Computer-Supported Meta-Reflective Learning Model via Learning Mathematical Word Problem to Acquire Seed Skill to Become a Self-Regulated Learner

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Doctoral Dissertation

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ABSTRACT

To make learners become self-regulated learners is a heart of education, because, after graduating from school or college, learners are expected to be able to learn many crucial skills informally for living their life by their own. To become self-regulated learners, learners must have motivation for maintaining their emotion to perform metacognitive skills to accomplish their tasks. However, learning or training metacognition is not a simple task due to the implicitness of metacognition and the complication of its training process. To avoid cognitive load and frustration which is a cause of demotivation in novices learners in training metacognition, there should be an implicit meta-level thinking skill which could be alike an assisting ladder to support them to step up to the stage of self-regulated learners. I would name that implicit skill as *Seed skill to become a self-regulated learner* (S2SRL). That is, S2SRL here refers to a skill in which learners are curious on their own understanding and awareness of self-improvement in their learning before learners can perform metacognitive questions by themselves to reflect their own cognition for planning, monitoring, and doing self-evaluation.

The goal of training metacognitive skills is to help learners to be comfortable with applying meta-level thinking on their cognitive process and become self-regulated learners who can automatically monitor and regulate their learning processes and be aware of their difficulties to achieve their tasks. However, it is also a difficult task for novices to think about metacognitive questions by themselves. Therefore, in this dissertation, before encouraging novice learners to use metacognitive skills, I proposed to provide them some examples of metacognitive questionings and examples of a situation to use those metacognitive questions to engage and encourage them to gain S2SRL. To promote metacognitive questionings corresponding to learners' learning process by using an adaptive method, computer technology is considered.

Moreover, to encourage learners to be curious on their own understanding and awareness of self-improvement in their learning or to gain S2SRL, it is necessary to motivate and facilitate them to have clear process of a given task in their mind. Later, they can use those in their mind as their cognitive target to perform meta-level thinking. From my past experience and evidence in standards test (e.g., PISA, TIMSS), most students have difficulties in solving MWP, due to they rarely take the time to monitor and regulate the use of cognitive strategies. This shows that solving MWP having a room to applied metacognitive skills. This is considered as an advantageous feature of MWP which could be employed as a medium to train metacognition.

To achieve my desire to design an environment for encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning, instead of just proposing a specific environment, there is more impact to create a framework for designing a required environment. Thus, CREMA has been developed to be a framework for designing an environment to encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning. This raised the research problems that "can the proposed framework really support learner to gain S2SRL?" And "how does it work in a practical environment?" In order to answer the research questions, the investigation to evaluate the effectiveness of and investigate the implementation of CREMA was performed by comparing three classes of low-performance students of grade-9 were assigned into three different learning groups: (i) a group of students who learnt MWP with our proposed method by implementing CREMA, (ii) a group of students who learnt MWP in traditional method combining MetaQ MetaQ—metacognitive questions and motivative statements, and (iii) a group of students who learnt MWP in traditional method.

The result from our investigation showed that MetaQ played an important role in CREMA while integrating computer and technology enhanced students' learning sense and empowered methodology to facilitate learning objects in the implementation of CREMA to effectively support students to gain S2SRL in MWP learning.

Keywords: Mathematical word problem; metacognition; metacognitive questioning; motivation; seed skills to become a self-regulated learner; self-regulated learners.

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LIST OF ABBREVIATIONS

MWP	**M**athematical **W**ord **P**roblem
S2SRL	**S**eed skill **TO** become a **S**elf-**R**egulated **L**earner
CREMA	**C**omputer-supported Meta-**Re**flective Learning **M**odel via M**A**thematical word problem
Q-L2SRL	**Q**uestionnaire for classifying a **L**earner who has gained Seed Skill TO become a **S**elf-**R**egulated **L**earner in MWP learning
UL	**U**nderstanding of MWP **L**earning
ASL	**A**wareness of **S**elf-improvement in MWP **L**earning
MetaQ	**Meta**cognitive **Q**uestions and Motivational Statements
QAS	Q/A Sequence
InDi	Inferential Diagram
STM	Stimulus
SUT	Self-understanding toward task
SUP	Self-understanding toward learning process
A	Attitude
G	Goal
M	Motivation
K	Background knowledge
P	Self-understanding of principle of a topic
D	Self-difficulty
S	Strategy
C	Learning concentration
CTRL	A group of students who learnt MWP solving by traditional method
CTRL+MetaQ	A group of students who learnt MWP solving by traditional method combining with the intervention of MetaQ
CREMA	A group of students who learnt MWP solving via computer application implemented from CREMA

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CHAPTER 1

Introduction

1.1. Background and Motivation

After graduating from school or college, learners are expected to be able to learn many crucial skills informally for living their life on their own. Then, to make learners become self-regulated learners is a heart of education to mature of lifelong learning skills (Jacobse, & Harskamp, 2012). As an inspirational quote from a well-known and classical Greek philosopher, Socrates (469 – 399 BC),

"*I cannot teach anybody anything. I can only make them think.*"

To make learners think by themselves is to make learners become self-regulated learners. Zimmerman (2002) revealed that what defines a learner as "self-regulated" is not their confidence in social independence of learning, but rather their personal initiative, perseverance, and adaptive skill. Self-regulated learners focus on how they activate, alter, and sustain specific learning practices in social as well as solitary contexts. Self-regulated learners are learners who are motivated to perform metacognitive skills to accomplish their tasks or learners who can automatically monitor and regulate their learning processes and be aware of their difficulties to achieve their tasks. That means from learners becoming self-regulated, they must have motivation for maintaining their emotion to perform metacognitive skills to accomplish their tasks.

Learning or training metacognition is not a simple task due to the implicitness of metacognition and the complication of its training process, especially, to change a learner status from a passive learner to become a self-regulated learner (i.e., an active learner). That is why there is unsuccessfulness of training metacognition in early studies. According to more recent studies, metacognitive skills can be taught to students to improve their learning performance (Habibian, 2015; Nakano, Hirashima, & Takeuchi, 2002; Nietfeld & Shraw, 2002; Tanner, 2012; Thiede, Anderson, & Therriault, 2003). From the report of OECD (2010), explicit or formal instruction of metacognitive strategies leads to an improvement in students' learning performance. That is students who received cognitive and metacognitive strategy instruction made more significant gains on measures of reading comprehension than students who only trained with conventional instruction (Baker, & Carter-Beall, 2009; Dole, Nokes, & Drits, 2009; Pressley, Graham, & Harris, 2006; Waters & Schneider, 2010).

The goal of training metacognitive skills is to help learners to be comfortable with applying meta-level thinking on their cognitive process and become self-regulated learners who can automatically monitor and regulate their learning processes and be aware of their difficulties to achieve their tasks, i.e., to transform learners to be able to perform metacognitive questioning to reflect their own cognition to do planning, monitoring, and self-evaluation. However, performing meta-level thinking is not that simple task, especially, for young learners or novice learners who have never been trained or familiar with this kind of activities. For example, the educational system in my country, metacognition have not been promoted explicitly, some schools or some teachers might talk about it but mostly it is a mysterious term. Teachers mainly teach only content to be able to finish their courses on time. For example in my case, I cannot imagine about myself using meta-level thinking or using metacognitive questions (such as, "did I understand what I read?", "what made me feel frustrated during class?", etc.) when I was a junior high school student. As I remembered, at that time, when I did not understand something I just gave up and did not want to do it. This happened to many Thai students I experienced. There are many students who encounter the same situations as me, at least in my country. I would like to do something to improve this kind of situation and would like to find an alternative way to support those students to gain a skill which could improve themselves in the future for their well-being.

To avoid producing cognitive load and frustration which is a cause of demotivation in novices or young learners and to encourage them to become familiar with and be able to perform metacognitive skill, I do believe that there should be an implicit meta-level thinking skill which could be alike an assisting ladder to support them to step up to the stage of self-regulated learners. I would name that implicit skill as Seed skill TO become Self-Regulated Learners (S2SRL). S2SRL refers to a very basic skill to be able to develop into metacognitive skills. It is defined in this study as a skill in which learners are curious on their own understanding and awareness of self-improvement in their learning before learners can perform metacognitive questions by themselves to reflect their own cognition for planning, monitoring, and doing self-evaluation. To encourage learners to be curious on their own understanding and awareness of self-improvement in their learning or to gain S2SRL, it is necessary to motivate and facilitate them to have a clear process of a given task in their mind. Later, they can use those in their mind (or their memories) as their cognitive target to perform meta-level thinking.

However, it is also a difficult task for novices to think about metacognitive questions by themselves. Therefore, in this dissertation, before encouraging novice learners to use metacognitive skills, I proposed to provide them some examples of metacognitive questionings and examples of a situation to use those metacognitive questions to engage and encourage them to gain S2SRL. To promote metacognitive questionings corresponding to learners' learning process by using an adaptive method, computer technology is considered. Although there is no evidence of using computer technology to support S2SRL before, there are studies showed its potential to support self-regulated learning in a number of ways (Hayashi, Seta, & Ikeda 2017; Jacobse & Harskamp, 2009; Schraw, Crippen & Hartley, 2006). A new and promising research subject may be assessing the effects of computer environments, which combine cognitive content with metacognitive support or as a construction tool for creating representations of mental models. Such metacognitive support can be designed in several ways, for example by using intelligent tutoring systems, educational multimedia systems, virtual agents, metacognitive hints, and so on (see e.g., Jacobse & Harskamp, 2009; Nakano, Hirashima, & Takeuchi, 2002).

Mathematics is one of the most important subjects to drive our society in all area, that's why it is in compulsory education in all countries, all students have to learn Mathematics. Mathematics is everywhere and in everything. For example, from the simplest daily activity like buy and sell to the successful phenomena to send a human to another planet or to connect the world through wireless technology. All of those use Mathematics as fundamental. The topic in Mathematics which is counted as its simplest application to link abstract concept to real-world concept is an algebraic approach to solve mathematical word problem (MWP)—mathematical problems written in a context in which students learn to model a problem described in natural language into mathematical notation. However, from my past experience as an educator and a mathematics teacher, solving MWP is like a bitter pill for students. Most Thai students have difficulties in learning and understanding how to solve MWP. This was evidenced in the report of OECD that placed the Thai students at the 50th among 65 nations participating in this worldwide study in the 2009 ranking. Programme for International Student Assessment (PISA) assessed how much students nearing the end of their compulsory education had acquired knowledge and skills needed for the full participation in the society, Thailand's poor results, which put the country in the bottom quarter of the ranking, reflected the weakness of Thai students in solving MWP and in critical thinking skills involving the indication of many layers of problems in Thai educational system.

Difficulty in solving MWP is not confined only to Thai students. The majority of mathematics learners also suffer. The evidence has been found from which there have been many researches related to enhancing students' performance in MWP solving and its pedagogy, and the topic has been also talked and discussed commonly in meetings or conferences toward education. The main difficulty that students encounter in solving MWP is to construct a problem model by making inferences from the problem context (Fuchs et al., 2008; Jacobse & Harskamp, 2009; Kintsch & Greeno, 1985). It was revealed by Schoenfeld (1992) that it is because they seldom spend time on monitoring and regulating the use of their own cognitive strategies, even if they understand the calculations in the background of the problem. This causes them to omit or put a wrong interpretation on information from the problem and misleads them to make an inappropriate decision on choosing a solution (Verschaffel et al., 1999). As mentioned in the beginning, the skills to monitor and regulate the use of cognitive strategies are involved in metacognitive skill—which is necessary to support students to structure their problem solving process in MWP as well as in real life (Flavell & Wellman, 1977; Flavell, 1979; Gama, 2004; Osman & Hannafin, 1992; Reeve & Brown, 1984). Moreover, there are studies (Artelt, Schiefele, & Schneider, 2001; Brown, Palincsar, & Armbruster, 2004) found a strong association between reading proficiency and metacognition in which solving MWP involves a process to practice reading comprehension. From this information, it could be seen that solving MWP having room to apply metacognitive skills. This is considered as an advantageous feature of MWP which could be employed as a medium to train metacognition. Since MWP solving has *'explicit form of solution process'* which is a good feature to support monitoring and to create representation framework to externalize problem-solving process. Moreover, its *'complexity of solution process'* and *'many explicit operators at each step'* are beneficial features to support metacognitive training, in which the former feature promotes reflectively analyzing the thinking process and the latter feature is good to promote regulation of making decision criteria. Instead of using a real life problem which is ill-defined that might be quite complicated and could cause frustration in novice learners due to the complexity/implicitness of metacognition combining with an unstructured problem.

In summary, to encourage learners to become self-regulated learners is a heart of education. After graduating from school or college, learners must learn many crucial skills informally for living their life. A self-regulated learner, here, is referred to a learner who is motivated to perform metacognitive skills to accomplish their task. To become self-regulated learners, learners must have motivation for maintaining their emotion to perform metacognitive skills to accomplish their tasks. To perform meta-level thinking, it is not a simple task for novices. There should be basic skills which could be the first start for them to learn and apply it later to improve themselves to become self-regulated learners. These challenge me to find out what are these skills and how to study if learners have developed them or not? And how to design an environment to encourage learners to gain those skills? These questions lie at the heart of my studies in the dissertation. The highlighted issues behind these questions will be elaborated in detail as follows.

1.2. Issues Driving Research

Considering the questions stated in the previous section about the processes to prepare learners to be ready for improving their self-regulation and about how to design an effective environment to encourage learners to gain S2SRL. It can be seen that there are already a number of studies showing metacognition is a significant factor for improving learning performance. Nevertheless, the interest for research on applying MWP learning as a medium to promote basic skills to develop learners to become self-regulated learners has never appeared yet. In order to answer the questions, there are issues and related questions must be figured out and taken into consideration as follows.

1.2.1. The common factors of self-regulated learners in learning MWP

Due to the implicitness and the abstraction of metacognition, it causes the definition of metacognition still remains quite blurred and confused (Dinsmore et al, 2008; Hacker, 1998; Veenman, Van Hout-Wolters, & Afflerbach, 2006), even though the number of researches on metacognition has been dramatically increased (Adey & Shayer, 1993; Jacobse & Harskamp, 2009; Kuhn & Pearsall, 1998; Wegerif, Myhill, Vickers, Goodall, & Allan, 2011). The excerpts below are certain definitions and conceptualizations of metacognition from different sources:

> *Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. (Flavell, 1976)*
>
> *Students learn to monitor and direct their own progress, asking questions such as "What am I doing now?," "Is it getting me anywhere?," "What else could I be doing instead?" This general metacognitive level helps students avoid persevering in unproductive approaches. . . (Perkins and Salomon, 1989)*
>
> *Metacognition also includes self-regulation—the ability to orchestrate one's learning: to plan, monitor success, and correct errors when appropriate—all necessary for effective intentional learning ...*

Metacognition also refers to the ability to reflect on one's own performance. (National Research Council, 2000)

Metacognition refers to meta-level knowledge and mental actions used to steer cognitive processes (Jacobse, & Harskamp, 2012).

Metacognition: awareness or analysis of one's own learning or thinking processes. (Merriam-Webster, 2012)

Delineation of distinct aspects of metacognition, development of tools for measuring these aspects, and strategies for teaching them to students are all active areas of inquiry among researchers across several social science disciplines (Schraw, Crippen, and Hartley, 2006; Zohar, & Barzilai, 2015). To perform a research or an investigation on this area, it is necessary to clarify the target factors or skills we would like to promote to be able to manage and handle a research strategy, i.e., to design an effective training environment and either the measuring and evaluating methods.

In summary, to enable the effective strategy for managing a fuzzy knowledge, precise definition of terms and factors related in our research should be clarified. Therefore, the first prior issue to accomplish is to precisely define the required skills of self-regulated learners in learning MWP. This enables us to precisely define the definition of S2SRL.

1.2.2. An environment to promote the basic skills for becoming self-regulated learns

Some decades ago, Flavell (1976) formulated the argument with regard to the trainability of metacognition. This issue is important in the development of the instructional training and theory (Schunk, 2008). As mentioned in the introduction, more recent studies showed evidence that metacognitive skills can be taught and it benefits learners' learning performance. There are studies showed the relation of metacognition improvement is associated with an overall academic performance of young students (Adey and Shayer, 1993; Baker, & Carter-Beall, 2009; Dole et al., 2009; Kuhn and Pearsall, 1998; Pressley et al., 2006; Waters & Schneider, 2010). Additionally, metacognition was linked to thinking skill improvement and conceptual change promotion in young students (Georghiades, 2000; White and Gunstone, 1989), as a consequence, poor metacognitive skill students did less well in academic performance than the others (Dunning, Johnson, Ehrlinger, & Kruger, 2003; Kruger & Dunning, 1999, 2002).

There is also a finding that less skilled problem solvers always be settled into shallow learning instead of deep understanding when solving problems (Jacobs, 2009). I learnt that there is a room for applying metacognition in solving MWP as mentioned in the introduction that MWP has *'explicit form of solution process', 'complexity of solution process',* and *'many explicit operators at each step'*. And everyone has to learn MWP. These raise the issue to utilize MWP as a medium to promote metacognition. Moreover, there remains much to be learned about the influence of metacognition on learning, especially among low-performance students. So, how can we use what is currently known about metacognition and the advantage features of MWP to benefit designing an appropriate environment to support learners' learning proficiency to support their basic skills to be able to benefit their development of self-regulation?

1.3. Research Goal

This dissertation, I would like to find a framework for designing an environment for encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire Seed Skill to become a self-regulated learner (S2SRL) in MWP learning. To achieve the research goal, these followings questions must be answered:

1. How to define Seed Skill to become a self-regulated learner in MWP learning?
2. Can the proposed framework really support learner to gain S2SRL in MWP learning?
3. How does the proposed framework work in a practical environment?

1.4. Research Methodology

In this dissertation, there are the works led to the journal and conference publications. The research methodology presented in this dissertation, thus, consists of sub-research themes which are described as follows.

