับองค์ความรู้เกี่ยวกับสภาพเมตาคอกนิชันของครูวิทยาศาสตร์ไทยและความเห็นของครูวิทยาศาสตร์เกี่ยวกับสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชันที่คุณครูพึงพอใจและในสภาพจริงรวมทั้งความสัมพันธ์ขององค์ประกอบดังกล่าวโดยองค์ความรู้นี้สามารถนำไปใช้ในการพัฒนาสภาพแวดล้อมการเรียนรู้ในห้องเรียนวิทยาศาสตร์ในประเทศไทยต่อไป

ขั้นตอนการวิจัย

การวิจัยนี้จะมีครูวิทยาศาสตร์ระดับมัธยมศึกษาตอนต้นเข้าร่วมประมาณ 20 คน หากท่านมีความสนใจจะเข้าร่วมโครงการ ท่านจะถูกสัมภาษณ์ผ่านระบบสื่อสารทางไกล เช่นโทรศัพท์ หรือโปรแกรมคอมพิวเตอร์ โดยคำถามในการสัมภาษณ์จะเกี่ยวกับข้อมูลทั่วไปของท่าน (ชื่อ ระดับชั้นที่สอน ประสบการณ์การสอน ฯลฯ) กระบวนการเรียนรู้ของท่านและความเห็นของท่านเกี่ยวกับสภาพแวดล้อมการเรียนในห้องเรียนวิทยาศาสตร์ในการสัมภาษณ์จะใช้เวลาประมาณ 30 นาที – 1 ชั่วโมง โดยท่านอาจจะไม่ตอบคำถามบางข้อที่ท่านไม่สะดวกจะตอบคำถามได้ หรือยกเลิกการสัมภาษณ์ได้ทุกขณะ เมื่อการสัมภาษณ์สิ้นสุด หากจำเป็นอาจจะมีการขอสัมภาษณ์ท่านเพิ่มเติมภายหลัง ระหว่างการสัมภาษณ์จะมีการบันทึกเสียงการสัมภาษณ์และบทสัมภาษณ์จะถูกส่งกลับมาให้ท่านเพื่อให้ท่านตรวจสอบยืนยันข้อมูลการสัมภาษณ์ของท่าน

ประโยชน์ที่คาดว่าจะได้รับ

ท่านอาจจะไม่ได้รับประโยชน์โดยตรงจากการเข้าร่วมโครงการวิจัยนี้แต่จากการถูกสัมภาษณ์ ท่านอาจจะได้รับข้อมูลสะท้อนกลับเกี่ยวกับสภาพเมตาคอกนิชันของท่านเอง รวมทั้งข้อมูลเกี่ยวกับสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชันที่ท่านพึงพอใจและในสภาพจริงในห้องเรียนวิทยาศาสตร์ของท่านองค์ความรู้ที่ได้จากการวิจัยนี้สามารถนำไปใช้ในการพัฒนาสภาพแวดล้อมการเรียนรู้ที่สอดคล้องกับการพัฒนาเมตาคอกนิชันในห้องเรียนวิทยาศาสตร์ โดยเฉพาะอย่างยิ่งในบริบทของการศึกษาไทย

ความเสี่ยง

การเข้าร่วมโครงการวิจัยนี้ไม่มีความเสี่ยง หรือสิ่งที่อาจก่อให้เกิดอันตรายใดใด อย่างไรก็ตามอาจจะมีปัจจัยเสี่ยงบางประการที่อยู่นอกเหนือความคาดหมายของผู้วิจัย ซึ่งหากผู้วิจัยตรวจสอบพบปัจจัยดังกล่าวที่ ผู้วิจัยจะแจ้งให้ท่านทราบโดยทันที

ค่าตอบแทน หรือ ของกำนัล

การวิจัยครั้งนี้ไม่มีค่าตอบแทน หรือของกำนัลใดใด แก่ผู้เข้าร่วมโครงการ

การเข้าร่วมโครงการเป็นไปตามความสมัครใจ

ท่านไม่ได้อยู่ภายใต้ข้อบังคับใดใดในการเข้าร่วมการวิจัยนี้ และหากท่านสมัครใจเข้าร่วม ท่านสามารถปฏิเสธการตอบคำถามใดใดที่ท่านไม่ต้องการ ท่านอาจจะขอถอนตัวจากการเข้าร่วมการวิจัยภายในหนึ่งเดือนหลังจากที่ท่านได้รับบทสัมภาษณ์จ

ากผู้วิจัย โดยท่านสามารถทำได้โดยการแจ้งผู้วิจัยผ่านทางโทรศัพท์ หรือทางอีเมล์ ข้อมูลของท่านจะถูกลบออกไปภายใน สองวันหลังจากผู้วิจัยได้รับแจ้งจากท่าน

การปกปิดข้อมูลเป็นความลับและไม่เปิดเผยชื่อของผู้เข้าร่วมโครงการวิจัย

ข้อมูลที่ท่านส่งกลับมาจะถูกปกปิดเป็นความลับและจะถูกนำไปใช้เพื่อการวิจัยนี้เท่านั้น มีเพียงผู้วิจัยเท่านั้นที่สามารถเข้าถึงข้อมูลดังกล่าวได้โดยข้อมูลจะถูกเข้ารหัสเฉพาะสำหรับการวิจัยนี้รายชื่อของท่านที่ผูกกับรหัสดังกล่าวจะถูกเก็บไว้ในไฟล์ข้อมูลซึ่งจัดเก็บในคอมพิวเตอร์ที่มีรหัสผ่านของผู้วิจัย บทสัมภาษณ์ของท่านจะถูกพิมพ์ออกมาเพื่อใช้ในการวิเคราะห์ข้อมูลโดยชื่อและข้อมูลเฉพาะของท่านจะถูกแทนที่ด้วยนามสมมติ เมื่อการวิจัยสิ้นสุดและข้อมูลถูกวิเคราะห์เรียบร้อยแล้วเมื่อการศึกษาวิจัยเสร็จสมบูรณ์ไฟล์ที่มีข้อมูลรายชื่อของท่านที่ผูกกับรหัสข้อมูลจะถูกลบออกไปผลการศึกษาจะถูกทำเสนอในรูปแบบข้อสรุปโดยไม่ปรากฏชื่อหรือข้อมูลเฉพาะของท่านในรายงานใดใด