For the first research questions related to the issue of required skills of a self-regulated learner in MWP solving, a study was performed to review the literature in self-regulated learning research. I discussed with mathematics teachers from three schools and asked them to suggest their outstanding students who were considered as self-regulated learners in MWP solving. The knowledge from the literature reviews of existing self-regulation research was applied for interviewing the selected students. Then utilized their common factors to design a survey. The survey was distributed among around 700 students in Thailand to see its consistency. And the survey result is used to confirm the target skills in this research.

Secondly, we introduced Seed Skills to become a self-regulated learner (S2SRL) by utilizing the result from the first step. The definition of S2SRL is clarified. Then it has been applied to design the framework to encourage a learner to gain S2SRL. Combining with the previous survey, a questionnaire for classifying a learner who has gained Seed Skill to become a self-regulated learner in MWP learning (Q-L2SRL) has been developed. Third, Q/A sequence (QAS) and Inferential diagram (InDi) were designed to facilitate meta-level thinking.

Lastly, ***C**omputer-Supported Meta-**Re**flective Learning Model via **Ma**thematics Word Problem* (CREMA) was proposed. To evaluate the effectiveness of and investigate the implementation of CREMA, three classes of low performance students of grade-9 were assigned into three different learning groups: (i) a group of students who learnt MWP with our proposed method by implementing CREMA, (ii) a group of students who learnt MWP in traditional method combining MetaQ—metacognitive questions and motivational statements, and (iii) a class of students who learnt MWP in traditional method, then the result was analyzed and discussed.

1.5. Research Novelty

Along the process of our research, I can emphasize four major novelties consisting in this research:

1. I introduced the term, S2SRL, as the basic skills to be able to develop into self-regulated learning skills. It is the initial state to promote to learners for developing themselves to become self-regulated learners.
2. I expressed the key features of MWP for utilizing it as a medium to promote meta-level thinking, i.e., MWP solving has an *'explicit form of solution process'* which is a good feature to support monitoring and to create representation framework to externalize problem-solving process. Moreover, its *'complexity of solution process'* and *'many explicit operators at each step'* are beneficial features to support metacognitive training, in which the former feature promotes reflectively analyzing the thinking process and the latter feature is good to promote regulation of making decision criteria.
3. I proposed QAS and InDi as media for supporting learners to acquire their self-difficulties in MWP learning.
4. I proposed CREMA to encourage learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning. The concept of our proposed model, CREMA, is to support/facilitate learners learn how to learn MWP and get used to utilize metacognitive questioning and answering by delivering appropriate metacognitive questions with Optional supports (Explanation, thinking process representation, practice) at the right time and events together with enhancing them to reflect on clearer process of problem solving by graphical representation.

1.6. A Brief Overview of The Dissertation

As mentioned above, issues in the theory, measurement, and training of metacognition using MWP solving as a medium are the main focal points of the study.

The topics in the dissertation are rearranged over the different chapters as briefly described below.

Chapter 2: This chapter reviews literatures related to existing theories and framework for training and promoting metacognition and self-regulation to support learners to become self-regulated learners in learning MWP.

Chapter 3: This chapter discusses the issues associated with the definition of metacognition and self-regulation and required skills of self-regulated learners. Then, it elaborates the methodology to precisely define the required skills of self-regulated learners in learning MWP for this research. The chapter leads to make a conclusion to the definition of the basic skills to be able to develop into the target skills, namely Seed skill to become self-regulated learners (S2SRL) in MWP learning.

Chapter 4: After learning theories and theoretical framework to support self-regulation were grounded in the previous chapter. In this chapter, it demonstrates the construction of the proposed learning model, CREMA. CREMA's learning architecture and its theoretical framework are illustrated and revealed. The chapter starts with the intention behind the creation of CREMA. Then the overall perspective of CREMA is depicted before its theoretical viewpoint is explained. The chapter will make clear of its functions and its relation to S2SRL.

Chapter 5: This chapter illustrates and exemplifies how to provide a learning environment to encourage learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning by applying CREMA as a framework. Then, this learning environment will be assessed its effectiveness and investigated to see how it works in the next chapter.

Chapter 6: This chapter discusses the research methodology to evaluate and investigate CREMA. It starts with designing the methodology. Then it explains the procedure of the evaluation and investigation step by step by providing samples and data collection instruments and explaining the experimental environment.

Chapter 7: This chapter reports the result from the previous chapter. The data collected from the investigation is summarized and analyzed using statistical technic. Then it will be presented in various forms of representations. Finally, those results are discussed and the conclusion of the finding is made.

Chapter 8: The last chapter makes a general conclusion of the overall dissertation from the first chapter. Then, the impact and contribution of the research study are appealed. Finally, the study limitation and suggestion of the future are revealed.

CHAPTER 2
Literature Reviews

2.1. Introduction

This chapter reviews literature related to existing theories and framework for training and promoting metacognition and self-regulation to support learners to become self-regulated learners in learning MWP. It mainly links the theory related to the target skill in this dissertation which will precisely define in the next chapter.

2.2. Self-Regulation

Self-regulation is the skill to monitor, control, and adjust one's own action, though, and emotions, to improve one's own performance. The self-control ability, especially in learning aspects, is one of the most important skills. It would be difficult to be successful in anything without this ability.

According to (Cook & Cook, 2009), mature self-regulation requires varieties of complex cognitive skills which include the adaptable ability to be able to achieve a goal; consciousness in the requirement of an assigned task; contemplation of oneself on how to successfully meet a task requirement; and the ability to observe their own consistency among their own though, action, and strategies. Aspects of self-regulation have correlation with several positive outcomes for learners—including academic performance, reading comprehension, and problem-solving skills (OECD, 2004); higher levels of intrinsic motivation, self-efficacy, perceived competence, self-value, moral cognition, and moral conduct (Kochanska, Murray, & Coy, 1997); and more satisfying interactions with peers and lower levels of psychopathology (such as, depression, anxiety, or paranoia) (Eisenberg, Smith, Sadovsky, & Spinrad, 2004).

From the process aspect, Zimmerman (1990) defined self-regulated learning as a process that learners regulate their own learning. Its processes include plan, set goals, self-monitor, and self-evaluate during the acquisition process. He proposed the structure and function of self-regulatory processes are expressed in terms of three cyclical phases: forethought, performance, and self-reflection, see Figure 2-1. The forethought phase refers to processes and beliefs that occur before efforts to learn; the performance phase refers to processes that occur during behavioral implementation, and self-reflection refers to processes that occur after each learning effort (Zimmerman, 2002). He considered self-regulation as the self-directive process in which learners convert their mental abilities to academic skills, and learning is a proactive process in which learners actively participate with major responsibility and motivation.

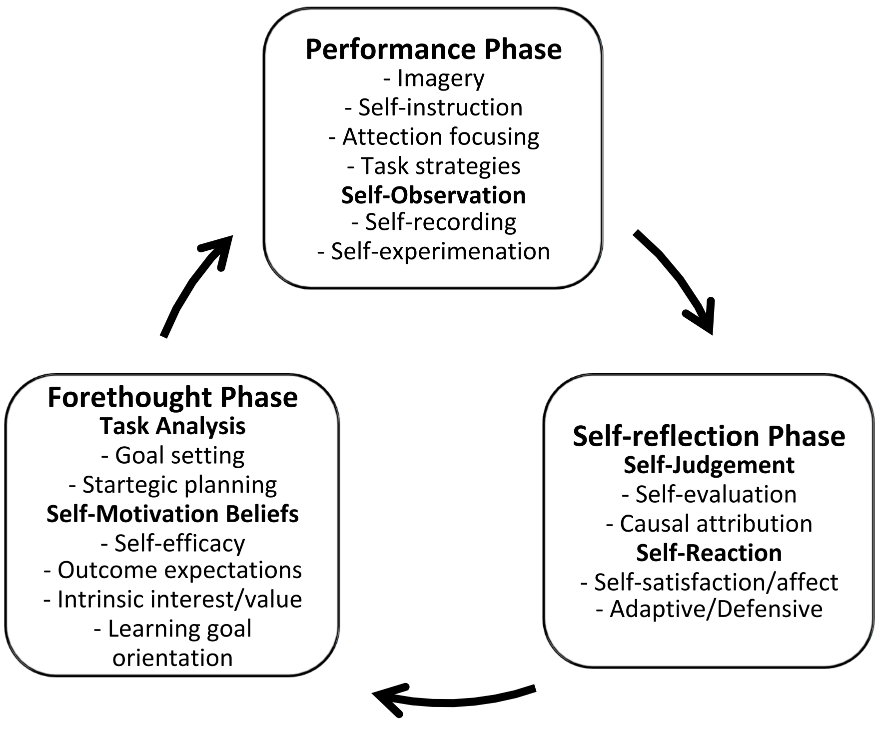


Figure 2-1 Phases and sub-processes of self-regulation (Zimmerman, 2002)

2.2.1. How can self-regulation be developed

Self-regulation comes from both internal sources and external factors, such as children's developing ability to adjust their behavior and opinion of a requirement, and the type of self-regulation being requested, respectively. It does not guarantee that children will perform self-regulation even though they can if they feel that a task or requirement is not reasonable. Therefore, encouraging children to see the reasonableness of tasks or request is helpful to understand that the change in behavior makes sense (Cook & Cook, 2009).

There have been studies showed that older children and adolescents become more able to perform self-regulation on their behavior, emotions and problem-solving strategies. For example, during the primary and middle school years children become more accurate in monitoring how well they understand what they read, and they gradually learn to adjust their own learning strategies to develop their understanding (Brown, Bransford, Ferrara, & Campione, 1983). Older children and adolescents have a tendency to use strategies to control their negative emotions in an appropriate way (Dufresne & Kobasigawa, 1989). If they are in an angry mood, they may calm down their mood by taking a deep breath or taking a walk; if they feel sad or disappointed, they may talk with a friend, draw a picture or engage in a distracting activity (Thompson, 1994). I do agree with Cook and Cook (2009) that it is important to know what level of self-regulation can be reasonably expected at different ages to be able to prepare an appropriate environment for each learner.

2.2.2. Factors influence the development of self-regulation

Thompson (2006) showed the evidence that self-regulation has roots in our biological makeup. He reported that the maturation of certain areas of the brain, especially the frontal lobes, enables children to resist interference and inhibit the response. Besides brain maturation, another important factor is temperament. Temperament appears to have a significant genetic component (Rothbart & Bates, 1998). There is research showed relation between aspects of temperament (e.g., restraint, anxiety, and effortful control) to several behaviors of self-regulation behaviors in preschool and early school-age children (e.g., behaving under discipline, cheating, and emotional regulation) (Kochanska, Murray, & Harlan, 2000; Rothbart & Bates, 1998).

However, self-regulation is not innate. The environment also has a strong influence, interacting with temperamental tendencies (Rothbart & Bates, 2006). Psychologists believe that although self-regulation is influenced by biological factors, it begins with external supervision by others and becomes internalized little by little. For example, children learn particular strategies to adjust their emotions and behavior through imitation of others' behavior (Schunk & Zimmerman, 1997).

There has another evidence from the study of Kochannska et al. (2000), they showed that the way in which adults tried to direct children's behavior and emotions correlated with the development levels of self-regulatory skills. For example, if children agree with the request, they have more tendencies to change their behavior. When children followed a request since they agreed to the request, they likely accept the request or regard it as sensible, and not look at it as troublesome to their effort or being independent. In obedience to these circumstances might eventually lead to more effective self-regulation (Cook & Cook, 2009).

2.3. Motivating Learning

2.3.1. The role of cognition, metacognition, and motivation

Schraw, Crippen, and Hartley (2006) proposed that self-regulated learning consists of three main components: cognition, metacognition, and motivation (see Figure 2-2). From this model, its three components could be divided into subcomponents.

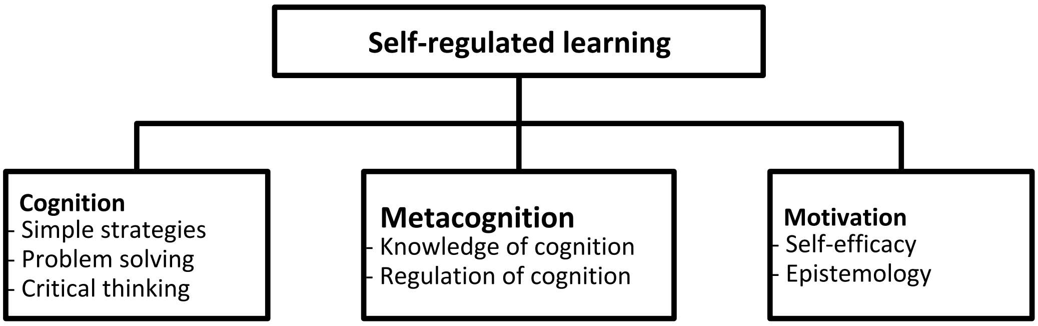


Figure 2-2 Components of self-regulated learning (Schraw, Crippen, & Hartley, 2006).

Cognition

Cognition includes three types of learning skills: cognitive strategies, problem-solving strategies, and critical thinking skills, to enable learners to encode, memorize, and recall information. According to Livingston (2003), cognitive strategies are used to help a learner achieve a goal while metacognitive strategies are used to ensure that the goal has been reached. Knowledge is considered to be metacognitive if it is actively used in a strategic manner to ensure that a goal is met. Metacognition enables us to become successful learners and has been associated with intelligence.

Metacognition

Metacognition is the complicated concept. It is a higher order thinking which involves active control over the cognitive processes engaged in learning. Activities such as planning how to proceed toward a given learning task, monitoring own understanding, and evaluating progress regarding the attainment of the task are metacognitive in nature (Livingston, 2003). As presented in Figure 2-2, Metacognition includes two main components: knowledge of cognition and regulation of cognition, to enable learners to understand and monitor their cognitive processes. Metacognitive knowledge of cognition refers to knowledge about cognitive processes, knowledge that can be used to control cognitive processes. It can be divided into knowledge of person, task, and strategy variables. Metacognitive regulation of cognition involves the use of cognitive strategies or cognitive regulation. In addition, there was empirical evidence that metacognition is trainable (Habibian, 2015; Lai, 2011; Nietfeld & Shraw, 2002; Tanner, 2012; Thiede, Anderson, & Therriault, 2003).

Motivation

Motivation is necessary for self-regulated learning. In basis, the term "motivation" refers to any kind of ordinary ambition for doing something (Baumeister & Vohs, 2007). Learners' motivation may come from their goal orientations, attributions, self-efficacy beliefs, expectations, social sources, helpfulness, moral principle, and interests (Zimmerman & Schunk, 2008). Motivation includes self-efficacy and epistemological beliefs that affect the use and development of cognitive and metacognitive skills. Each of these components is necessary but not sufficient for self-regulated learning. The role of motivation in self-regulated learning can be (apud. Zimmerman & Schunk, 2008):

a) a precursor to self-regulated learning, such as individual differences in interest regarding an academic task;
b) a mediator of self-regulated learning, such as whether a training-induced motive leads to improve effort for self-regulated learning;
c) a concomitant of self-regulated learning outcomes, such as whether a learning strategy produces changes in intrinsic interest in the task; and
d) a primary outcome of self-regulated learning, such as whether self-regulated learning leads to lower levels of defensiveness about taking courses in MWP solving.

2.3.2. Motivation driving self-regulation

Pintrich and De Groot (1990) offered the theoretical framework for conceptualizing learner motivation by comparing the studies of Eccles (1983) and Pintrich (1988 & 1989). The framework is an adaptation of a general expectancy-value model of motivation. In the model, there are three motivational components that link to the three different components of self-regulation: an expectancy component, a value component, and an affective component. The detail of each component is described below.

Expectancy component

An expectancy component includes learners' beliefs about their ability to perform a task. The expectancy component of learner motivation has been conceptualized in various methods in the motivational literature, such as self-efficacy, recognized proficiency, and control beliefs. However, its ground formation involves the self-beliefs of learners that they are possible to accomplish the task and that they are responsible for their own performance. In this regard, the expectancy component involves learners' answers to the question, "Can I do this task?" Different viewpoints of the expectancy component have been linked to learners' metacognition, i.e., their effort management and their use of cognitive strategies. Generally, it was suggested that learners who believed they are able to engage in more metacognition, use more cognitive strategies, and have a tendency to endure at a task than learners who do not believe they can accomplish the task (Fincham & Cain, 1986; Paris & Oka, 1986; Schunk, 1985).

Value component

A value component includes learners' goals of an assigned task and beliefs about the importance and interest of the task. Even though this component has been also conceptualized in various methods (such as intrinsic versus extrinsic orientation, learning versus potential goals, intrinsic interest and task worth), learners' motive for performing a task is highlighted in this motivational component or what do learners answer to the question "why do I have to do this task?" It was suggested that learners with a motivational orientation involving goals of mastery, learning, and challenge, together with beliefs that the task is interesting and important, likely engage more in metacognitive activity, cognitive strategy use, and effective effort management (Ames & Archer, 1988; Meece, Blumenfeld, & Hoyle, 1988; Nolen, 1988; Paris & Oka, 1986).

Affective component

The third motivational component concerns learners' affective or emotional reactions toward tasks. The question, "how do I feel about this task?" is an important issue in this component. Once more, there are various responses that might be significant, such as, pride, anger, or guilty, etc. However, in the formal educational context like schools, one of the most crucial elements is test anxiety (Wigfield & Eccles, 1989). Test anxiety had been shown to be correlated to awareness of performance (Nicholls, 1976), but it can be distinct in theoretical and empirical aspects. Research on test anxiety (e.g., Benjamin, McKeachie, Lin, & Holinger, 1981; Tobias, 1985) was reported to have a link to learners' metacognition, effort management, and use of cognitive strategies. Even if a value component and expectancy components show simple and linear relations in a positive direction with the self-regulated learning components, but it is not that straightforward for the results of test anxiety. For example, even though high-anxious learners appeared to be as effortful and persistent as low-anxious learners, they were revealed to be incompetent and ineffective learners who frequently used inappropriate cognitive strategies for pursuing fulfillment (Benjamin et al., 1981). On the other hand, the research from Hill and Wigfield (1984) suggested that high-anxious learners were not persistent or often keep away from hard tasks.