การเก็บรักษาข้อมูล

ข้อมูลบันทึกการสัมภาษณ์ และไฟล์ข้อมูลบทสัมภาษณ์จะถูกเข้ารหัสและเก็บไว้ในฮาร์ดไดรฟ์ ซึ่งจะถูกนำไปเก็บในตู้ที่มีกุญแจล็อกในห้องทำงานของผู้วิจัยและไฟล์สำเนาจะถูกเก็บไว้ในคอมพิวเตอร์ที่มีรหัสผ่านใน Department of Secondary Education, University of Alberta ไฟล์ข้อมูลจะถูกเก็บรักษาไว้เป็นเวลาห้าปีจากนั้นไฟล์ข้อมูลดังกล่าวจะถูกลบออกจากระบบ

ข้อมูลเกี่ยวกับผลการวิจัย

ผลการวิจัยจะถูกนำไปใช้เป็นข้อมูลในวิทยานิพนธ์ของผู้วิจัยและนำไปตีพิมพ์ในวารสารวิชาการรวมทั้งถูกเอาไปนำเสนอในการประชุมวิชาการต่างๆที่เกี่ยวกับการเรียนและการสอนวิทยาศาสตร์ หากท่านสนใจ ท่านสามารถติดต่อผู้วิจัยเพื่อขอข้อมูลผลการวิจัยได้ โดยผู้วิจัยจะส่งสรุปโดยย่อของผลการวิจัยมายังท่านเมื่อการทำวิจัยเสร็จสมบูรณ์แล้ว

ข้อมูลติดต่อ

หากท่านมีข้อสงสัยประการใด หรือต้องการข้อมูลเพิ่มเติมเกี่ยวกับงานวิจัยนี้ ท่านสามารถติดต่อมายังผู้วิจัยหรืออาจารย์ที่ปรึกษาตามที่อยู่ที่ปรากฏในเอกสารนี้

แผนการวิจัยนี้ได้ถูกตรวจสอบโดย Research Ethics Board, University of Alberta หากท่านมีคำถามเกี่ยวกับสิทธิของท่านหรือ การจัดการการศึกษาวิจัยนี้ ท่านสามารถติดต่อผ่านโทรศัพท์ (+1) 780-492-2615 หน่วยงานนี้เป็นอิสระจากผู้วิจัย

<u>ข้อความแสดงความยินยอมในการเข้าร่วมการวิจัย</u>

ข้าพเจ้าได้อ่านเอกสารฉบับนี้ และได้รับคำอธิบายเกี่ยวกับการวิจัยนี้เรียบร้อยแล้ว ทั้งนี้ข้าพเจ้าได้รับโอกาสในการถามคำถามหากมีข้อสงสัย และได้คำอธิบายต่อข้อสงสัยแล้ว หากข้าพเจ้ามีข้อสงสัยเพิ่มเติม ข้าพเจ้ามีข้อมูลและทราบว่าต้องติดต่อผู้ใด

ข้าพเจ้าให้ความยินยอมในการเข้าร่วมการวิจัยนี้และข้าพเจ้าจะได้รับสำเนาหนังสือแสดงความยินยอมในการเข้าร่วมวิจัยหลังจากที่ได้ลงลายมือชื่อเรียบร้อยแล้ว

ลายเซ็นผู้เข้าร่วมโครงการวิจัย	ชื่อและนามสกุล (ตัวบรรจง) ผู้เข้าร่วมโครงการ	วันเดือนปี
ลายเซ็นผู้วิจัย	ชื่อและนามสกุล (ตัวบรรจง) ผู้วิจัย	วันเดือนปี

APPENDIX F

The Rasch Analysis Results From the Winstep Program of Each Subscale in the Questionnaire for Assessing Teachers' Metacognition

Subscale Declarative Knowledge

```
TABLE 23.0 214spss_Mc_blank_final.sav          ZOU950WS.TXT  Sep 20 2022 14:35
INPUT: 214 PERSON  6 ITEM  REPORTED: 214 PERSON  6 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                          Eigenvalue   Observed   Expected
Total raw variance in observations     =     10.0860 100.0%         100.0%
  Raw variance explained by measures   =      4.0860  40.5%          40.6%
    Raw variance explained by persons  =      2.8355  28.1%          28.1%
    Raw Variance explained by items    =      1.2505  12.4%          12.4%
  Raw unexplained variance (total)     =      6.0000  59.5% 100.0%   59.4%
    Unexplned variance in 1st contrast =      1.4620  14.5%  24.4%
    Unexplned variance in 2nd contrast =      1.3060  12.9%  21.8%
    Unexplned variance in 3rd contrast =      1.1827  11.7%  19.7%
    Unexplned variance in 4th contrast =      1.0837  10.7%  18.1%
    Unexplned variance in 5th contrast =       .9581   9.5%  16.0%
```

```
TABLE 23.99 214spss_Mc_blank_final.sav          ZOU950WS.TXT  Sep 20 2022 14:35
INPUT: 214 PERSON  6 ITEM  REPORTED: 214 PERSON  6 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT ITEM
-------------------------------
|CORREL-| ENTRY     | ENTRY     |
|  ATION|NUMBER IT  |NUMBER IT  |
|-------+-----------+-----------|
|  -.32 |      1 D1 |      4 D4 |
|  -.29 |      2 D2 |      6 D6 |
|  -.29 |      2 D2 |      4 D4 |
|  -.27 |      1 D1 |      5 D5 |
|  -.27 |      3 D3 |      5 D5 |
|  -.22 |      2 D2 |      3 D3 |
|  -.20 |      2 D2 |      5 D5 |
|  -.18 |      3 D3 |      4 D4 |
|  -.17 |      4 D4 |      5 D5 |
|  -.16 |      3 D3 |      6 D6 |
|  -.15 |      5 D5 |      6 D6 |
|  -.13 |      4 D4 |      6 D6 |
|  -.13 |      1 D1 |      6 D6 |
|  -.09 |      1 D1 |      3 D3 |
|  -.08 |      1 D1 |      2 D2 |
-------------------------------
```

Subscale Learning Process Knowledge

```
TABLE 23.0 working data_Update_LP_Feb2023.sav    ZOU624WS.TXT  Feb 25 2023 12:21
INPUT: 214 PERSON  8 ITEM  REPORTED: 214 PERSON  8 ITEM  4 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                          Eigenvalue   Observed   Expected
Total raw variance in observations     =      16.8743 100.0%         100.0%
  Raw variance explained by measures   =       8.8743  52.6%          51.9%
    Raw variance explained by persons  =       7.9686  47.2%          46.6%
    Raw Variance explained by items    =        .9057   5.4%           5.3%
  Raw unexplained variance (total)     =       8.0000  47.4% 100.0%   48.1%
    Unexplned variance in 1st contrast =       1.8470  10.9%  23.1%
    Unexplned variance in 2nd contrast =       1.4213   8.4%  17.8%
    Unexplned variance in 3rd contrast =       1.2754   7.6%  15.9%
    Unexplned variance in 4th contrast =       1.0868   6.4%  13.6%
    Unexplned variance in 5th contrast =        .9486   5.6%  11.9%
```

```
TABLE 23.99 working data_Update_LP_Feb2023.sav   ZOU624WS.TXT  Feb 25 2023 12:21
INPUT: 214 PERSON  8 ITEM  REPORTED: 214 PERSON  8 ITEM  4 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT ITEM
-------------------------------
|CORREL-| ENTRY      | ENTRY      |
|  ATION|NUMBER ITE |NUMBER ITE |
|-------+-----------+-----------|
|   .38 |      1 LP1 |      2 LP2 |
|-------+-----------+-----------|
|  -.32 |      2 LP2 |      7 LP7 |
|  -.31 |      5 LP5 |      8 LP8 |
|  -.28 |      2 LP2 |      5 LP5 |
|  -.27 |      1 LP1 |      6 LP6 |
|  -.27 |      2 LP2 |      4 LP4 |
|  -.25 |      1 LP1 |      7 LP7 |
|  -.23 |      6 LP6 |      8 LP8 |
|  -.21 |      3 LP3 |      8 LP8 |
|  -.20 |      3 LP3 |      5 LP5 |
|  -.19 |      7 LP7 |      8 LP8 |
|  -.17 |      2 LP2 |      6 LP6 |
|  -.17 |      3 LP3 |      6 LP6 |
|  -.17 |      3 LP3 |      4 LP4 |
|  -.17 |      1 LP1 |      4 LP4 |
|  -.16 |      1 LP1 |      3 LP3 |
|  -.15 |      6 LP6 |      7 LP7 |
|  -.14 |      4 LP4 |      6 LP6 |
|  -.14 |      1 LP1 |      5 LP5 |
|  -.13 |      4 LP4 |      5 LP5 |
-------------------------------
```

Subscale Regulation

```
TABLE 23.0 214spss_Mc_blank_final.sav          ZOU703WS.TXT  Sep 20 2022 14:39
INPUT: 214 PERSON  13 ITEM  REPORTED: 214 PERSON  13 ITEM  4 CATS WINSTEPS 5.2.3.0
-------------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                          Eigenvalue   Observed     Expected
Total raw variance in observations     =      23.0459 100.0%          100.0%
  Raw variance explained by measures   =      10.0459  43.6%           43.4%
    Raw variance explained by persons  =       8.5730  37.2%           37.0%
    Raw Variance explained by items    =       1.4729   6.4%            6.4%
  Raw unexplained variance (total)     =      13.0000  56.4% 100.0%    56.6%
    Unexplned variance in 1st contrast =       1.7954   7.8%  13.8%
    Unexplned variance in 2nd contrast =       1.6083   7.0%  12.4%
    Unexplned variance in 3rd contrast =       1.3578   5.9%  10.4%
```

```
TABLE 23.99 214spss_Mc_blank_final.sav          ZOU703WS.TXT  Sep 20 2022 14:39
INPUT: 214 PERSON  13 ITEM  REPORTED: 214 PERSON  13 ITEM  4 CATS WINSTEPS 5.2.3.0
-------------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT ITEM
---------------------------------
|CORREL-| ENTRY      | ENTRY      |
|  ATION|NUMBER ITE  |NUMBER ITE  |
|-------+-----------+-----------|
|    .18 |      2 R2  |      3 R3  |
|    .17 |     10 R10 |     11 R11 |
|-------+-----------+-----------|
|   -.30 |      5 R5  |     10 R10 |
|   -.27 |      7 R7  |     13 R13 |
|   -.26 |      1 R1  |      6 R6  |
|   -.26 |      2 R2  |     12 R12 |
|   -.25 |      7 R7  |     11 R11 |
|   -.24 |      6 R6  |     12 R12 |
|   -.23 |      5 R5  |      8 R8  |
|   -.23 |      4 R4  |      8 R8  |
|   -.22 |      1 R1  |      2 R2  |
|   -.22 |      4 R4  |      9 R9  |
|   -.21 |      1 R1  |      3 R3  |
|   -.20 |      9 R9  |     10 R10 |
|   -.20 |      4 R4  |      7 R7  |
|   -.19 |      3 R3  |     12 R12 |
|   -.19 |     10 R10 |     13 R13 |
|   -.18 |      9 R9  |     13 R13 |
|   -.17 |      1 R1  |      7 R7  |
|   -.17 |      3 R3  |     11 R11 |
---------------------------------
```