In summary, from these models, it can be considered that to perform metacognition, learners should be able to perform or have a clear understanding of their cognition in which they motivation play an important role in this self-regulation as a stimulus to stimulate their cognition and metacognition, as illustrated in Figure 2-3. Therefore, in this dissertation, required skills of self-regulated learners have been considered into three aspects: Stimulus, Self-understanding toward task, and self-understanding toward learning process. The detail explanation of each aspect is described in the following section.

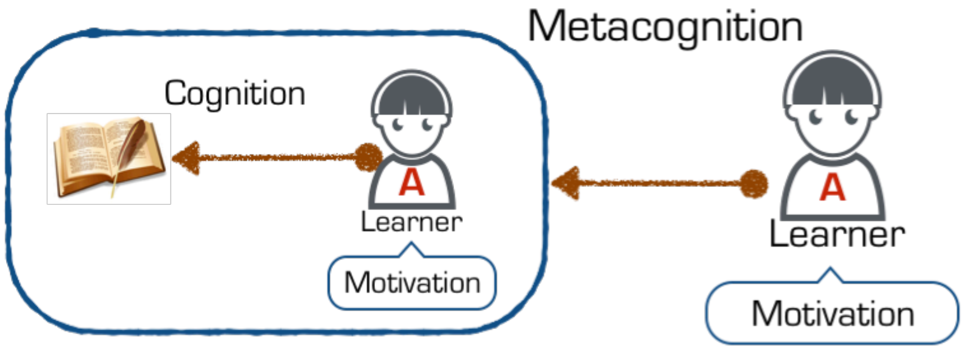


Figure 2-3 Relation of Cognition, Metacognition, and Motivation in Self-regulation.

2.4. Required Skills to Become Self-Regulated Learners

To promote metacognition, explicit or formal instruction of metacognitive strategies leads to improvement of learners' learning performance (OECD, 2010). This section, I review existing methodology to promote learners to gain required skills of self-regulated learners.

2.4.1. Promoting learning stimulus

2.4.1.1 Attitude

It is important that learners should realize on their own feeling and thought to make themselves feel easy in learning MWP. But, on the emotional level, learners might be struggling: they may think MWP is too difficult for them, they feel that they cannot do it. In order to be successful in any kinds of tasks, it is essential to develop the right attitude in learning. Research showed that attitude is one of the most crucial factors of the indicator to predict academic achievement. Positive attitude to learn is not inborn, it requires time and effort to be developed and encouraged (Credé, & Kuncel, 2008). If learners have confident attitudes and perceptions, they have a mental climate—a function of the attitudes and perceptions of learners—that is good for learning. If those attitudes and perceptions are not in place, learners have a mental climate not good for learning (Marzano, 1992). Marzano (1992) classified types of attitudes and perceptions affecting learners' mental climate into *a sense of acceptance* and *a sense of comfort and order*.

2.4.1.2 Goal setting

Learning goal is thought as the guidelines to regulate learners' learning behaviors (Schunk, 2001). For example, learners may have a simple goal to get a good grade or to just to pass the test. To reach long-term ambition, short-term achievable goals are helpful. For instance, if a learner set their long-term goal to get A in mathematics, they may set they achievable goals such as submitting all assignments and concentrating in all classes to make themselves understanding in all topics during the course to ensure that they can do the exam. Encouraging learners to set short-term goals can be an effective method to support learners to keep track of their learning progress (Zimmerman, 2004). It could be an effective support to encourage learners to be aware of the importance to realize of their own learner goals in MWP learning to be able to set their own short- and long- term goals.

2.4.1.3 Self-motivation

When learners autonomously apply strategies to keep tracking on achieving a learning goal, self-motivation occurs. Self-motivation is essential to self-regulated learning process by virtue of it requires learners to presume regulation over their cognition (Corno, 1993). According to (Zimmerman, 2004), self-motivation is found in the absence of external rewards or stimulus. As a consequence, it can be a crucial indicator that learners will become more independent. Learners have a tendency to endure throughout difficult tasks and frequently feel better and more pleasant with the learning process when they set their own learning goals and find motivation from within to make progress toward those goals (Wolters, 2003). Therefore, to encourage learners to find motivation in learning MWP would help them to improve their self-regulation.

2.4.2. Promoting self-understanding toward task

2.4.2.1 Background knowledge understanding

Supporting learners to observe their own background knowledge on the topic that they have to learn is to help them to gain more understanding on their own about what they know and they do not know toward the topic that would help them in planning. Planning, like goal setting, can assist learners to regulate their own learning before engaging in an assigned task. Schunk (2001) indicated that planning and goal setting are processes which work harmoniously. Since planning could assist learners to shape well thought-out goals and strategies to get achievement in a task. He expressed that planning involved in three stages of the learning process: setting a goal, forming learning strategies to accomplish the goal, and verifying the possibility to achieve the goal. There have been studies (e.g., Pressley, 1990; Scheid, 1993) showed the evidence that teaching learners to catch up learning tasks by performing planning is a practical way to promote self-regulation. Therefore, in order to help learners to establish or form well planning to ensure achievement toward a given task, encouraging or supporting them to realize and understand their background knowledge would be helpful.

2.4.2.2 Self-understanding of principle of topic

Encouraging learners to be curious about their own understanding of the principle of solving MWP is to support them to monitor their learning process. It is necessary that learners presume ownership for their learning and attainment results in order to develop themselves to be strategic learners (Kistner, Rakoczy, & Otto, 2010). In complementary, monitoring one's own learning process helps learners to become more understanding on their own understanding toward tasks. Learners must set learning goals, make a plan, motivate themselves to achieve the goals, keep their focus on the assigned task, and adjust their learning strategies to acquire comprehension of learning material, in order to monitor their own learning progress (Zimmerman, 2004).

2.4.2.3 Self-difficulty understanding

Winne (2009) revealed that learners likely become self-regulated learners when they have abilities to evaluate their own learning and be able to be independent of summative assessments in their learning class. Learners who can evaluate their learning can understand more about their own learning difficulties. This may facilitate them to make an adjustment for similar tasks in the next chance (Schraw & Moshman, 1995). Moreover, if learners precisely understand their learning difficulties, it enables them to find appropriate methods or to effectively seek proper help to accomplish the assigned tasks. There is some misunderstanding that self-regulated learners have to do all tasks or solve all problems on their own. Self-regulated learners are not necessary to complete all tasks on their own, on a contrary, they seek help from others when necessary (Butler, 1998). Ryan, Pintrich, and Midgley (2001) elaborated that the difference between self-regulated learners and their peers is that they do not only seek advice from others, but they do so with the goal of making themselves to be able to rely on their own.

2.4.3. Promoting self-understanding toward learning process

2.4.3.1 Learning strategy understanding

Encouraging learners to be curious about their own learning strategies would support them to keep track of pursuing to achieve their learning goal. The ability to implement multiple learning strategies across tasks and modify those strategies as required is essential for self-regulated learners to facilitate their progress towards their expected goals (Paris & Paris, 2001). However, for novices or inexperienced learners, this might be very difficult to think about various strategies as options. As revealed in (van de Broek, Lorch, Linderholm, & Gustafson, 2001), their finding showed that most primary grade students in their study did not have a large repertoire of learning strategies at their disposal. Therefore, an appropriate amount of examples and scaffolding would help learners to gain more experience and imitate more skills to become to be able to perform it by themselves.

2.4.3.2 Learning concentration understanding

In order to support learners to keep focusing on their learning process not to be distracted before achieving their goals, maintaining self-concentration in learning process is also important. Self-regulated learns must be able to control their attention (Winne, 2009). There is research showed that academic performance positively correlated with focused time spent on tasks (Kuhl, 1985). Frequently, attention control refers to clearing the mind to get rid of learning distraction, together with making or finding a surrounding environment to be conducive to learning (Winne, 2009). Therefore, it is crucial to encourage learners to be curious on their sources of learning distractions to be able to help them to consider about the way to resolve the distractions and build up their learning concentration to expand their attention spans.

2.5. MWP and Metacognition

2.5.1. Metacognition in MWP

Mathematical word problem (MWP) solving is a basic topic in many other higher-level educational fields. It is based on a textual description of a real word context, which requires students to apply their mathematical knowledge. However, according to reports from many standard tests (e.g. TIMSS, PISA, etc.), many students had difficulties in learning MWP solving. The main difficulty that students encounter in solving MWP is they cannot construct a problem model of a context by making inferences from the text (Fuchs et al., 2008). To do so, students need to perform a variety of activities to fully seize that problem (Jacobse & Harskamp, 2009). It was revealed by Schoenfeld (1992) that it is because they rarely spend the time to monitor and regulate the use of cognitive strategies, even if they understand the calculations embedded in that word problem. This causes them to skip or misinterpret information from the problem and choose inappropriate solutions. The skills to monitor and regulate the use of cognitive strategies are necessary to help students to structure their problem-solving process in MWP as well as in any other learning domain. These processes to regulate and monitor the use of problem-solving strategies are known as metacognition (Flavell, 1979). These are evidence to show that solving MWP requires metacognition, i.e., solving MWP having room to apply metacognitive skills. This is considered as an advantageous feature of MWP which could be employed as a medium to train meta-level thinking in this dissertation.

Corresponding to (Efklides, 2006; Nelson, 1996), they differentiated the two categories of applied metacognition: metacognitive monitoring and metacognitive regulation. Metacognitive monitoring was described as students' ongoing control over the learning process. And metacognitive regulation was described as regulating oneself to utilize appropriate cognitive strategies to resolve a task. Successful problem solvers apply a combination of the two categories of metacognition and cognitive strategies to structure their problem solving, for example, if a learner encountered with a sophisticated MWP, they may judge from their background or prior knowledge and experience that this MWP is too difficult for them. According to this observation, the learner might make a decision to carefully reread and analyze the problem and pick important information from the problem context. This process is metacognitive regulation while reading the problem context is the cognitive result of this situation. During processing a solution plan, the learner may recognize some mistake and then reconsider on their previous decision to update the selected information to modify their plan. The learner's recognition of a mistake is an example of metacognitive monitoring, which alternately affects the use of metacognitive regulation of cognitive strategies to solve the problem. As exemplified, a metacognitive process can be differentiated from cognitive processes, but they always work simultaneously. In solving MWP, if a learner cannot perform cognitive strategies involves MWP solving (e.g., skills to read a problem, do mathematical calculation, or understand a basic concept of mathematics), then metacognition will not be productive. On the other words, metacognition can only flourish on basis of cognitive strategies. In this case is MWP solving.

The interplay of cognition and metacognition is included in theories of self-regulated learning as well. Though theoretically related, self-regulated learning theories have a broader focus than of metacognition. Self-regulated learning includes not only metacognitive and cognitive activities in learning but also motivational regulation of, for instance, goal orientation, task value, and regulation of emotion (Boekaerts, 2011; Dinsmore, Alexander, & Loughlin, 2008). Depending on the focus of the dissertation on self-regulation, some findings were used to inform theory about metacognition and learning to achieve my goal to find an appropriate method to promote seed skill to become a self-regulated learner via MWP learning. However, the focal point in this dissertation is not initially specified for self-regulation in MWP learning on self-regulation in a broader sense.

Providing a room for learners to regulate or control their problem-solving behavior is a good method to enhance flexible metacognitive regulation (Jacobse & Harskamp, 2009). Schoenfeld (1992) performed the investigation to compare the behaviors of novice and expert problem solvers in solving MWP by distinguishing between five 'episodes' in the process of solving MWP. The five episodes on the basis of Schoenfeld's study are:

i. survey the problem (read, analyze);
ii. activate prior knowledge (explore);
iii. make a plan (plan);
iv. carry out the plan (implement);
v. check the answer (verify).

His finding showed the significant differences between the process of experts and novices. Experts spent much time in analyzing the process and followed the episodes more systematically. While experts spent time on analyzing problems and gathering information before making a plan, novices almost started to solve problems straight away in a poorly defined or without planning. Moreover, experts always checked their plan by tracking back between the episodes if the current plan is still on the track of the problem situation. Then, he proposed to teach learners the use of the episodes through metacognitive questions and hints related to the episodes. According to the finding of Schoenfeld, novice learners need to learn how to work through problem-solving process more effectively to build up their metacognition.

2.5.2. Key Features of MWP for Promoting Metacognition

As previously mentioned, MWP solving is the topic that many students have difficulties in. However, due to its nature and structure, it is found that there are beneficial features of MWP solving to support metacognitive training. In this dissertation, the proposed key features of MWP solving to support metacognitive training are:

1. *Complexity of the solution process*: the reasonably complex solution process provides a way to reflectively analyze the thinking process.
2. *Explicit form of solution process*: this feature is beneficial for designing *observable representation* of the thinking processes to support the monitoring and representation framework to externalize/reflect/regulate problem-solving process.
3. *Many explicit operators at each step*: this feature promotes regulation of criteria to select one operator from operators.

2.6. Computer Programs with Metacognitive Support

Due to the advancement of computer and technology, computer environments have been widely developed in various methods (e.g., using virtual agents, intelligent tutoring systems, educational hypermedia systems, metacognitive guiding cards, metacognitive hints, and so on) to support learning and teaching. Nevertheless, in the difficult and complex domain as mathematics, some learners might encounter some difficulties to utilize metacognitive skills to regulate their cognition in such environments (Azevedo, 2005). Thus, assessing and investigating of computer environments combining metacognitive support become a trend of a new topic in this area.

There have been studies about the effectiveness of a computer environment using student controlled metacognitive questions and hints (e.g., Mathan & Koedinger, 2005; Harskamp & Suhre, 2007). In the study of Mathan and Koedinger, they developed a model of the intelligent novel. In their model, students first assigned to work out spreadsheet problems without any supports, if the students would like to move over a problem before solving it correctly, they had to accept help or support to complete the problem. From the finding of Mathan and Koedinger, it was shown that students who used this model learnt faster and performed better on a conceptual understanding test and on transfer test than students who did use the model.

In the study of Harskamp and Suhre, they assessed the effectiveness of a training program based on the five problem-solving episodes from Schoenfeld (mentioned in the section 2.4.1) with hints to help secondary school students solve MWP. In their proposed environment, students had a freedom to choose the hints on their own. Their finding found that the students in the experimental group who used the program with hints outperformed students who used the program without hints.

Extension research was performed by Pol, Harskamp, Suhre, and Goedhart (2008), they provided hints over the episodes analyze, explore, plan, implement, and verify in a web-based computer program, but in the different subject domain, physics. Their study showed that students in the group that received problem-solving hints increased their systematic use of the hints. Moreover, the systematic hint use correlated to enhancing problem-solving performance.

Another study of Azevedo, Greene and Moos (2007) was performed in a hypermedia environment. They made use of a human tutor giving external adaptive self-regulative support in the domain of science. The study showed that students, who assisted by external metacognitive hints by a human tutor, gained more declarative knowledge and reach a higher mental model during the posttest.

The investigation of an intelligent tutoring system is found in the study of Aleven, McLaren, Roll, and Koedinger (2006). They proposed the intelligent tutoring system to guide students' metacognitive help-seeking in parallel with cognitive hints.

Their investigation of this system showed much promise in understanding how to enhance student help-seeking skills.

Furthermore, there have been other studied, e.g., Bannert (2006), Bannert, Hildebrand, & Mengelkamp (2009), Clark & Mayer (2008), Teong (2003), Wood & Wood (1999) that their findings coincide with the assumption found in the former studies that metacognitive support in computer environments could positively affect on learning performance of students in several ranges of ages.

However, Graesser and colleagues (2007) showed the argument that not all metacognitive tools enhance learning outcomes. To avoid cognitive load, Roll and colleagues (2007) and Schraw (2007) suggested that metacognitive tools should not be too complicated. And, it is better to make clear for learners about the benefits of metacognition to encourage and motivate the learners to alter their learning styles.

Azevedo (2005) summarized the characteristic requirements of effective metacognitive computer support tools. He suggested that an effective metacognitive computer support tool should have the following additional characteristics ():

1. It requires learners to make instructional decisions regarding instructional goals. For example, setting learning goals, sequencing instruction; looking for, assembling, managing, and coordinating instructional resources; making decision on which embedded and contextual tools to use and when to use them to support their learning goals; making decision on which representation of information to use, attend to, and perhaps modify to meet goals. (e.g., Harskamp & Suhre, 2007; Pol et al., 2008; Wood & Wood, 1999)
2. It is embedded in a specific learning circumstance that might need learners to make a decision regarding the circumstance in ways that support successful learning. For example, how much support is needed from contextual resources, what type of contextual resources may facilitate learning, locating contextual resources, when to seek contextual

resources, determining the utility and value of contextual resources. (e.g., Clark & Mayer, 2008)

3. It is a computer-based environment that models, prompt, and supports learners' self-regulatory processes, which may include cognitive (e.g., learning strategies, activating prior knowledge, solving problem), metacognitive (e.g., feeling of knowledge, judgment of learning, evaluate self-understanding), motivational (e.g., self-efficacy, task value, interest, effort), or behavioral (e.g., engaging in help-seeking behavior, modifying learning conditions; handling task difficulties and demands) processes. (e.g., Teong, 2003)
4. It is an environment that models, prompts, and supports learners to engage or participate in using task-, domain-, or activity-specific learning skills (e.g., skills necessary to engage in online and collaborative inquiry), which also are necessary for successful learning. (e.g., Veenman et al., 2006; Roll et al., 2007)
5. It is an environment that belongs to a specific learning context in which peers, tutors, or artificial agents play some role in supporting learner's learning by serving as external regulating agents. (e.g., Aleven et al., 2006; Azevedo et al., 2007)
6. It is an environment in which learner use and employment of key metacognitive and self-regulatory process prior to, during, and following learning are critical for successful learning. (e.g., Roll et al., 2007)

CHAPTER 3

Seed Skills to Become a Self-Regulated Learner

This chapter explains how the target skills used thought this research was defined. It starts by explaining why it is important to define precise terminologies for a particular study in the educational field. Next, literature related to metacognition, self-regulation, and factors of self-regulated learners are reviewed. Then, the tentative required skills of self-regulated learners in learning MWP are suggested. To confirm the proposed target skills, I performed the investigation by conducting both quantitative and qualitative analysis using the survey and interview, respectively. At the end of the chapter, it concludes the definition of the basic skills to be able to develop into the proposed factors, namely Seed skill to become self-regulated learners in MWP learning.