Item difficulty of all item in the scale from the same analysis

```
TABLE 10.1 working data_Update_LP_Feb2023.sav    ZOU997WS.TXT  Feb 25 2023 12:27
INPUT: 214 PERSON  27 ITEM  REPORTED: 214 PERSON  27 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------
PERSON: REAL SEP.: 3.27  REL.: .91 ... ITEM: REAL SEP.: 3.15  REL.: .91

         ITEM STATISTICS:  MISFIT ORDER
```

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM
5	897	213	-.22	.16	1.58	4.44	1.75	4.74	A .49	.64	73.0	74.8	D5
2	925	213	-.92	.16	1.59	4.97	1.61	4.00	B .55	.62	63.2	74.2	D2
4	891	214	.03	.16	1.50	3.82	1.53	3.49	C .53	.65	68.8	74.7	D4
21	861	214	.75	.15	1.37	2.82	1.45	3.06	D .59	.67	71.7	74.9	R7
26	874	214	.45	.15	1.32	2.48	1.43	2.92	E .56	.66	71.7	75.1	R12
3	880	212	.10	.16	1.13	1.12	1.13	.95	F .68	.65	71.4	74.7	D3
1	937	212	-1.33	.16	1.01	.09	1.12	.87	G .59	.60	75.4	73.6	D1
14	862	210	.33	.16	1.02	.18	1.02	.21	H .65	.66	71.6	75.2	LP8
27	880	214	.30	.16	1.02	.18	.94	-.46	I .66	.66	74.6	75.1	R13
6	888	213	.01	.16	1.01	.11	.90	-.70	J .68	.65	77.9	74.7	D6
23	873	213	.37	.16	.97	-.25	.98	-.09	K .68	.66	74.0	75.0	R9
24	864	213	.59	.15	.96	-.28	.98	-.14	L .63	.67	79.9	75.0	R10
10	909	214	-.41	.16	.96	-.34	.91	-.65	M .65	.64	75.6	74.6	LP4
22	862	213	.64	.15	.92	-.62	.95	-.36	N .65	.67	77.0	74.9	R8
15	862	214	.73	.15	.88	-.99	.94	-.45	m .73	.67	76.6	74.9	R1
18	885	214	.18	.16	.93	-.62	.87	-.98	l .63	.66	77.6	74.9	R4
20	883	212	.02	.16	.90	-.81	.87	-.94	k .69	.65	75.9	74.8	R6
11	900	212	-.39	.16	.89	-1.01	.85	-1.21	j .66	.64	74.4	74.6	LP5
8	903	207	-1.02	.16	.87	-1.35	.83	-1.39	i .66	.61	74.2	74.0	LP2
17	889	213	-.03	.16	.82	-1.67	.77	-1.84	h .67	.65	75.5	74.8	R3
19	870	213	.44	.16	.80	-1.76	.81	-1.52	g .72	.66	77.5	75.1	R5
25	867	211	.33	.16	.81	-1.71	.73	-2.20	f .71	.66	76.2	75.1	R11
12	889	214	.08	.16	.80	-1.87	.73	-2.20	e .74	.65	77.6	74.8	LP6
7	922	211	-1.06	.16	.76	-2.61	.72	-2.27	d .67	.61	80.7	74.1	LP1
13	883	213	.12	.16	.76	-2.20	.70	-2.46	c .70	.65	78.9	74.9	LP7
16	896	214	-.09	.16	.76	-2.28	.71	-2.42	b .70	.65	77.6	74.8	R2
9	881	211	.00	.16	.58	-4.28	.51	-4.45	a .74	.65	83.7	74.7	LP3
MEAN	886.4	212.6	.00	.16	1.00	-.16	.99	-.24			75.3	74.7	
P.SD	19.8	1.6	.54	.00	.25	2.17	.30	2.17			3.9	.4	

The Wright Map of all item in Mc questionnaire

```
TABLE 12.2 working data_Update_LP_Feb2023.sav    ZOU997WS.TXT  Feb 25 2023 12:27
INPUT: 214 PERSON  27 ITEM  REPORTED: 214 PERSON  27 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

MEASURE    PERSON - MAP - ITEM
               <more>|<rare>
    9            ###  +
                   .  |
                      |
                      |
    8              .  +
                      |
                   .  |
                   .  |
    7             .# T+
                   .  |
                   #  |
                      |
    6             .#  +
                   #  |
              .####   |
                .## S|
    5             .#  +
               .###   |
                 .#   |
               .###   |
    4             ##  +
              .#### M|
              #####   |
                .##   |
    3 .############   +
               .###   |
                .##   |
                 .#   |
    2              . S+
               .###   |
                   .  |
                   .  |
    1             .#  +T
                   .  |   R1     R7     R8
                  .#  |S  R10    R12    R5
                     T|   LP8    R11    R13    R4     R9
    0              #  +M  D3     D4     D6     LP3    LP6    LP7    R2     R3
                          R6
                   .  |   D5
                      |S  LP4    LP5
                      |
   -1                 +T  D2     LP1    LP2
                      |   D1
                      |
                   .  |
   -2                 +
               <less>|<freq>
 EACH "#" IS 3: EACH "." IS 1 TO 2
```

APPENDIX G

The Rasch Analysis Results From the Winstep Program of Each Subscale in the Questionnaire for Assessing Teachers' Perceptions of Their Actual MOLEs