3.1. Introduction

Conducting research in some particular field has a tendency to use technical terms without defining them. The researchers assume that their readers know the definitions. However, this is not common in the education field. There is no rule of common definitions in this field. It is not a good idea to presume that readers will have a common understanding with the researchers on the meanings and borderlines of terms especially in an area where definitions can easily make confusion. Providing clear definitions of metacognition, and self-regulation is a major issue in this research field that researchers encounter with (Dinsmore, Alexander, & Loughlin, 2008). This situation is a kind of problematic. How to define processes that are consistent with the measuring method used to assess them and how to interpret and analyze the research results. This might become a trouble and can create inconsistency when researchers conducted their research under muddled definitions or when using different definitions and measuring tools.

Another issue is that research related to metacognition and self-regulation must be tightly linked with theory. An ambiguous guiding conceptual framework leads researchers to interchangeably use terms and creates confusion in their research. (Winters, Greene, & Costich, 2008). Consequently, instead of raising a question 'how metacognition is involved during self-regulation?', it then ends up with 'is metacognition is the same as self-regulation?' Such definitional quandaries frustrate research progress. Even though the frameworks of Bandura, Flavell, and Zimmerman are often referred to in research on metacognition and self-regulation, they are not the only relevant ones (Schunk, 2008). Dinsmore and colleagues (2008) and Fox & Riconscente (2008) revealed that other perspectives also have influenced these fields. Researchers are able to decide on their theoretical frameworks, and it is essential to do so. Research which is not well connected with theory has a tendency to be unconnected to other research and will have a trouble in implications for educational policy and practice.

In summary, to enable the effective strategy for managing a fuzzy knowledge, precise definition of terms and factors related in our research should be clarified. Therefore, in this study, the first prior issue to accomplish is to precisely define the common factors of self-regulated learners in learning MWP.

3.2. Literature review towards self-regulated learners

In this section literatures related to metacognition, self-regulation, and self-regulated learners are reviewed to be able to discuss and make a decision on definitions of terms used in this research and to decide the scopes of those terminologies.

3.2.1. Metacognition and self-regulation

There are always overlaps between definitions used for metacognition and other self-regulation. For example, in (National Research Council, 2000), self-regulation is included in metacognition. It defined metacognition as the ability to orchestrate one's learning: to plan, monitor success, and correct errors when appropriate and the ability to reflect on one's own performance.

One of the popular definitions of metacognition used in this field is from (Flavell, 1976). He defined metacognition as one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, *I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact*. Perkins and Salomon (1989) defined metacognition as the ability that students learn to monitor and direct their own progress, asking questions such as "*What am I doing now?*", "*Is it getting me anywhere?*", or "*What else could I be doing instead?*" These all share some common explanation of self-regulation. For example from Cook and Cook (2014), they defined self-regulation as the ability to monitor and control our own behavior, emotions, or thoughts, altering them in accordance with the demands of the situation. It includes the abilities to inhibit first responses, to resist interference from irrelevant stimulation, and to persist on relevant tasks even when we don't enjoy them.

In this dissertation, self-regulation is considered into two types: self-regulation in own learning and self-regulation in an assigned task. What is focused in this dissertation is a self-regulation in an assigned task, i.e., if learners were assigned some task, how can we encourage them to become curious about their learning performance on a given task? Do it possible to make them become curious about self-improvement on an assigned task?

3.2.2. Required skills of Self-regulated learners

Zimmerman (2002) revealed that what defines a learner as "self-regulated" is not their confidence in social independence of learning, but rather their personal initiative, perseverance, and adaptive skill. He explained that self-regulated learners focus on how they activate, alter, and sustain specific learning practices in social as well as solitary contexts. There are studies showed that self-regulated learners are more engaged in their learning. For examples, they regularly sit in the front row of a classroom (Labuhn, Zimmerman, & Hasselhorn, 2010), they enthusiastically volunteer to answer questions (Elstad & Turmo, 2010), they always search for additional knowledge to master themselves (Clarebout, Horz, & Schnotz, 2010; de Bruin, Thiede, & Camp, 2001), and they are able to manipulate their learning environments to enhance their learning performance and to avoid their learning distraction (Kolovelonis, Goudas, & Dermitzaki, 2011; Labuhn et al., 2010). Therefore, the criteria to distinguish self-regulated learners from their peers are their proactive qualities and self-motivating abilities.

In summary, in this dissertation, I proposed three aspects for considering the required skills of self-regulated learners in learning MWP: learning stimuli, self-understanding toward task, and self-understanding toward learning process. Their explanations are provided in the flowing list.

1. *Learning stimuli*: are things to stimulate and drive their learning desire which involves attitude, goal, and motivation.
2. *Self-understanding toward task*: to become a self-regulated learner in MWP, it is important that a learner should: (i) understand on their MWP background knowledge, (ii) understanding of self-understanding of MWP principle, and (iii) understanding of self-difficulties in MWP learning to be able to improve their MWP learning performance and become master in this task.
3. *Self-understanding toward learning process*: is composed of (i) understanding of their MWP learning strategy—they need to monitor, regulate and alter their learning strategy—and (ii) understanding of their learning concentration of the topic to be able to achieve their learning goal.

3.3. Investigating required skills of self-regulated learners in MWP learning for this research

The tentative required skills of self-regulated learners are suggested. To confirm the proposed skills, I conducted some interview and used what I got from the interview to design the questionnaire to distribute the questionnaire to students around Thailand to be able to make a conclusion on the required skills of self-regulated learners applied along this research.

3.3.1. Interviews with self-regulated learners

To confirm such issues, ten students who were self-regulated learners in mathematics class were interviewed. They were from three different schools (from north, northeast, central) in Thailand. Most of them were reported from their mathematics teachers that they were very outstanding in class not only their mathematics score but also their behavior in the class that they regularly submitted assignments in time and did it themselves and they were very active students in the classes of those teachers. The purpose of the interviews was to confirm and to investigate the required skills that self-regulated learners in MWP learning should have. Following are the summary from the interviews.

- Most interviewees expressed that they like mathematics. The few students said mathematics is difficult, however, they thought in the topic that they have to learn it is a basic mathematics which is necessary for they future and it is not that harder than their effort to be able to understand if other students can do it why they cannot. Thus, most of the students think that mathematics is important, it is a basic in several fields and it is necessary for their future education, although they can ignore it that time, they still have to face it in the future, this is worse to take effort from now.
- For the students who like mathematics solving MWP is like playing a game they would like to accomplish more advanced problems. They said they were very happy when they could solve difficult problems that other students could not solve. For the students who do not like mathematics, they would like to maintain their grade at a good level for their future and also make their parents become happy. They all need to be able to pass the national test to use it for their further education.

- It is quite obvious that the students who like mathematics have intrinsic motivation to accomplish this task. Moreover, some students stated that they really like their mathematics teacher who taught MWP they wanted their teacher to be proud of them. They would like to keep doing well in their teachers' class. For students who do not like mathematics, they keep thinking about their family and their future when they feel they did not want to do it. Their teacher was one of their willpower to make them keep trying and did not give up.
- Most students gave consistent statements and showed the evidence that they were curious about that they knew or did not know for the class. They explored the textbook read over all what did they need to accomplishing it. For the students who like to solve MWP, they always search for the challenging problem and figure out how it can be difficult and find the way to solve it. They thought it is very important for them to fulfill their weak points and improve themselves in effective ways.
- Most students always reflect on that "did they really understand the principle of MWP?" They expressed that learnt MWP by trying to understand the principle of MWP not just only remember the types of problems and imitate it. They all agreed that make clear understanding on problem structure and its principle could help them better solve unseen problems.
- Understanding of their own difficulties is one important thing that most students mentioned. The students stated that when they could not solve some problems they became curious about why they could not solve it. They asked friends who could solve or asked the teacher to clear their state of having difficulties. And to make sure that they would not encounter with the same problem, it is important to clarify what was that difficulties then they tried with same kinds of problems to make sure that they were really improved.
- Most students always reflect themselves could they did it well in learning MWP, whether they still on the way that they could achieve good score in

this class and whether what they did during the classes really help them to keep their good progress, anything they have to change or improve to make it better.

- For some students who like mathematics, they rarely had distraction during their classes. They happily learnt and practiced MWP. The more difficult problems, the more challenge for them. They took this class as the first priority. Some students expressed their hard feeling to keep concentrate and became getting bored. Some said it was from themselves that feel disappointed on that even they tried harder than some peers the result still not better than that peers, however, after they expressed this feeling to their parents/teacher, the parents/teacher gave them some suggestions. They realized that their results were not bad and they should better concentrate on their performance and better think about it whether they did it their best and what else they could improve. The students who did not like mathematics expressed the interesting issue that because they know that they did not really feel happy to learn this topic then they tried not to be in the state that they have a confusion in any topic to avoid getting stuck and become getting bored and getting a failure in their goal.

3.3.2. Survey of required skills of self-regulated learners

3.3.2.1. Participants

The purpose of the survey was to confirm the proposed skills of self-regulated learners in learning MWP and to investigate the difference between normal learners and self-regulated learners to be able to precisely define the target skills for applying as a framework in this research. The participants were students during grade8-12 who have already learnt MWP both in public and private schools in Thailand. In total, there were 699 students from about 31 schools responded to the survey.

3.3.2.2 Material

In order to collect quantitative data from the participants, the questionnaire in the table 3-2 was used. In the instruction of the questionnaire, there is an explanation about the intention of the questionnaire and asking the participants for their consents to using their information in the research.

The first part of the questionnaire asked the participants to give their general demographic information including gender, age, class level, and schools' name.

There was only one question in the second part of the questionnaire to ask participants to rate themselves on how they are confident as self-regulated learners in their past MWP class by providing explanation to them that if they thought they did their best and took their efforts as possible as they can without anyone asking them to do it on the class, they could put their confidence as 10 (the confidence level was rated from 0 (not confident at all) -10 (very confident)).

In the last part, there were 8 items of questions which were composed in 7 points Likert-type scale which allows the students to express how much they agree or disagree with a particular statement as listed below. (1—Very untrue of me, 2—Untrue of me. 3—Somewhat untrue of me, 4—Neutral, 5—Somewhat true of me, 6—True of me, and 7—Very true of me).

The eight items of the questions in this part were separated into 3 aspects: Stimulus, Self-understanding toward task, and Self-understanding towards learning process. There were 3 question items in Stimulus aspect, 3 question items in Self-understanding toward task aspect, and 2 question items in Self-understanding toward learning process aspect. The translations of all the 8 items are shown in table 3-2.

3.3.2.3. Procedure

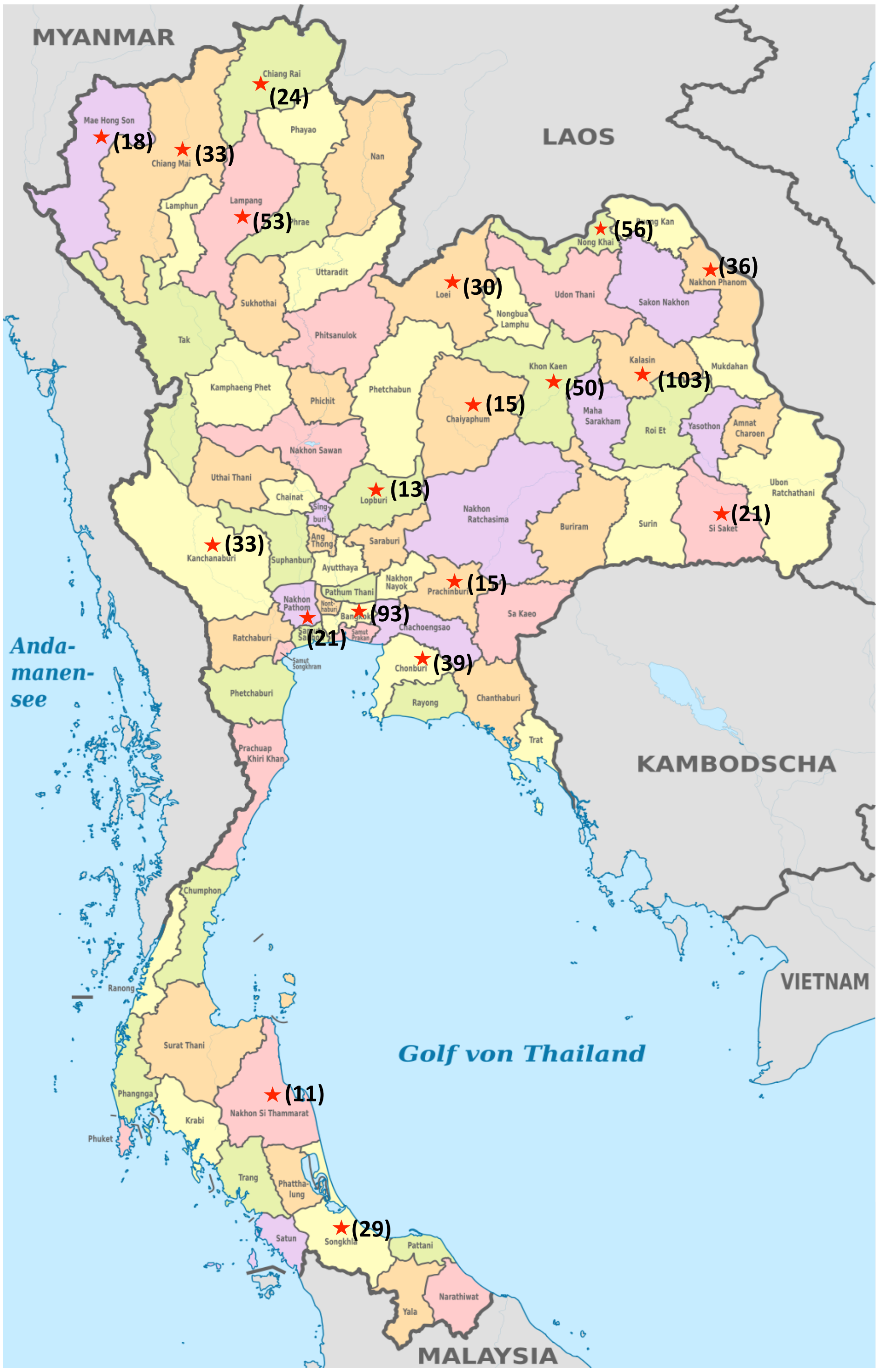
The survey was obtained online via a Google spreadsheet. The survey was distributed in various sizes of schools and in several regions of Thailand in both private and public schools.

3.3.2.4. Result

In total, there were 699 students from about 31 schools responded to the survey.

Table 3-1 shows the number of schools and responses divided by provinces.

Province	**Number of schools**	**Number of responses**
Bangkok	4	93
Chaiyaphum	1	15
Chiang Mai	2	33
Chiang Rai	1	24
Chonburi	2	39
Kalasin	3	102
Kanchanaburi	1	33
Khonkaen	2	50
Lampang	2	53
Loei	2	30
Lopburi	1	13
Mae Hong Son	1	18
Nakhon Pathom	1	21
Nakhon Phanom	1	36
Nong Khai	2	56
Prachinburi	1	15
Sisaket	2	21
Songkla	1	29
Nakhonsrithammarat	1	11
Unidentified		7
Total		**699**



Resource of the picture:
https://commons.wikimedia.org/wiki/File:Thailand,_administrative_divisions_-_de_-_colored.svg#file

Figure 3-1 shows the geographical distribution of the survey.

Response to the first part of the Questionnaire

The data from the first part of the questionnaires showed that gender statistics of the participants were 25% males (n=177) and 75% females (n=522). The range of participants' age was between 12–18 years old (mean=15.6, SD=1.9). The percentage of participants who were in junior high school and high school are 45% and 55%, respectively.

Table 3-2 shows the translations of the questionnaire for confirming the required skills of self-regulated learners in MWP learning.

Aspects	Categories	Question items
Stimulus (STM)	Attitude (STM-A)	1. I like to learn MWP or I think MWP is the important to learn.
	Goal (STM-G)	2. I set up my goal for MWP class.
	Motivation (STM-M)	3. I had a good motivation in learning MWP, e.g. because I like to solve MWP, so I am really happy to learn MWP, I want to be an engineer and MWP is important topic for master my math proficiency, etc.
Self-understanding toward task (SUT)	Background knowledge (SUT-K)	4. I do always reflect myself on what I know and don't know in learning MWP.
	Self-understanding of principle of topic (SUT-P)	5. I do always reflect myself on whether I really understand the principle of MWP or not.
	Self-difficulty (SUT-D)	6. I do always reflect myself on what difficulties I have when I stuck in some parts or some problem when learning MWP.
Self-understanding toward learning process (SUP)	Strategy (SUP-S)	7. I do always reflect myself on my own learning strategy to make sure that I am able to achieve my goal for learning MWP.
	Concentration (SUP-C)	8. I do always reflect on myself to figure out distraction when learning MWP to dissolve it.

Response to the second part of the Questionnaire

In this part, the participants were classified into three groups from their rating of confidence as self-regulated learners in learning MWP.

1. *SR*: A group of students who were confident that they are self-regulated learners, the participants who rated themselves into 7 – 10 level of confidence. There were 247 participants in this group.
2. *notSR*: A group of students who were confident that they are NOT self-regulated learners, the participants who rated themselves into 0 – 3 level of confidence. There were 125 participants in this group.
3. *unCertain*: A group of students who were NOT confident that they are self-regulated learners, the participants who rated themselves into 4 – 6 level of confidence. There were 327 participants in this group.

Response to the third part of the Questionnaire

A Pearson correlation coefficient was computed to assess the relationship between confidences as self-regulated learners and each proposed required skills. There were a positive correlation between the two variables, $r > 0.6$, $n = 699$, $p < 0.01$. A scatterplot summarizes the results (Figure 3-2 – 4). Overall, there was a strong, positive correlation between confidences as self-regulated learners in learning MWP and each particular proposed skills.

An independent-samples t-test was conducted to compare two groups of participants who were confident as self-regulated learners in learning MWP (SR) and who were confident as not self-regulated learners in learning MWP (notSR) for individual items in the third part of the questionnaire. From table 3-3, the analysis of the result shows that, for all question items, there were significant differences in the scores of SR and notSR; $t(370) > 16$, $p < 0.01$. Moreover, in table 3-4 compares the results in percentage of participants who thought they had the proposed skills between SR and notSR. The results can imply that self-regulated learners in learning MWP have a strong tendency to have the proposed skills.

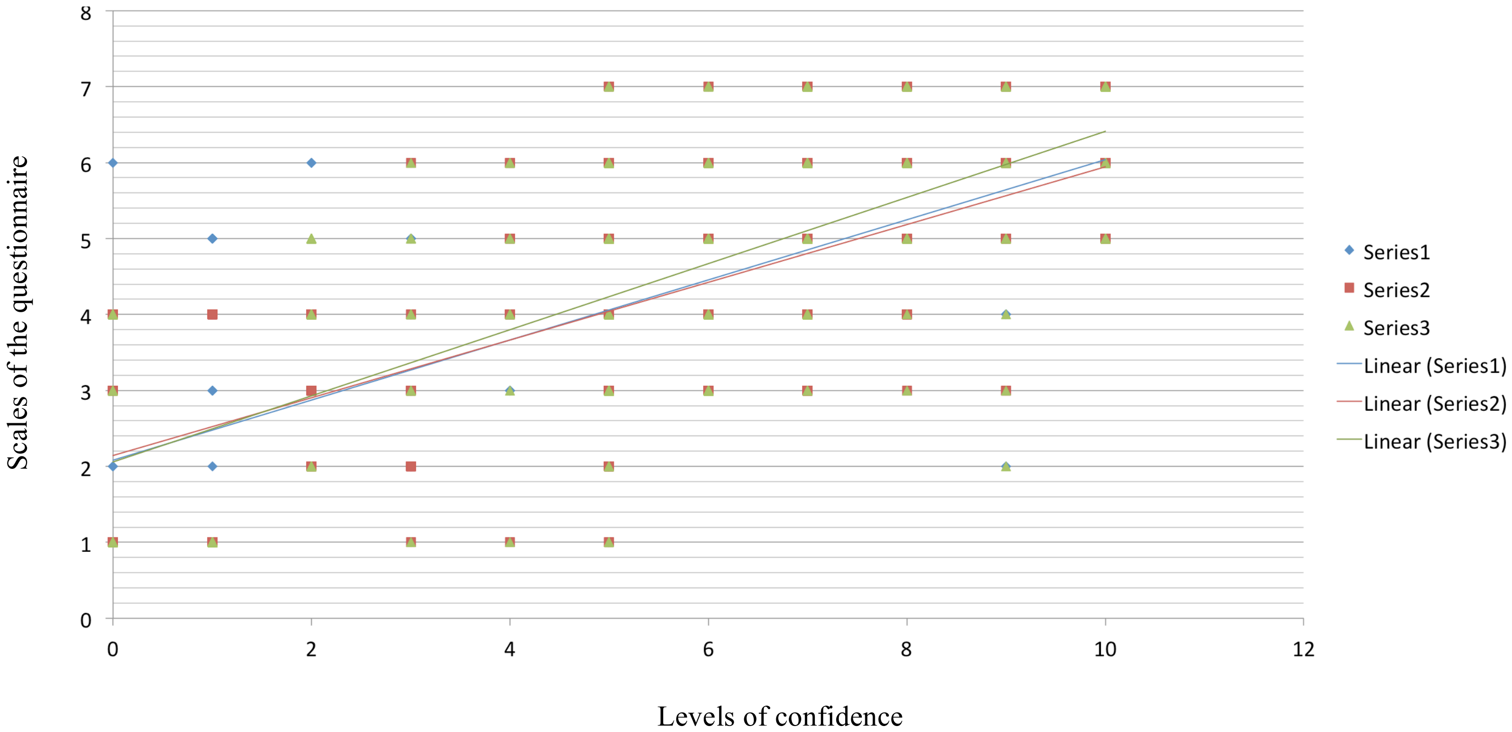


Figure 3-2 A scatterplot summarizes the results of items in STM.

Note*: Series 1, 2, and 3 refer to item-1, 2, and 3 in the questionnaire, respectively.*

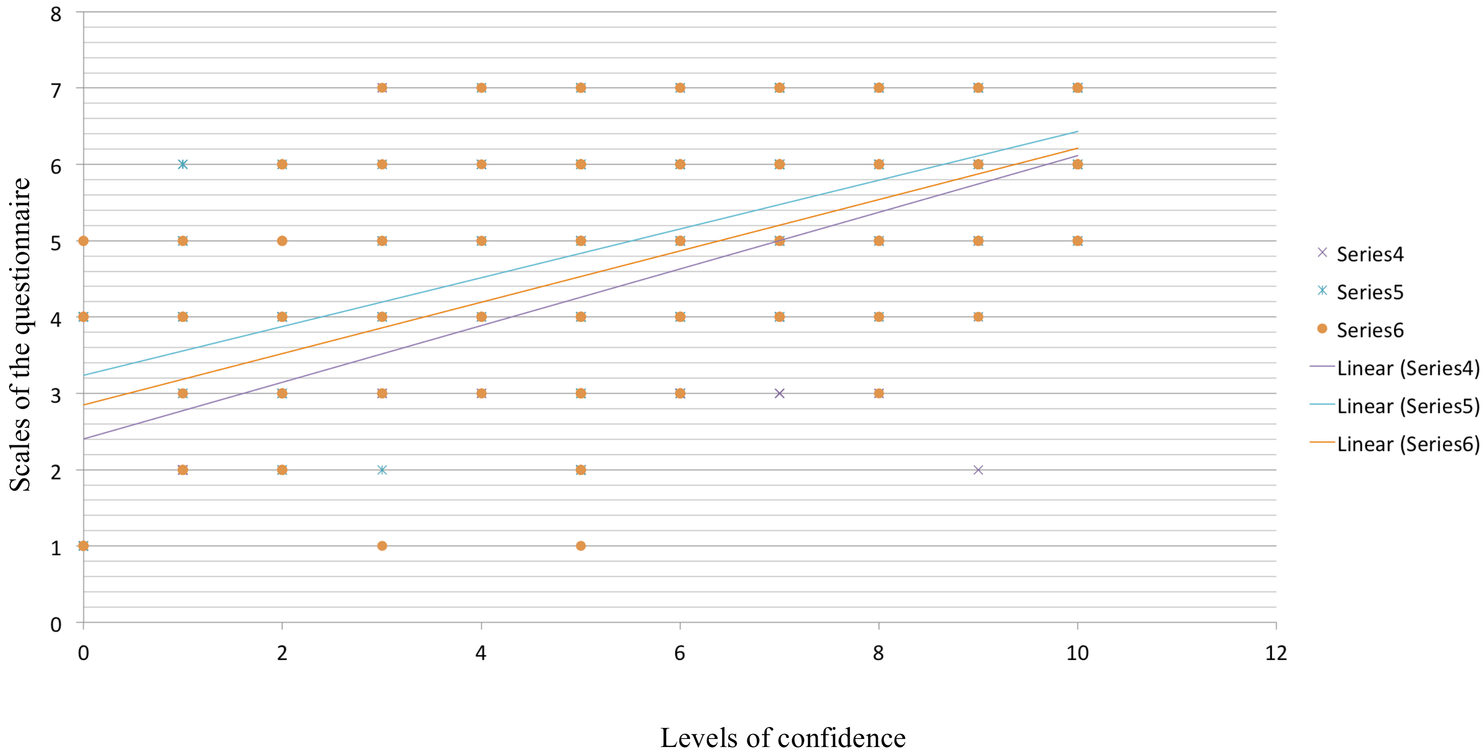


Figure 3-3 A scatterplot summarizes the results of items in SUT.

Note*: Series 4, 5, and 6 refer to item-4, 5, and 6 in the questionnaire, respectively.*

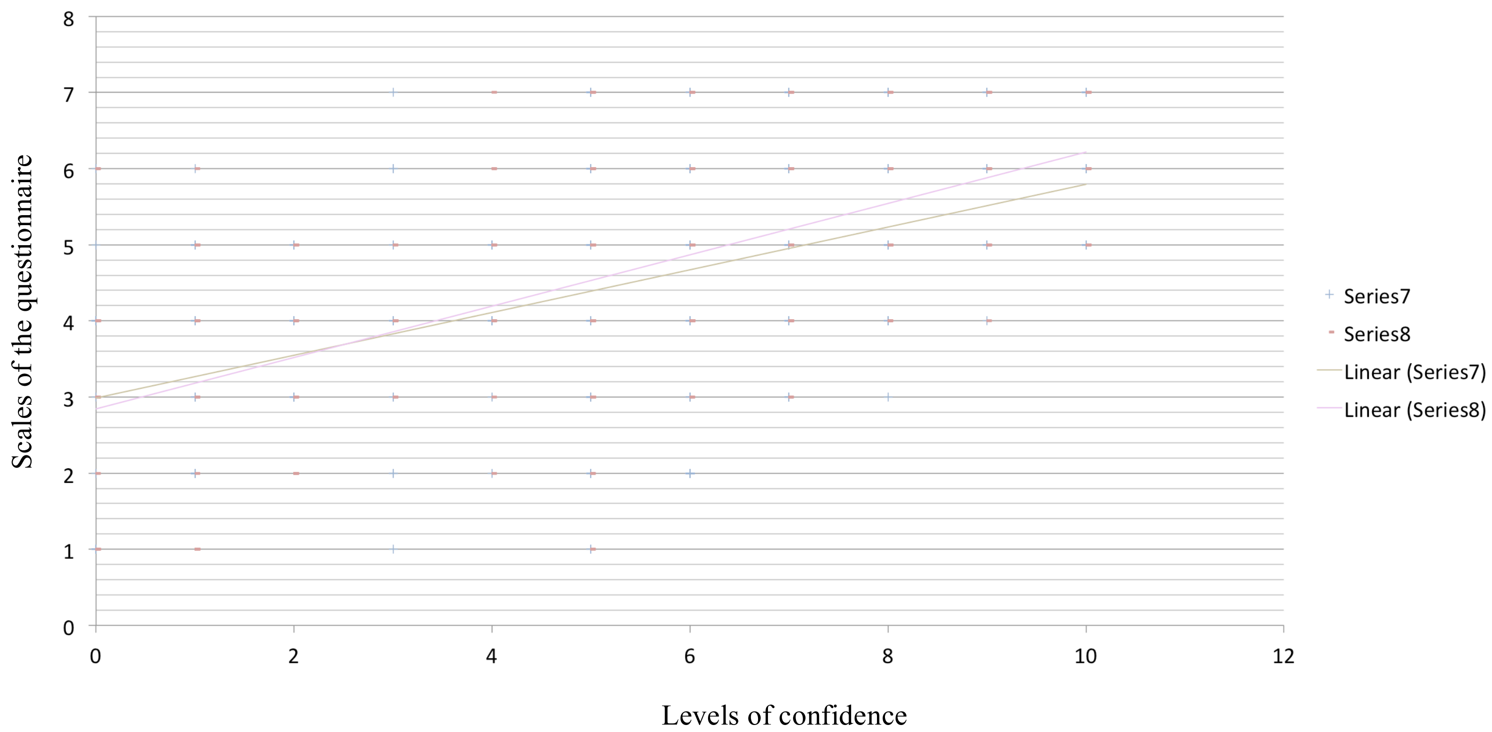


Figure 3-4 A scatterplot summarizes the results of items in SUP.

***Note**: Series 7 and 8 refer to item-7 and 8 in the questionnaire, respectively.*

Table 3-3 compares two groups of participants who were confident as self-regulated learners (SR) and who were confident as not self-regulated learners (notSR) for individual items in the third part of the questionnaire.

Items	Participant Groups	**N**	**Mean**	**Std. deviation**	**Std. error mean**
STM-A	SR	247	5.46	0.99	0.98
	notSR	125	2.76	1.46	2.12
STM-G	SR	247	5.34	1.14	1.31
	notSR	125	2.66	1.34	1.79
STM-M	SR	247	5.67	1.07	1.24
	notSR	125	2.69	1.62	2.62
SUT-K	SR	247	5.76	1.11	1.23
	notSR	125	3.25	1.34	1.8
SUT-P	SR	247	6.14	0.91	0.82
	notSR	125	3.95	1.31	1.71
SUT-D	SR	247	5.85	0.88	0.78
	notSR	125	3.57	1.50	2.26
SUP-S	SR	247	5.57	0.96	0.93
	notSR	125	3.66	1.23	1.52
SUP-C	SR	247	5.72	1.03	1.06
	SR	125	3.44	1.42	2.01

Note: $t_{STM-A} = 21.05391$, (t_{STM-A} refers to t-value for STM-A),
$t_{STM-G} = 20.11888$, $t_{STM-M} = 21.25528$, $t_{SUT-K} = 19.19453$, $t_{SUT-P} = 19.19453$,
$t_{SUT-D} = 18.4523$, $t_{SUP-S} = 18.4523$, $t_{SUP-C} = 17.7273$, for all $p < 0.01$.

Table 3-4 compares the results in percentage of participants who thought they had the proposed skills between SR and notSR.

Items	SR (n=247)	notSR (n=125)
STM-A	84%	10%
STM-G	79%	1%
STM-M	89%	16%
SUT-K	88%	12%
SUT-P	95%	27%
SUT-D	95%	25%
SUP-S	87%	21%
SUP-C	88%	24%

3.3.3. Summary

The survey and interview were conducted as qualitative and quantitative confirm for the tentative required skills of self-regulated learners in learning MWP from the reviews of related literature. The quantitative statistical analysis from the survey implies that self-regulated learners in learning MWP have a strong tendency to have the proposed skills. By the qualitative analysis from the interview, it could explain the phenomenon that for some students who really like mathematics they might not have any distraction during their learning and they learnt it with passion and it was their first priority, however, for students who might not like mathematics but they were self-regulated learners this factor was quite prominent. Therefore, the required skills of self-regulated learners in MWP learning would be used along this research are listed in table 3-5.

Table 3-5 shows the required skills of self-regulated learners in MWP learning for this dissertation.

Aspects	Categories	Explanation
Stimulus (STM)	Attitude (STM-A)	I am curious about the source of my feeling and think about how to find the benefit/application of learning MWP to make it easy for me to learn MWP.
	Goal (STM-G)	I am curious about my goal of MWP learning and think about how to encourage myself to achieve the goal I set for learning MWP.
	Motivation (STM-M)	I am curious about my reason why I should have to learn MWP to motivate myself in accomplishing my goal.
Self-understanding toward task (SUT)	Background knowledge (SUT-K)	I am curious about what I know in learning MWP and also curious to find a way to update my background knowledge to meet the knowledge required for learning MWP.
	Self-understanding of principle of topic (SUT-P)	I am curious about my understanding of MWP principle and also curious to find a method to improve my understanding of MWP principle.
	Self-difficulty (SUT-D)	I am curious about my difficulty with MWP learning and always think about the way to resolve it to be able to improve my performance.
Self-understanding toward learning process (SUP)	Strategy (SUP-S)	I am curious about the appropriate strategy to achieve my goal in MWP learning and always think about finding my own effective way to achieve my goal in MWP learning.
	Concentration (SUP-C)	I am curious about the source of my distraction in learning MWP and want to find a way to resolve it so that I can concentrate on my learning.

3.4. Defining Seed Skills to Become a Self-Regulated Learner in MWP learning

As mentioned in the first chapter, Seed skill TO become Self-Regulated Learners (S2SRL) refers to a very basic skill to be able to develop into metacognitive skills. It is defined in this study as a skill in which learners are curious on their own understanding and awareness of self-improvement in their learning before learners can perform metacognitive questions by themselves to reflect their own cognition for planning, monitoring, and doing self-evaluation. From the required skills of self-regulated learners in MWP learning, the expected behavior of a self-regulated learner in MWP learning is depicted as in Figure 3-5. A self-regulated learner in learning MWP is able to perform metacognitive questioning skill to acquire "*understanding of MWP learning (UL)*" and "*awareness of self-improvement in MWP learning (ASL)*" which would activate them to drive their metacognitive skills: planning, monitoring, and self-evaluation, when they learn or solve MWP.

In this dissertation, S2SRL in MWP learning is defined as a basic skill that learners can further develop to be the required skills of self-regulated learners in MWP learning. That is, learners are curious on their own "*understanding of MWP learning*" and "*awareness of self-improvement in MWP learning*" before learners can perform metacognitive questions by themselves to reflect their own cognition for planning, monitoring, and doing self-evaluation. "*Understanding of MWP learning*" and "*awareness of self-improvement in MWP learning*", here, are considered in 3 aspects (Stimulus, Self-understanding toward task, Self-understanding toward learning process) of the required skills of self-regulated learners in MWP learning as shown in Table 3-6.