Subscale Student Teacher Negotiation

```
TABLE 23.0 214spss_Mc&Am_blank.sav              ZOU605WS.TXT  Sep 16 2022 12:24
INPUT: 214 PERSON  7 ITEM  REPORTED: 214 PERSON  7 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                          Eigenvalue   Observed     Expected
Total raw variance in observations     =      18.6976 100.0%          100.0%
  Raw variance explained by measures   =      11.6976  62.6%           62.5%
    Raw variance explained by persons  =       8.7093  46.6%           46.5%
    Raw Variance explained by items    =       2.9883  16.0%           16.0%
  Raw unexplained variance (total)     =       7.0000  37.4% 100.0%    37.5%
    Unexplned variance in 1st contrast =       1.9679  10.5%  28.1%
    Unexplned variance in 2nd contrast =       1.2811   6.9%  18.3%
    Unexplned variance in 3rd contrast =       1.0825   5.8%  15.5%
    Unexplned variance in 4th contrast =        .9829   5.3%  14.0%
    Unexplned variance in 5th contrast =        .8516   4.6%  12.2%
```

```
TABLE 23.99 214spss_Mc&Am_blank.sav              ZOU605WS.TXT  Sep 16 2022 12:24
INPUT: 214 PERSON  7 ITEM  REPORTED: 214 PERSON  7 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT ITEM
-----------------------------------
|CORREL-| ENTRY      | ENTRY      |
|  ATION|NUMBER ITEM |NUMBER ITEM |
|-------+------------+------------|
|   .16 |      2 STN2 |      3 STN3 |
|   .11 |      1 STN1 |      3 STN3 |
|   .10 |      1 STN1 |      2 STN2 |
|-------+------------+------------|
|  -.39 |      1 STN1 |      6 STN6 |
|  -.32 |      2 STN2 |      6 STN6 |
|  -.31 |      3 STN3 |      6 STN6 |
|  -.30 |      2 STN2 |      7 STN7 |
|  -.28 |      2 STN2 |      4 STN4 |
|  -.28 |      3 STN3 |      4 STN4 |
|  -.28 |      3 STN3 |      7 STN7 |
|  -.25 |      3 STN3 |      5 STN5 |
|  -.22 |      1 STN1 |      5 STN5 |
|  -.22 |      5 STN5 |      7 STN7 |
|  -.21 |      2 STN2 |      5 STN5 |
|  -.20 |      1 STN1 |      4 STN4 |
|  -.17 |      1 STN1 |      7 STN7 |
|  -.14 |      6 STN6 |      7 STN7 |
|  -.08 |      4 STN4 |      6 STN6 |
|  -.07 |      4 STN4 |      5 STN5 |
|  -.04 |      5 STN5 |      6 STN6 |
-----------------------------------
```

Subscale Teacher Openness

```
TABLE 23.0 214spss_Mc&Am_blank_update.sav       ZOU242WS.TXT  Sep 16 2022 12:27
INPUT: 214 PERSON  5 ITEM  REPORTED: 214 PERSON  5 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                           Eigenvalue   Observed   Expected
Total raw variance in observations     =      12.2415 100.0%         100.0%
  Raw variance explained by measures   =       7.2415  59.2%          59.3%
    Raw variance explained by persons  =       5.5245  45.1%          45.3%
    Raw Variance explained by items    =       1.7170  14.0%          14.1%
  Raw unexplained variance (total)     =       5.0000  40.8% 100.0%   40.7%
    Unexplned variance in 1st contrast =       1.5543  12.7%  31.1%
    Unexplned variance in 2nd contrast =       1.3463  11.0%  26.9%
    Unexplned variance in 3rd contrast =       1.1346   9.3%  22.7%
    Unexplned variance in 4th contrast =        .9623   7.9%  19.2%
    Unexplned variance in 5th contrast =        .0011    .0%    .0%
```

```
TABLE 23.99 214spss_Mc&Am_blank_update.sav       ZOU242WS.TXT  Sep 16 2022 12:27
INPUT: 214 PERSON  5 ITEM  REPORTED: 214 PERSON  5 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT ITEM
```

CORREL-ATION	ENTRY NUMBER ITE	ENTRY NUMBER ITE
-.41	3 TO3	4 TO4
-.37	2 TO2	3 TO3
-.35	1 TO1	5 TO5
-.34	3 TO3	5 TO5
-.29	1 TO1	3 TO3
-.19	2 TO2	5 TO5
-.17	1 TO1	2 TO2
-.11	1 TO1	4 TO4
-.09	2 TO2	4 TO4
-.06	4 TO4	5 TO5

Subscale Teacher Value and Support

```
TABLE 23.0 214spss_Mc&Am_blank.sav            ZOU960WS.TXT  Sep 16 2022 12:29
INPUT: 214 PERSON  4 ITEM  REPORTED: 214 PERSON  4 ITEM  4 CATS WINSTEPS 5.2.3.0
-------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                          Eigenvalue   Observed   Expected
Total raw variance in observations     =      9.6866 100.0%         100.0%
  Raw variance explained by measures   =      5.6866  58.7%          58.5%
    Raw variance explained by persons  =      4.6999  48.5%          48.4%
    Raw Variance explained by items    =       .9867  10.2%          10.2%
  Raw unexplained variance (total)     =      4.0000  41.3% 100.0%   41.5%
    Unexplned variance in 1st contrast =      1.7502  18.1%  43.8%
    Unexplned variance in 2nd contrast =      1.3936  14.4%  34.8%
    Unexplned variance in 3rd contrast =       .8437   8.7%  21.1%
    Unexplned variance in 4th contrast =       .0145    .1%    .4%
    Unexplned variance in 5th contrast =       .0014    .0%    .0%
```

```
TABLE 23.99 214spss_Mc&Am_blank.sav           ZOU960WS.TXT  Sep 16 2022 12:29
INPUT: 214 PERSON  4 ITEM  REPORTED: 214 PERSON  4 ITEM  4 CATS WINSTEPS 5.2.3.0
-------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT ITEM
---------------------------------
|CORREL-| ENTRY     | ENTRY     |
|  ATION|NUMBER ITE |NUMBER ITE |
|-------+-----------+-----------|
|   .13 |     2 VS2 |     4 VS4 |
|-------+-----------+-----------|
|  -.48 |     1 VS1 |     2 VS2 |
|  -.47 |     3 VS3 |     4 VS4 |
|  -.41 |     2 VS2 |     3 VS3 |
|  -.37 |     1 VS1 |     3 VS3 |
|  -.29 |     1 VS1 |     4 VS4 |
---------------------------------
```