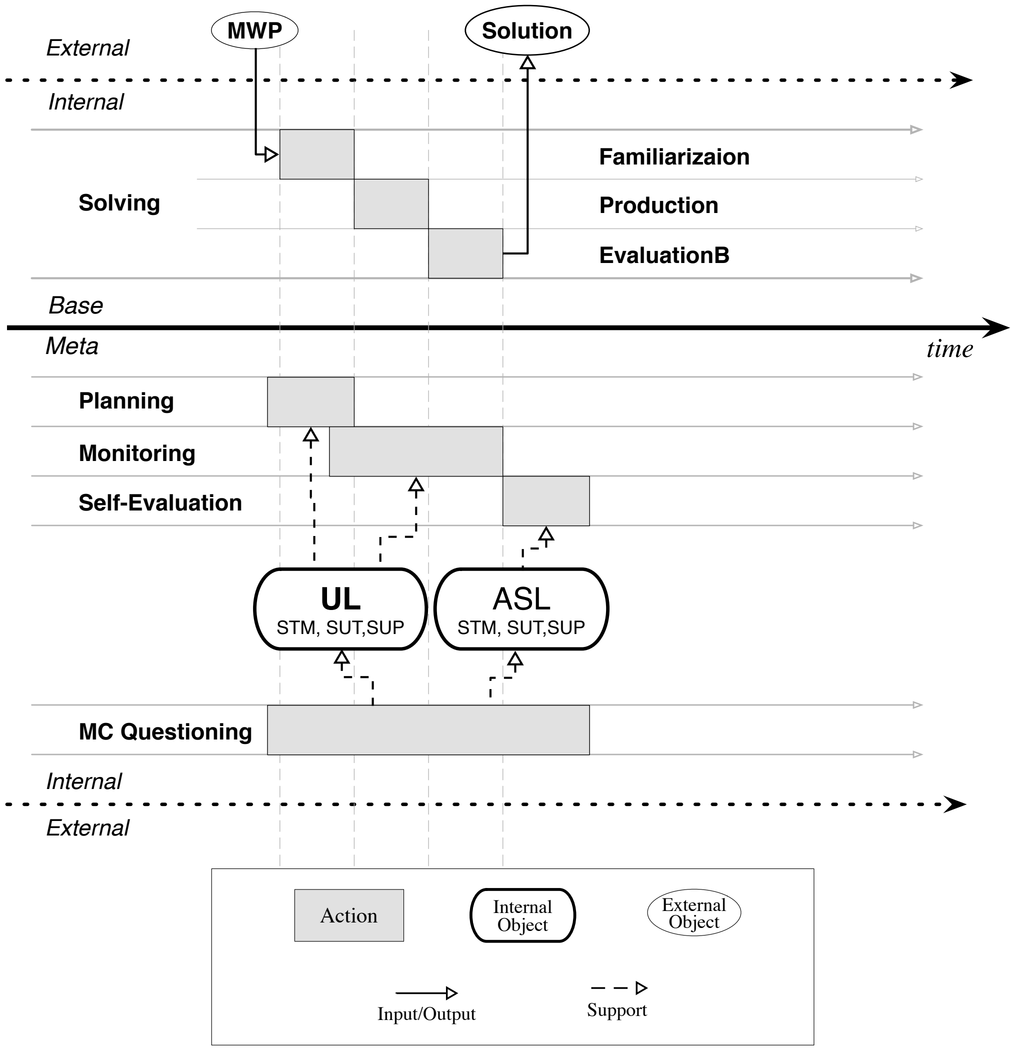


Figure 3-5 shows Learning Process Diagram of the expected behavior of a self-regulated learner in MWP learning.

Remark of Figure3-5*: the thickness of the arrows in Learning Process Diagram represents a timeline and divides the space into Meta-level space (Meta) and Base-level space (Base) to display meta-level things and base-level things, respectively. In a similar way, the Arrow doted lines divide Meta/Base -level spaces into External and Internal spaces to display external and internal things, respectively. For example, solving MWP is a base-level action and metacognitive questioning is a meta-level action, both of which are driven internally.*

Table 3-6 shows the categories in each aspect of UL and ASL

Aspects	Categories	Understanding of MWP learning (UL)	Awareness of self-improvement in MWP learning (ASL)
Stimulus (STM)	Attitude (STM-A)	Understanding of their attitude on MWP learning	Awareness of self-improvement in their attitude on MWP learning
	Goal (STM-G)	Understanding of their goal of MWP learning	Awareness of self-improvement in their goal of MWP learning
	Motivation (STM-M)	Understanding of their motivation on MWP learning	Awareness of self-improvement in their motivation on MWP learning
Self-understanding toward task (SUT)	Background knowledge (SUT-K)	Understanding of their MWP background knowledge	Awareness of self-improvement in their MWP background knowledge
	Self-understanding of principle of topic (SUT-P)	Understanding of self-understanding of MWP principle	Awareness of self-improvement in self-understanding of MWP principle
	Self-difficulty (SUT-D)	Understanding of self-difficulty in MWP learning	Awareness of self-improvement in self-difficulty in MWP learning
Self-understanding toward learning process (SUP)	Strategy (SUP-S)	Understanding of their strategy of MWP learning	Awareness of self-improvement in their strategy of MWP learning
	Concentration (SUP-C)	Understanding of their concentration of MWP learning	Awareness of self-improvement in their concentration of MWP learning

CHAPTER 4

Computer-Supported Meta-Reflective Learning Model via MWP (CREMA)

In this chapter, I demonstrate the construction of the proposed learning model, CREMA. CREMA's learning architecture and theoretical framework are illustrated and revealed. The chapter starts with the intention behind the creation of CREMA. Then the overall perspective of CREMA is depicted before its theoretical viewpoint is explained.

4.1. Introduction

According to the previous chapter, S2SRL in MWP learning is defined as skills in which learners are curious on their own "*understanding of MWP learning*" and "*awareness of self-improvement in MWP learning*" before learners can perform metacognitive questions by themselves to reflect their own cognition for planning, monitoring, and doing self-evaluation. "*Understanding of MWP learning*" and "*Awareness of self-improvement in MWP learning*" are considered in 3 aspects: Stimulus, Self-understanding toward task, Self-understanding toward learning process (recall Table 3-6 in section 3.4 of Chapter 3). To achieve my desire to design an environment for encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning, instead of just proposing a specific environment, there is more impact to create a framework for designing a required environment. Therefore, I have developed **C**omputer-Supported Meta-**Re**flective Learning Model via **Ma**thematical word problem learning (CREMA) to be a framework for designing an environment to encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning.

4.2. Overall perspective of CREMA

As mentioned previously, CREMA is proposed to encourage learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning. The concept of the proposed model, CREMA, is to support/facilitate learners learn how to learn MWP and get used to performing self-reflection while learning MWP by using computer technology to enhance their learning sense and to empower methodology to facilitate learning objects.

Firstly, two stands of the target skills and the supports for those skills were considered. The target skills here are Understanding of MWP learning (UL) and Awareness of self-improvement in MWP learning (ASL) for all three aspects, in which, metacognitive questions and motivational statements (MetaQ's) are integrated with appropriated supports for particular target skills by support of computer technology, for example, to deliver adaptive metacognitive questions or to facilitate thinking representation. The initial concept is depicted as shown in Figure 4-1.

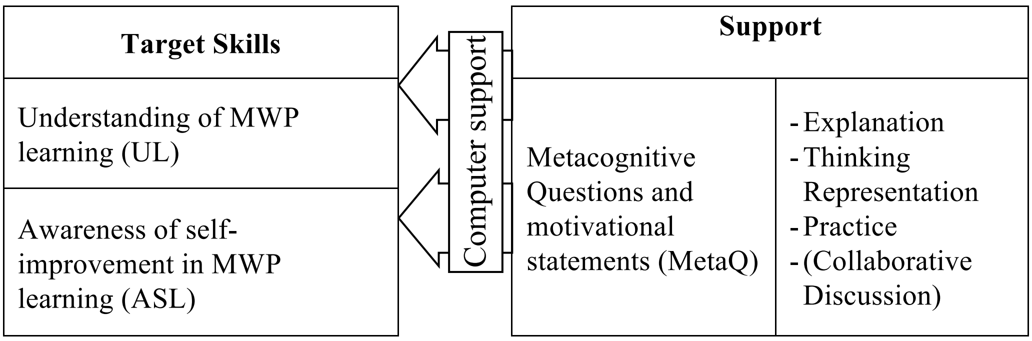


Figure 4-1 shows the structure of the initial concept of CREMA

Then, CREMA has been developed into a holistic approach of learning and its support to illustrate the clearer process and to manifest the intention for applying supports in particular target skills. Figure 4-2 illustrates the structure of CREMA. CREMA can be represented in the learning cycle of three learning phases: Preparation phase, Observation phase, and Experiencing phase. Each phase in the diagram shows the target skills and the learning supports involved.

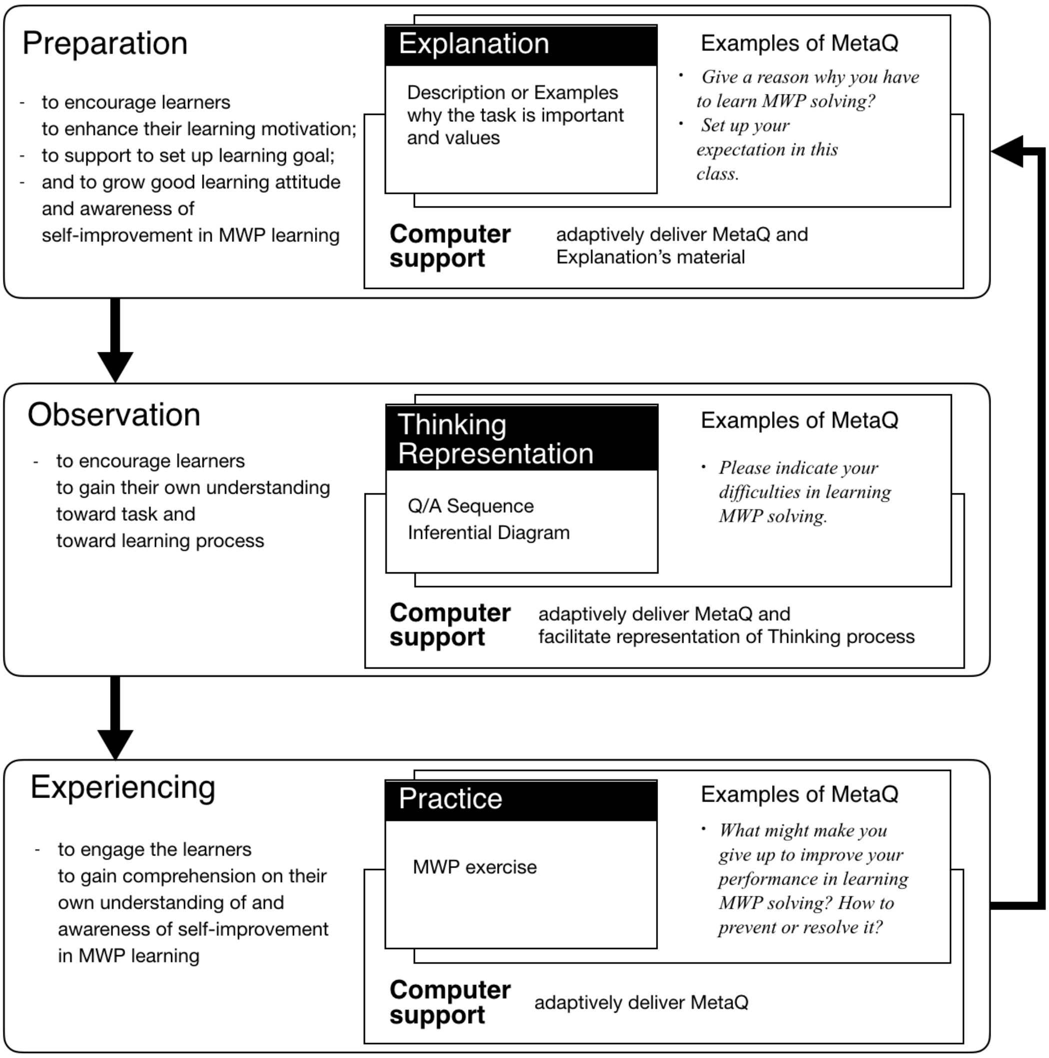


Figure 4-2 shows the diagram of the learning cycle of CREMA.

In the starting phase, Preparation phase, MetaQ is applied with Explanation—description or examples why the task is important and values—to encourage learners to enhance their motivation; to support their learning goal creation and to grow their good learning attitude and their awareness of self-improvement in MWP learning. In the second phase, Observation phase, MetaQ is applied with Thinking representation—examples or demos of thinking process in the assigned task, i.e., MWP solving—to encourage learners to gain their own understanding toward task and learning process. In the last phase, Experiencing phase, MetaQ is integrated with

Practice—a practical task in which the learners will encounter—to engage the learners to gain comprehension on their own understanding of and awareness of self-improvement in MWP learning by experience/internalize what they learnt from the previous phases.

MetaQ, such as, "*what is your goal to learn MWP?"* and "*how can you determine whether your answer makes sense*?", is an effective method to engage learners to reflect on their thinking processes. There have been studies showed that learners who were trained to use metacognitive questions and answers which focused on the formation of relationships between prior and new knowledge were better able to understand the contents than students who were trained to ask different kinds of questions, who in turn outperformed the students who were in the control group that not were involved in any training (King, 1994; Mevarech & Kramarski, 2003; Schoenfeld, 1985). In our proposed model, CREMA, MetaQ is considered to be the main support combining with particular supports in each phase. The particular supports (Explanation, thinking representation, and practice) in each phase are applied together with MetaQ to enhance its function.

The detail explanation of each phase and its support theories are described in the following subsections.

4.3. Preparation phase

Self-regulated learning is generally recognized to cover learners being motivated to learn, learners set appropriate learning goals to direct the learning process using appropriate knowledge and skills to handle learning and learners consciously select learning strategies appropriate to their task. There is research (*e.g.*, Boekaerts, 1999) that established the importance of a combination of those attributes in a particular learning circumstance (OECD, 2004). It is necessary that learners can draw on a range of resources concurrently. Since, some resources are cognitive resources, which are concerned with knowledge toward processing information, and some resources are metacognitive resources, which are concerned with awareness of the learning process. It is possible that, although learners are aware of appropriate learning strategies, they still make a wrong choice (Flavell and Wellman, 1977). For that reason, motivational resources are also necessary to learners for contributing to their readiness; to foster them to set up their own goals; to interpret their success and failure appropriately; and to translate their desires into aims and plans (Weinert, 1994). Learners who were motivated to learn (not only for receiving high score) and believed that their assigned task was important and interesting, they were further cognitively got involved in spending their effort to learn and understand the task (Pintrich, & De Groot, 1990). In addition, in self-motivation through goals aspirations, it is in part on the basis of efficacy beliefs that learners decide which is the interesting challenge, how long to continue confronting with difficulties and how much effort to invest. Challenging goals increases motivation and performance achievement (Bundura, 1991; Latham & Locke, 1991; Locke & Latham, 1990).

In general, self-regulation and motivation work simultaneously to describe learner learning and achievement. When learners are motivated to learn, they are more likely to spend time and effort on the learning task and apply self-regulated learning skills, as well as when they can successfully utilize self-regulation strategies, they are more motivated to accomplish learning tasks (Zimmerman, 2000). They involve their interests and values in making a decision when they contemplate why they should complete the task and how hard it is. If they do not think a learning task is important enough, they are less likely to spend time in setting goals and planning to accomplish the task (Simons, Dewitte, & Lens, 2004; Wang & Holcombe, 2010; Wolters, 2003).

As shown in Figure 4-2, in this phase, MetaQ is integrated with Explanation. Explanation here refers to description or examples of why the task is important and values. It is important that learners should have a positive attitude and motivation on their tasks. Then in this phase, MetaQ and Explanation are applied in order to prepare learners' mental to be ready for the learning process. Certain examples of applications of MWP related to their daily life or future are demonstrated. Following by encouraging them to set up their own learning goals and their proposal to achieving the goals. These are aimed to drive their motivation along the learning process and to stimulate them to become aware of improving themselves for their learning achievement.

4.4. Observation phase

Self-efficacy belief—confidence in own ability to achieve tasks—are positively related to learner cognitive engagement and competency tasks. If learners believed that they are competent, they become more likely to report the use of cognitive strategies, to be more self-regulated with regard to reporting more use of metacognitive strategies, and to continue more frequently at troublesome or boring. These relations do not depend on and associate with test anxiety and levels or intrinsic value of previous success. Moreover, self-efficacy also plays a role as facilitator in connection with cognitive engagement (Schunk, 1985), but cognitive engagement is more directly linked to learners' actual performance (Pintrich, & De Groot, 1990). There is research suggested that teaching learners about different cognitive and self-regulatory strategies may be more important for improving actual performance on classroom academic tasks, but improving their self-efficacy beliefs may lead to more use of these cognitive strategies (Borkowski, Weyhing, & Carr, 1988; Garner & Alexander, 1989; Schunk, 1985)

In this phase, I aim to encourage learners to gain Self-understanding toward task and learning process in MWP learning which supports them to increase self-efficacy belief. Zimmerman (2000) revealed that self-efficacy belief plays an important role in self-regulation. Increasing self-efficacy beliefs has a positive impact to improve the use of self-regulation strategies (Bouffard-Bouchard, Parent, & Larivee, 1991; Pajares, 2008; Schunk, 1984; Zimmerman & Martinez-Pons, 1990). When encountered with obstacles, disappointment, and defeat, those who mistrust their competencies loosen their attempt to stop trying for ordinary solutions. On the other hand, those who have strong belief in their competencies make more attempts and try to find the better strategy to master the challenges (Bundura, 1999).

Externalizing thinking process into an observable format helps learners to reduce their cognitive load and enables them to observe and reflect on their thinking process more easily (Kayashima et al., 2005). This corresponds to the study of Rau and colleagues (2012, 2015) which showed that multiple external representations could significantly enhance learners' learning. To achieve the aim of this phase, thinking process of MWP solving is simulated as Q/A Sequence (QAS, see Fig 4-3) and Inferential Diagram (InDi, see Fig 4-4) to facilitate learners to observe thinking process of MWP solving to enhance and clarify their understanding of MWP solving process (Duangnamol, Supnithi, Suntisrivaraporn, & Ikeda, 2015). Consequently, MetaQ is applied to enable them to engage in reflecting on their own understanding of task and learning strategies of MWP learning by the support of QAS and InDi.