Subscale Metacognition Prompt

```
TABLE 23.0 214spss_Mc&Am_blank.sav              ZOU905WS.TXT   Sep 16 2022 12:31
INPUT: 214 PERSON   4 ITEM  REPORTED: 214 PERSON  4 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                           Eigenvalue   Observed   Expected
Total raw variance in observations     =       9.2894 100.0%         100.0%
  Raw variance explained by measures   =       5.2894  56.9%          57.0%
    Raw variance explained by persons  =       3.8150  41.1%          41.1%
    Raw Variance explained by items    =       1.4744  15.9%          15.9%
  Raw unexplained variance (total)     =       4.0000  43.1% 100.0%   43.0%
    Unexplned variance in 1st contrast =       1.6936  18.2%  42.3%
    Unexplned variance in 2nd contrast =       1.2564  13.5%  31.4%
    Unexplned variance in 3rd contrast =       1.0469  11.3%  26.2%
    Unexplned variance in 4th contrast =        .0023    .0%    .1%
    Unexplned variance in 5th contrast =        .0011    .0%    .0%
```

```
TABLE 23.99 214spss_Mc&Am_blank.sav              ZOU905WS.TXT   Sep 16 2022 12:31
INPUT: 214 PERSON   4 ITEM  REPORTED: 214 PERSON  4 ITEM  5 CATS WINSTEPS 5.2.3.0
--------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT ITEM
---------------------------------
|CORREL-| ENTRY     | ENTRY     |
|  ATION|NUMBER ITE |NUMBER ITE |
|-------+-----------+-----------|
|  -.50 |     1 MP1 |     2 MP2 |
|  -.50 |     2 MP2 |     4 MP4 |
|  -.33 |     1 MP1 |     3 MP3 |
|  -.30 |     2 MP2 |     3 MP3 |
|  -.29 |     3 MP3 |     4 MP4 |
|  -.05 |     1 MP1 |     4 MP4 |
---------------------------------
```

Item difficulty of all item in the scale from the same analysis

TABLE 10.1 214spss_Mc&Am_blank_update.sav ZOU974WS.TXT Sep 16 2022 12:22
INPUT: 214 PERSON 20 ITEM REPORTED: 214 PERSON 20 ITEM 5 CATS WINSTEPS 5.2.3.0

PERSON: REAL SEP.: 2.91 REL.: .89 ... ITEM: REAL SEP.: 9.27 REL.: .99

ITEM STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM
10	847	213	-.18	.10	1.41	3.63	1.30	2.70	A .61	.58	54.5	55.6	TO3
8	878	213	-.51	.11	1.32	2.88	1.20	1.82	B .56	.56	53.1	57.2	TO1
18	707	212	1.08	.09	1.18	1.84	1.28	2.73	C .52	.65	42.0	48.8	MP2
9	879	214	-.47	.11	1.18	1.71	1.08	.79	D .63	.57	62.1	57.3	TO2
12	862	212	-.38	.11	1.15	1.44	1.13	1.21	E .62	.57	59.0	56.7	TO5
19	824	214	.10	.10	1.08	.82	1.13	1.28	F .50	.60	57.0	53.8	MP3
11	891	212	-.72	.11	1.12	1.12	.98	-.17	G .63	.55	63.7	58.7	TO4
7	694	213	1.21	.09	1.05	.59	1.07	.71	H .64	.65	40.8	48.4	STN7
6	679	213	1.31	.09	1.05	.56	1.05	.56	I .58	.66	49.8	48.0	STN6
14	964	213	-1.68	.13	1.04	.40	.90	-.68	J .48	.48	65.3	65.5	VS2
16	976	211	-2.05	.14	1.01	.14	.99	.00	j .42	.45	65.9	69.9	VS4
17	770	214	.60	.09	.98	-.17	.95	-.51	i .56	.63	56.1	50.7	MP1
15	942	212	-1.40	.12	.96	-.39	.88	-.91	h .54	.50	62.7	63.3	VS3
13	940	213	-1.30	.12	.93	-.67	.83	-1.41	g .58	.51	66.2	62.5	VS1
1	759	211	.59	.09	.91	-.86	.88	-1.23	f .68	.62	55.5	50.6	STN1
4	692	211	1.16	.09	.87	-1.35	.88	-1.22	e .68	.65	48.8	48.4	STN4
20	789	214	.43	.10	.87	-1.37	.85	-1.62	d .58	.62	57.5	51.8	MP4
2	767	212	.56	.09	.83	-1.82	.81	-1.98	c .63	.62	58.5	51.1	STN2
3	760	214	.69	.09	.80	-2.11	.79	-2.24	b .70	.63	59.8	50.4	STN3
5	724	214	.98	.09	.77	-2.62	.79	-2.37	a .68	.64	53.3	49.1	STN5
MEAN	817.2	212.7	.00	.10	1.03	.19	.99	-.13			56.6	54.9	
P.SD	93.9	1.0	1.01	.01	.17	1.61	.16	1.52			7.0	6.2	

The Wright Map of all items in ActualMOLEs

```
TABLE 12.2 214spss_Mc&Am_blank_update.sav        ZOU974WS.TXT  Sep 16 2022 12:22
INPUT: 214 PERSON  20 ITEM  REPORTED: 214 PERSON  20 ITEM  5 CATS WINSTEPS 5.2.3.0
----------------------------------------------------------------------------------

MEASURE    PERSON - MAP - ITEM
               <more>|<rare>
    6                +
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                     |
                .#   |
    5                +
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    4            .   +
                    T|
                 .   |
                .#   |
                ##   |
                ##   |
    3         .###   +
              .###   |
              #### S|
               .##   |
                ##   |
           ######    |
    2          ###   +T
              ####   |
         ########    |
             .#### M|
         ########    |   STN6
         ########    |   STN4    STN7
    1     #######    +S MP2      STN5
               ###   |
         ########    |   MP1     STN1    STN3
              ####   |   MP4     STN2
               ### S|
                .#   |   MP3
    0        .####   +M
             .####   |   TO3
                .#   |   TO5
                 #   |   TO1     TO2
                 .   |   TO4
                .# T|
   -1            .   +S
                 .   |
                     |   VS1     VS3
                     |
                     |   VS2
                     |
   -2                +T VS4
               <less>|<freq>
EACH "#" IS 2: EACH "." IS 1
```