Figure 4-3 and 4-4 show an example of QAS and InDi, respectively. QAS is a sequence of questions and answers to acquire information on how to accomplish a solution of a given MWP. To compose a good QAS, there are criteria for creating good QAS. The criteria are shown as follows.

Criteria for Good QAS

---

1. *The sequence leads to a problem solution.*
2. *Qs and As in the sequence have to be consistent and well-ordered.*
    2.1 Each question has to contain a correct answer.
    2.2 No question early in the sequence requires information from a question later in the sequence to answer.
3. *The sequence contains necessary questions.*

Use algebra to solve a given MWP.
A measure of a vertex angle of an isosceles triangle is 87 degree.
What are the measures of the rest angles of this triangle?

Q1: What does the problem ask for?
A1: the measures of the rest angles of the given triangle.
Q2: What information is given from the problem?
A2: the triangle is isosceles. its vertex angle has measure 87 degree.
Q3: How to solve the problem?
A3: By algebraic approach. We need
Q4: What is the variable?
A4: x = the measure of each of the rest angles.
Q5: What is the information that can use to form an equation?
A5: The total sum of all interior angles of any triangle is equal to 180 degree.
Q6: What is an equation for this problem?
A6: $x + x + 87 = 180$
Q7: What is the value of x?
A7: $x = 46.5$ then the answer is 46.5 degree.

Figure 4-3 An example of Q/A sequence.

An example of InDi is shown in Figure 4-4. InDi is a diagram for showing a flow of information and its source/reason for accomplishing a solution of a given MWP. InDi is composed of,

1. Information Tag (in the top of each Information node)—to indicate the source of the information (there are six tag options: Goal, Sub-Goal, Given Information, Hidden Information, Result, and Others),
2. Order Link (solid arrow)—to show the consecutive order in which the information used,

3. Reason (in a rounded-corner rectangle over certain Information nodes)—to indicate why information applied, and
4. Sequential Link (dashed arrow)—to illustrate the result which needs information that is not consecutively linked.

Use algebra to solve a given MWP.

A measure of a vertex angle of an isosceles triangle is 87 degree.

What are the measures of the rest angles of this triangle?

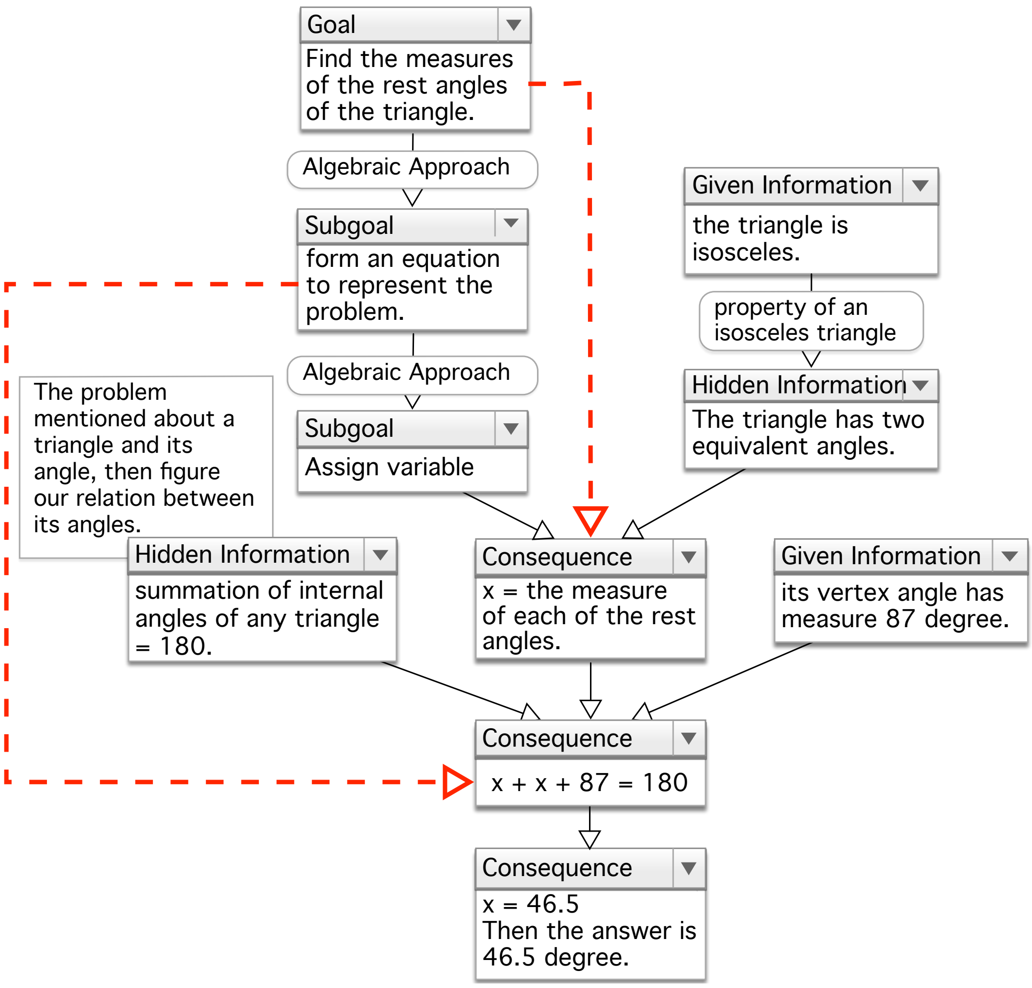


Figure 4-4 An example of Inferential Diagram.

4.5. Experiencing phase

Tsai and Lee (2006) showed the results from their study that an “incomplete learning cycle” is one of the reasons why explicit knowledge could not be successfully converted into tacit knowledge. In consequence, when a more complete learning cycle is followed, explicit knowledge is more easily converted into tacit knowledge.

In this phase, its design intention is for learners to experience/internalize what they learnt from the previous phases. MetaQ is applied while learners are practicing solving MWP. To say that, a MWP solving task is assigned to learners concurrently with asking them to predict and evaluate their performance before and after their exercise. The learners have the situation to evaluate their performance on the learning task with respect to the effectiveness of the strategies that they chose. During this stage, the learners either have a chance to manage their emotions about the outcomes of their learning experience. These self-reflections then influence their future planning and goals. This may initiate the cycle to begin again. Moreover, they can reflect on their learning performance in this phase and monitor their own difficulties in learning MWP to engage them to reflect on what and how they can improve themselves to be able to become master in the assigned topic.

To investigate the effects and conditions of CREMA more deeply in practical to promote S2SRL in MWP learning, I performed the experiment as described in the next section.

CHAPTER 5
A Learning Environment to Encourage Learners to Use Intrinsic Comprehension of Metacognitive Questioning to acquire S2SRL in MWP learning

5.1. Introduction

In order to assess and investigate the effectiveness of CREMA, in this chapter, I illustrate and exemplify how to provide a learning environment to encourage learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning by applying CREMA as a framework. Then, this learning environment will be assessed its effectiveness and investigated to see how it works in the next chapter.

5.2. Ideal of the System Architecture

As described in the previous chapter, CREMA has been developed into a holistic approach of learning and its support to illustrate the clearer process and to manifest the intention for applying supports in particular target skills. CREMA is represented in the learning cycle of three learning phases: Preparation phase, Observation phase, and Experiencing phase, as shown in Figure 4-2.

Figure 5-1 shows the ideal of the system architecture of CREMA implementation. The ideal system is composed of a database and four components:

Explanation component, Thinking representation component, Practice component, and Interactive Metacognitive Q/A module (ImQA module).

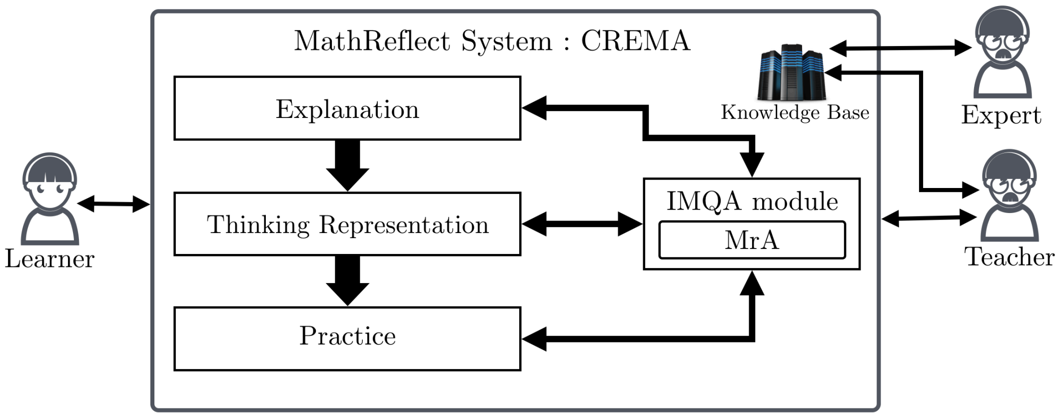


Figure 5-1 shows the IDEAL of the system architecture of MathReflect.

Corresponding to CREMA, Explanation component, Thinking representation component, and Practice component are compared to the three supports in the three learning phases of CREMA in which Explanation component provide learning description and examples of MWP application related to learners' interest, Thinking representation component is composed of two parts: QAS constructing toolkit and InDi composing toolkit, and the last component provide MWP practice. While ImQA module is compared to MetaQ in which it works in relation with the other components. In ImQA, it has Metacognitive-Responding Agent (MrA) to automatically deliver MetaQ and to receive responses from a learner and keep it in the database.

Due to the limitation of time and resources, I performed the investigation using partial components of the ideal system integrated with manual arrangement and Google classroom.

5.3. Technical Information of the tools used in the investigation

MathReflect

I have developed a web application system, called MathReflect, as a part of an environment for CREMA. The system has been implemented by Yii2 framework using PHP (version 5.6.2) and JavaScript (JQuery version 3.2.0) combining with MySQL (version 5.5.38).

Google Classroom

Google Classroom is a free web service developed by Google for schools that aims to simplify creating, distributing and grading assignments in a paperless way. Google Classroom combines Google Drive for assignment creation and distribution, Google Docs, Sheets and Slides for writing, Gmail for communication, and Google Calendar for scheduling. Students can be invited to join a class through a private code, or be automatically imported from a school domain. Each class creates a separate folder in the respective user's Drive, where the student can submit work to be a graded by a teacher. Mobile apps, available for iOS and Android devices, let users take photos and attach to assignments, share files from other apps, and access information offline. Teachers can monitor the progress for each student, and after being graded, teachers can return work, with comments ("Google Classroom," 2018, para. 1-2).

I then explain each phase of the learning environment implemented by applying CREMA as a framework.

5.4. Learning Environment of Preparation Phase

When learners are motivated to learn, they are more likely to spend time and effort on the learning task and apply self-regulated learning skills (Zimmerman, 2000). If they do think a learning task is important enough, they are likely to take time in setting goals and planning to accomplish the task (Simons, Dewitte, & Lens, 2004; Wang & Holcombe, 2010; Wolters, 2003). Therefore, in this phase, MetaQ was integrated with Explanation. Explanation here refers to description or examples why a given task is important and values in order to motivate learners to accomplish the task. In addition, it is important to engage and encourage learners to have positive attitude and motivation on their tasks in the starting phase to prepare learners' mental to be ready for the learning process.

In Preparation phase, MetaQ and Explanation were applied via manual arrangement integrating with MathReflect. First, it started with the manual arrangement. A teacher explained and described learning objective and indicated why it is worth to learn MWP by giving some examples of applications of MWP in daily life and examples that related and necessary to their life. The teacher asked the students about their dream job and their parents' occupations, then gave certain MWP application examples, e.g., applications of mathematics for farmers which related to majority of students and very close to their life, they can use mathematics to calculate farming cost to make a plan in farming process to optimize the farming process and to reduce the risk in the process. Then, the teacher told the students to write down their goals for learning MWP by giving them some examples (*e.g., to understand clearly about how to model a problem using algebra, to have clearer understanding on how to apply MWP in real life situation*) and asked them to think about their motivation that would drive them to achieve their goals.

Secondly, MathReflect was applied. Students used MathReflect to learn the learning objectives of the training and of MWP solving by themselves. After students logged-in into the system, they could access the introduction page that contains the learning objectives of the training and the topic from the dashboard in this page, see Figure 5-3. In the introduction page, there was a direction for informing the students to read and make understanding on the provided information, see Figure 5-4. The students could move over this page or this phase only after they responded to MetaQ from the system in the dialog box of MrA in the bottom left of the page, see Figure 5-5.

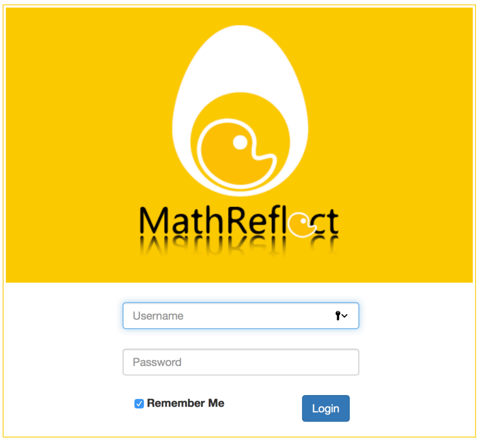


Figure 5-2 Log-in page of MathReflect.

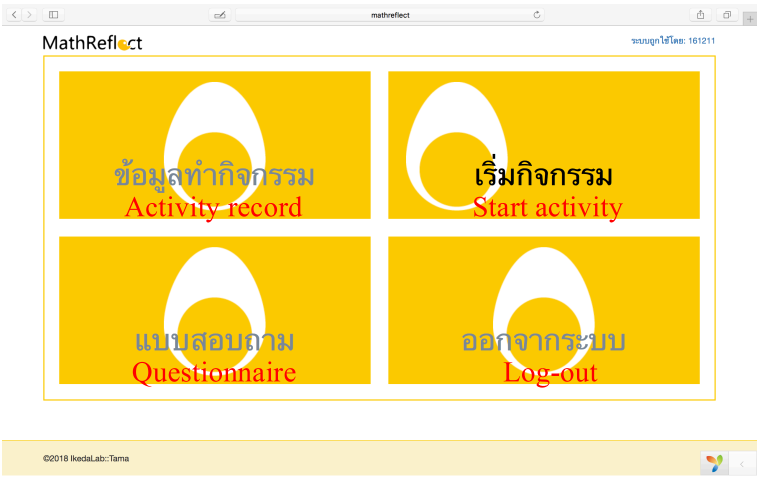


Figure 5-3 Dashboard panel of MathReflect.

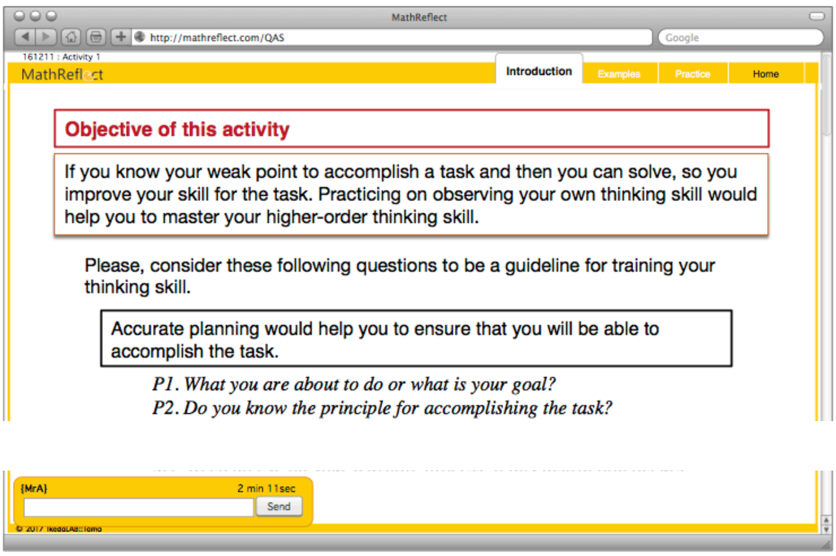


Figure 5-4 Introduction page of MathReflect.

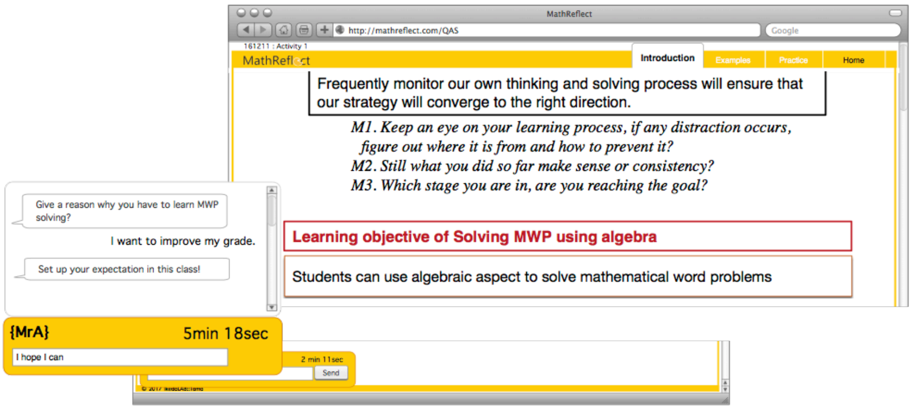


Figure 5-5 Students could see MetaQ and answer to MetaQ via the dialog box of MrA in the bottom left of the introduction page.

MetaQ raised in this page:

1. *Give a reason why you have to learn MWP solving?*
   Example answers: I want to expert in MWP solving, To use it in my carrier, I want to be engineer, I want to improve my grade, I want to graduate with good grade, I want to make my parents proud of me, I want to be able to enter to a good faculty, etc.