APPENDIX H

The Questionnaire for Assessing Science Teachers' Metacognition, its Subscales, and Items

Subscales	Items id	Q No.	Questionnaire Items
Declarative Knowledge	D1	1	I know what it means to learn science.
	D2	6	I know how learning science is different from learning other subjects.
	D3	5	I know my strength(s) in learning science.
	D4	11	I know my weakness(es) in learning science.
	D5	18	I know which part of learning science is difficult for me.
	D6	23	I know which part of learning science is easy for me.
Learning Strategic Knowledge	LP1	2	I know how to learn science.
	LP2	3	I know how I learn science.
	LP3	24	I am aware of learning strategies that I use to learn science.
	LP4	19	I know various strategies to learn science.
	LP5	7	I know various strategies to learn science in different situations.
	LP6	8	I know which learning strategies to use to learn science in different situations.
	LP7	16	I know when to use a specific learning strategy to learn science.
	LP8	4	I have ways to check if I understand science correctly
Regulation	R1	20	I know when my science learning strategy works best.
	R2	10	When I learn science, I am aware of what I am thinking.
	R3	15	When I learn science, I am aware of how rationale of my thinking.
	R4	21	When I learn science, I am aware of my learning difficulties.
	R5	25	When I learn science, I am aware if what I am thinking aligns with a process of learning science.
	R6	14	When I learn science, I am aware of what step to take in the learning process.
	R7	9	I evaluate myself to know if I learn science.
	R8	12	I evaluate if I meet my science learning goals.
	R9	13	In learning science, I evaluate the effectiveness of my science learning process.
	R10	17	I know pitfall(s) of my science learning processes.
	R11	26	I know the strength(s) of my science learning processes.
	R12	27	When I do not understand a science concept, I change my learning strategy.
	R13	22	When I do not understand science, I know what I should do to help me understand science.

APPENDIX I

The Questionnaire for Assessing Science Teachers' Perceptions of their Actual MOLEs, its Subscales, and Items

Subscale	ID	Q No.	Questionnaire Item
			In my **actual** science classroom
Student-Teacher Negotiation	StN1	16	Students discuss with me about different ways of learning science.
	StN2	20	Students discuss with me about how well they are learning science.
	StN3	19	Students discuss with me about how they can improve their learning of science.
	StN4	17	Students help me decide which activities they do.
	StN5	7	Students help me to decide which activities are best for them.
	StN6	3	Students help me decide how much time they spend on activities.
	StN7	15	Students help me decide when it is time to begin a new topic.
Teacher Openness	TO1	18	It is OK for students to tell me when they don't understand science.
	TO2	14	It is OK for students to ask me why they have to do a certain activity.
	TO3	6	It is OK for students to suggest alternative science learning activities to those proposed by me.
	TO4	13	It is OK for students to speak out to me about activities that are confusing.
	TO5	9	It is OK for students to speak out to me about anything that prevents them from learning.
Teacher Value and Support	VS1	12	I support students who try new ways of learning science.
	VS2	10	I value students' efforts.
	VS3	8	I respect students' ideas.
	VS4	11	I respect students' individual differences.
Metacognition Prompt	MP1	5	I ask students to think about how they learn science.
	MP2	1	I ask students to think about their difficulties in learning science.
	MP3	2	I ask students to think about how they could become better learners of science.
	MP4	4	I ask students to try new ways of learning science.

APPENDIX J

Experts' Information

Questionnaire Face Validity

Gregory Thomas

Thomas is a supervisor of this research study. Over three decades of working profession in educational area, he has vast experience such as a school teacher, university professor, researcher, committee chair, journal reviewer, keynote speaker, including management roles as a research center director or head of department. His areas in research expertise are including research methodologies, science education, learning environments, and metacognition. He also has profound understanding of educational context not only in the western setting as in the North America, but also in the eastern setting as in Hong Kong and Thailand. His cumulative research grant is over 1.2 m CAD. He has almost 100 papers in publications so far.

Warawan Chantharanuwong

Warawan is an expertise science educator who are excellent both in practice and theory. As a teacher, she has more than 25 years of experience in science classrooms. As a researcher, her research interests are about metacognition, teaching and learning thinking skills, etc. She has released more than 20 research papers including the area of metacognition since 2007. She has also published many books about thinking and learning including *Thinking and Metacognition: Guideline to improve learners' thinking and learning* which was released in 2014.

Linguistic Validity

Chalita Thanyakoop

Chalita holds strong proficiency in English and Thai language, and she also has high expertise in both science and education area. She finished her degree in science from the USA, bachelors' degree from California Institute of Technology and doctoral degree from University of California, Santa Barbara. She has been working in area of science education for more than 12 years. Her professional experiences include a lecturer, science educator, and education project manager in prominent institutions, for example, Mahidol University, the Institute for the Promotion for Teaching Science and Technology, Kenan Foundation Asia, and UNICEF Thailand.

Sattiya Langkhapin

Sattiya holds high competence in English and Thai language, and expertise in science education. She graduated bachelor's and master's degree in science area from University of Cambridge, UK. She has more than 20 years of working profession in science education in national and international organizations. Her experiences are, for example, the Director of Special Initiative Division at the Institute for the Promotion of Teaching Science and Technology, and the Director of Corporate Affairs at Intel Microelectronics (Thailand) Ltd. Currently, she has been working as the Chief of Party at Education Development Center (EDC).

Peer Debriefing

Tawinan Saengkhattiya

Tawinan has solid background both in science and education area. She graduated her bachelor's and master's degree in science. She has been working as an educator at the Institute for the Promotion of Teaching Science and Technology (IPST), Ministry of Education, Thailand since 2013. Her profession is in the areas of gifted science students and science Olympiad students. Currently, she is a Ph.D. student at the Department of Education, Brunel University, UK. She is interested in fields of STEM activity, primary science education, problem-solving, and education for sustainable development.

Wichuratree Klubseang

Wichuratree has more than ten years of working experience as a science educator at the Institute for the Promotion of Teaching Science and Technology (IPST), Ministry of Education, Thailand. She has strong background in science as she received her bachelor's and master's degree in Geography and Earth Science respectively. At present, she is doing a Ph.D. in education at the Mallinson Institute for Science Education (MISE), Western Michigan University.

Appendix K

Codes, Sub-themes, and Themes in relation to Research Questions (1-4)

Codes	**Sub-Themes**	**Themes**	**Research Questions (number)**
Love learning science, family driven, random opportunity	Inspiration in being a science teacher	Supportive information	
Applying in everyday life, thinking processes,	How learning science is important	Supportive information	
having new knowledge, building from old knowledge, having new skills	What learning is	Supportive information	
Have never heard the concept, have heard the concept, not familiar with the Mc concept	Knowledge about metacognition concept	Supportive information	
Able to identify, able to identify with hints, not able to identify, affection as strengths in learning	My strengths in learning science	Metacognitive Knowledge (Declarative knowledge)	1
Able to identify, able to identify with hints, not able to identify,	My weaknesses in learning science	Metacognitive Knowledge	1

Codes	Sub-Themes	Themes	Research Questions (number)
affection as weakness in learning		(Declarative knowledge)	
Promptly explaining	Processes of Learning Science	Metacognitive Knowledge (Procedural knowledge)	1
Having different processes in learning, using one process in learning	Different processes of Learning Science	Metacognitive Knowledge (Conditional knowledge)	1
Able to identify my learning strategy(ies), able to identify with hints, not able to identify	My learning strategies	Metacognitive Knowledge (Procedural knowledge)	1
Fully Aware, reluctant to answer,	Monitoring/Aware if I understand science/ not understand science concept	Regulation/ (monitoring/ awareness)	1

Codes	Sub-Themes	Themes	Research Questions (number)
Explaining with criteria, able to explain, not clear explanation, learning is automatic process	Evaluating/ explain how I get to learn science	Regulation (evaluation)	1
Improving my cognition, using my cognition in beneficial way(s), no evidence	Managing my own cognition	Regulation	1
Always, sometimes, rarely	Discussing/ encouraging students to think about own learning	Actual MOLEs	2
Always, sometimes, rarely	Sharing learning techniques to my students	Actual MOLEs	2
Always, sometimes, rarely, cognition ways, metacognition ways	Suggesting how to learn science to students	Actual MOLEs	2
Always, sometimes, rarely	Students asking how to learn Sc	Actual MOLEs	2
Always, sometimes, rarely	Students sharing their learning process to me	Actual MOLEs	2

Codes	**Sub-Themes**	**Themes**	**Research Questions (number)**
Always, sometimes, rarely	Students and students discussion on how to learn	Actual MOLEs	2
Extremely positive, positive, moderate/low interest	Attitude to MOLEs	Preferred MOLEs	2
Highly interest, if I have a chance	Attitude toward training for instruction for metacognition	Preferred MOLEs	2
Tight curriculum, time in classrooms, school policy, assessments, teachers' extra works, teachers' attitude to change, teachers' knowledge about Mc instruction, parents' expectations, school extra activities, students' attention, students' economic status, students' learning ability	Obstacle in implementing instruction for metacognition	Why Actual and Preferred MOLEs are different (obstacles)	4

Codes	Sub-Themes	Themes	Research Questions (number)
Budget/learning materials (additional from obstacle in Mc instruction)	Obstacles in teaching and learning	Supportive information	
Mc is for students in higher level, Mc is for high performance students	Metacognition for which group of students	Preferred MOLEs	
Rural, sub-urban, urban, no evidence	School area	Supportive information	
High participation, depending on group, low participation	Student participation in classrooms	Supportive information	
Much evidence, evidence, no evidence, evident as not much	Teacher’s openness to Students	Supportive information	
Cognition/ skills focuses, metacognition, metacognition in math problems	My science instruction	Supportive information	
Cognition/skills	My dream instruction	Supportive information	
Using questions, using task, observing gestures	How I know if Students learn	Supportive information	

Codes	**Sub-Themes**	**Themes**	**Research Questions (number)**
Absolutely different, some parts are similar, not different	If learning Sc is different from learning other subjects	Supportive information	
Mention relationship between Mc and Buddhism, doing Buddhism practice and relate to Mc, no evidence	Metacognition and Buddhism	Supportive information	
No action, had some thoughts on instruction for learning, tried somethings in classrooms	My actions after the first interview	Supportive information	

Appendix L

Examples of Results of Factor Analysis of the PreferredMOLEs Questionnaire

Rotated Component Matrix[a]

	Component			
	1	2	3	4
pes4	.850			
pes1	.829			
pes3	.774			
pes2	.746			
psv1	.730			
pts4	.699			
psv5	.670			.409
pts3	.657			.449
psv4	.623			.528
pmd5	.530	.449		.433
pst4		.797		
pst2		.791		
pst3		.774		
pst5		.768		
pst1		.682		
pmd4	.414	.611		
pmd2		.562		
pmd1		.492	.414	
pdc4			.807	
pdc3		.428	.764	
pdc5			.758	
pdc2		.445	.744	
pmd3				.655
psv3	.477			.592
psv2	.508			.539

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Rotated Component Matrix[a]

	Component	
	1	2
psv1	.798	
pes1	.787	
pes4	.783	
pts3	.766	
psv5	.765	
psv4	.756	
pes2	.754	
pes3	.740	
pts4	.733	
psv2	.660	
psv3	.648	
pst3		.856
pst4		.847
pst1		.805
pst2		.785
pdc2		.784
pst5		.777
pmd1		.671
pdc5		.646
pmd2		.608

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.