2. *Set up your expectation in this class.*
   Example answers: can understand more about MWP, can interpret a context problem into a mathematical notation, can apply MWP in daily life problem, etc.

5.5. Learning Environment of Observation Phase

In this phase, MetaQ was integrated with Thinking representation. Thinking representation here was referred to the representation of thinking process of MWP solving. Here, it was represented as Q/A sequence (QAS, see Fig 4-3 in Chapter 4) and Inferential diagram (InDi, see Fig 4-4 in Chapter 4). QAS and InDi were proposed to facilitate learners to observe thinking process of MWP solving to enhance and clarify students' understanding of MWP solving process to encourage learners to gain Self-understanding toward task and learning process in MWP learning which support them to increase self-efficacy belief, which influences students' improvement in the use of self-regulation strategies (Bouffard-Bouchard, Parent, & Larivee, 1991; Pajares, 2008; Schunk, 1984; Zimmerman & Martinez-Pons, 1990).

In Observation phase, MetaQ and Thinking representation were provided in MathReflect. First, the system showed the example of QAS and InDi to clarify the tasks in this phase, as shown in Figure 5-6. Then the system raised MetaQ, via MrA, to ask students to initially evaluate themselves on their confidences in MWP solving performance from observing an example of QAS and InDi. After responding to MrA, the students could access the composing QAS page and the completing InDi page, respectively. The activity sequence was described as follows:

1. MWP was shown with the direction with an instruction to inform students to read the problem carefully.
   A question from MrA for this activity is
   "Do you completely understand the problem?"
   If students answered
   YES >> QAS constructing page appears.
   NO >> possible difficulties were suggested as examples (e.g. *don't know the meanings of some words in the problem, cannot imagine about the situation, don't understand the situation in the problem*) together with the direction for telling students to answer MetaQ.
   MetaQ raised here was "*What do you think it is the reason that you cannot understand the problem clearly? (Choose from the list or state your own opinion)*"

2. In the Constructing QAS page, see Figure 5-8 and 9, the students had a task to construct QAS by matching questions and answers then put them in an appropriate order by following the criteria in section 4.4. Students had to match questions and answers then put them in an appropriate order (incorrect QAS had no permission to access the next page). The system could suggest that their ongoing QAS had the wrong pair of Q/A or unreasonable sequence when they submitted incorrect QAS. If students

think they cannot do it, they can click for a hint to see a solution and follow it, however, this action would be recorded and made them could not move over this task. If the class period was over before they finish the task, they needed to start to compose that QAS from the beginning next time they logged-in into the system.

Meta Q for this activity,

"What is your problem to compose QAS?" Or

"Which question is might be difficult for you?"

3. Next is the activity to complete InDi, In the Completing InDi page, see Figure 5-10, the students had a task to complete InDi by selecting appropriate Information Tags and Reasons from the provided lists for existing information and respond to MetaQ. The same as in the QAS constructing page, the students could move over this page for the next step only if they completed InDi correctly and answered MetaQ.

   MetaQ for this activity,

   "Which #box of information that is difficult to remind?"

MetaQ for this phase:

- *Please indicate your difficulties in learning MWP solving (Choose from above list or state your own opinion)*
- *What might make you give up to improve your performance in learning MWP solving? How to prevent or resolve it?*

Observation phase was finished if students could compose QAS and completed InDi without following a solution suggested from the system. The same problem was re-occurred until they could make it themselves. Then a new problem was shown until they could complete an unseen problem without clicking for a solution. Then, the numbers of periods that the students took to finished this phase varied depending on individual performance.

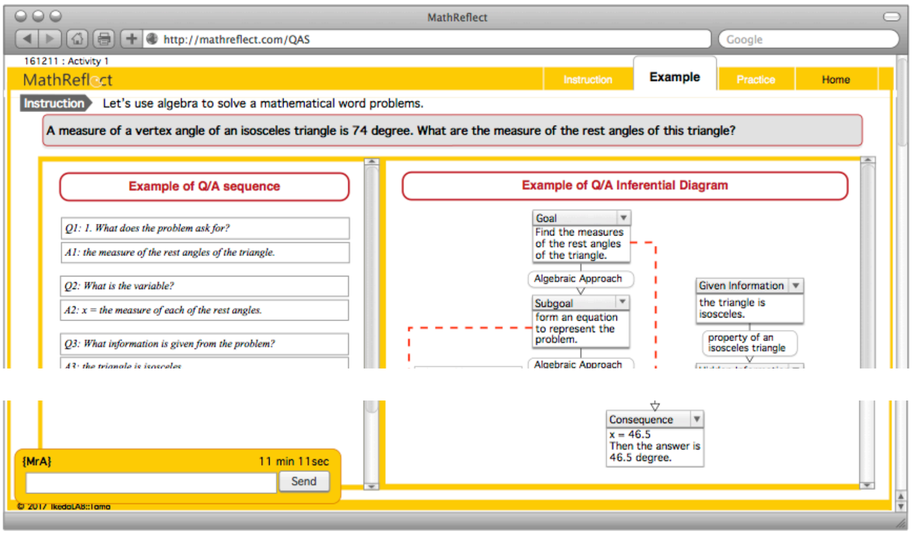


Figure 5-6 The page to show an example of QAS and InDi.

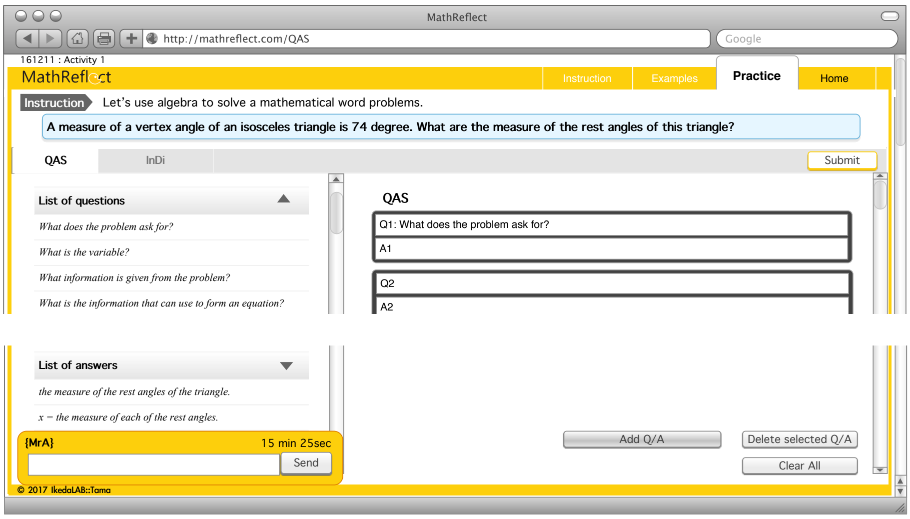


Figure 5-7 QAS constructing page.

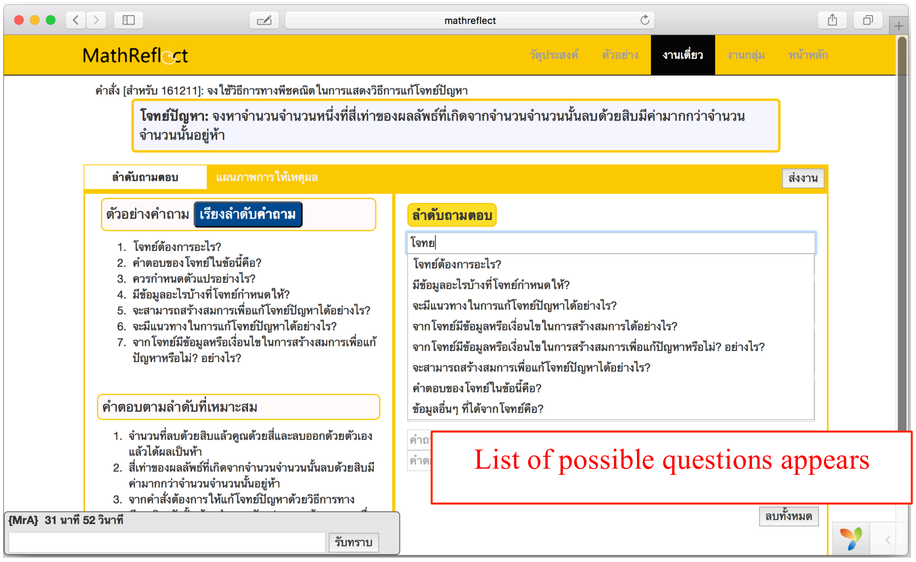


Figure 5-8 Showing when students type in Q/A box, there is a list of problems which contains that keyword appears.

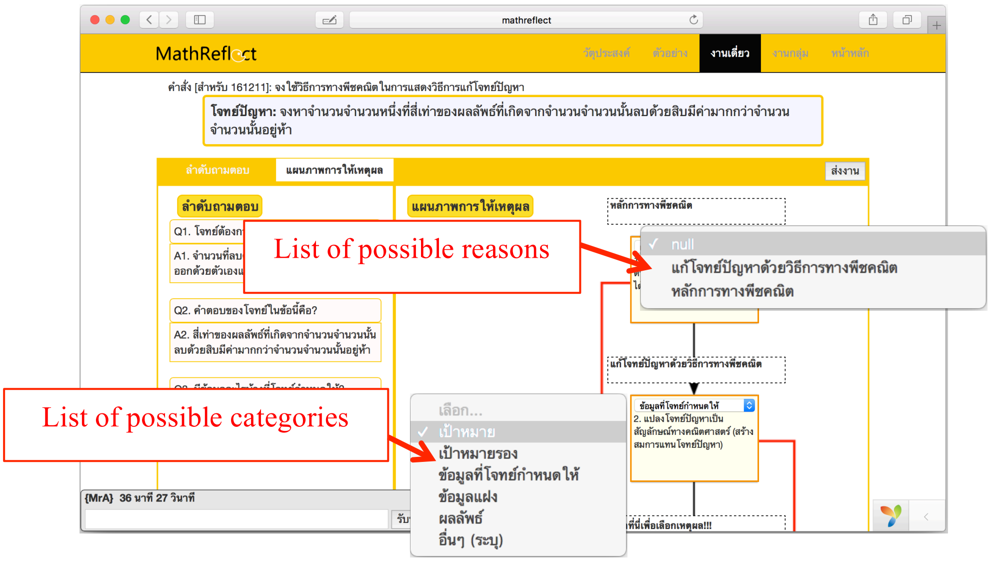


Figure 5-9 InDi completing page shows students can select reasons and categories of given information.

5.6. Learning Environment in Experiencing Phase

In this phase, MetaQ was applied with Practice. Practice here refers to practicing to solve MWP. MetaQ was applied while the students practiced solving MWP to complete their learning cycle to support them to experience/internalize what they learnt from the previous phases or to facilitate them to convert explicit knowledge into tacit knowledge. During this stage, the students either have a chance to manage their emotions about the outcomes of their learning experience. Moreover, they can reflect on their performance in this phase and monitor their difficulties in learning MWP to engage them to reflect on what and how they can improve themselves in learning MWP.

In Experiencing phase, MetaQ and Practice were applied via manual arrangement and Google Classroom. MWP solving task was assigned to the students concurrently with asking them to predict and evaluate their performance before and after their try. The students have the situation to evaluate their performance on the learning task with respect to the effectiveness of the strategies that they chose.

MetaQ attached with MWP:

- (Before solving MWP) *Read the given question carefully, then evaluate your confidence to complete this problem as percentage, before writing a solution*
- (After solving MWP) *After your try, please evaluate your solution in percentage of completion*.

MetaQ released for completing the final phase:

- *Criticize your own difficulties in learning MWP solving.*
- *What might make you give up to improve your performance in learning MWP solving? How to prevent or resolve it?*

CHAPTER 6
Methodology for Investigating Effectiveness of CREMA

6.1. Introduction

This chapter discusses the research methodology to evaluate and investigate CREMA. It starts by recalling the research questions and explaining the investigation design. Then it reveals the procedure of the research methodology step by step from the sampling process, teaching and training procedure, and data collecting instruments.

6.2. Designing the Investigation

In this dissertation, I would like to find a framework for designing an environment for encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning. To achieve the research goal, these followings questions must be answered:

1. Can CREMA really support learners to gain S2SRL in MWP learning?
2. How does CREMA work in a practical environment?
   2.1. Is MetaQ a factor in CREMA to support learners to gain S2SRL?
   2.2. Can computer support really enhance training effect in CREMA?

To answer the first questions, a group of students who learnt MWP with the proposed method by implementing CREMA was compared with a group of students who learnt MWP in the traditional method.

To answer the second question, there are three sub-questions to be considered. To answer the question 2.1, a group of students who learnt MWP in traditional method was compared with a group of students who learnt MWP in traditional method combining with MetaQ to investigate and ensure the effect of the intervention of MetaQ in the traditional class. To answer the question 2.2, a group of students who learnt MWP with the proposed method by implementing CREMA was compared with a group of students who learnt MWP in traditional method combining with MetaQ to see the effect of using MetaQ with and without computer support from implementing CREMA.

That is to answer the questions, these following groups of students were considered:

1) *Control Group 1* (CTRL): students in this group learnt MWP solving by the traditional method.
2) *Control Group 2* (CTRL+MetaQ): students in this group learnt MWP solving by the traditional method combining with the intervention of metacognitive questioning and motivational statements (MetaQ).
3) *Experimental* G*roup* (CREMA): students in this group learnt MWP solving via computer application implemented by applying CREMA as a framework.

In the following sections, I explain the procedure of the investigation design from the sampling procedure to the methodology of data collection, in order to be able to answer the research questions.

6.3. Sampling Procedure

The experiment was taken at a public school in a small district in the northeast of Thailand in the province named Kalasin. Students of this school almost came from surrounding rural villages of the district which are farming area. And most of their families were farmers.

To differentiate students who really gained improvement from the proposed approach and students who were already self-regulated learners, I specifically considered students who confused and could not recognize/realize their difficulties in solving MWP. The subjects were sampled from grade-9 students. There were in total 12 classes of grade-9 students in this school. The grade-9 students in this school have already learnt MWP when they were in grade-7 and 8. They had to learn MWP again in grade-9. First, I went to the school and observed the environment of the school and their learning activities. I selected 7 classes out of the total 12 classes of the grade-9 students from my observation and considering their teachers' report that these 7 classes of students were low-performance students with comparable mean socioeconomic status level. Next, these 7 classes of students were screened into 3 classes by a MWP solving test together with metacognitive questions. Its translation is shown as follows:

(1) Read the question carefully, evaluate your confidence to complete this problem as percentage, before writing a solution.

Let's use algebra to solve a mathematical word problem:
A measure of a vertex angle of an isosceles triangle is 87 degree.
What are the measures of the rest angles of this triangle?

(2) After your try, evaluate your solution in percentage of completion.

(3) Why can't you solve the problem?
(…) I don't know!
(…) I have no idea! Or Express your reason: …………

(4) What is difficult for you that make you fail to solve MWP?
(…) I don't know!
(…) I have no idea! Or Express your reason: …………

In addition, a result from the questionnaire for classifying a learner who gained S2SRL in learning MWP (Q-L2SRL) was also considered in this screening. The detail explanation of Q-L2SRL is described in the section 6.4.2. This screening process was taken about one month before the intervention. Finally, 3 classes of students were selected from the classes that most of their students failed the MWP test and could not express their reasons in the metacognitive questions and their Q-L2SRL pretest were not significantly different.

6.4. Teaching and Learning Procedure

The three selected classes from the sampling process were assigned to the three distinct learning groups (i.e., CTRL, CTRL+MetaQ, and CREMA). The numbers of students in each class were 37 (17 males, 20 females), 37 (17 males, 20 females), and 36 (13 males, 23 females) students, respectively. All groups learnt the same MWP solving topic and experienced the same level of MWP practice problems. The total course had six periods (50 minutes each) in three weeks (two periods a week). The learning procedure in each group is described as follows:

1. CTRL: a mathematics teacher in the school taught the students in this group by traditional method using white broad and explanation of how to solve MWP. The teacher gave homework and assignments to the students after class. The students' works were checked as correct (checked mark) and incorrect (cross mark). The teacher often showed the solutions of some assignments in the beginning of her class and asked the students to take note.
2. CTRL+MetaQ: I taught students in this group by myself using traditional method almost similar to CTRL. It is different from CTRL that, in this group, MetaQ's were raised during class while I was giving the lecture and during the time the students practicing problems. And the students' assignments were returned with comments and suggestions about the possibilities of their failures and suggestions how to improve it.
3. CREMA: in this group, the students used computers as media to learn MWP. The teacher of this group monitored, controlled, and managed atmosphere of the class. The teacher took responsibility as a facilitator and supporter when the students needed some help or confused with the learning flow. The training program was composed of three phases inherited from CREMA as described in chapter 5: *Preparation phase, Observation phase, and Experiencing phase*.

Figure 6-1 Learning environment of Experimental group (CREMA).

Figure 6-2 Learning environment of Control group 2 (CTRL+MetaQ).

Figure 6-3 Learning environment of Control group 1 (CTRL).

I) *Preparation phase*: This phase included an extra period (took place before the class). In the extra period, the teacher explained how important to learn MWP and gave some examples of applications of MWP related to their interest and their daily life. The teacher asked the students about their dream job and gave certain MWP application examples. Then, the teacher told the students to write down their goals for learning MWP by giving them some examples and asked them to think about their motivation that would drive them to achieve their goals. Then, in the first period of the course, the students were allowed to access to the system, called MethReflect, which is explained in the previous chapter. The scope of Preparation phase in MathReflect was only at the introduction page—the first page after students started the activity in the system when logged-in into the system. In the introduction page, the learning objectives of the training program and the topic were provided. There was a direction for informing the students to read and make understanding on the provided information. The students could move over this page or this phase only after they responded to MetaQ from the system in the dialog box in the bottom left of the page, see Figure 6-5. MetaQs raised in this page were *"Q1: Give a reason why you have to learn MWP solving? Q2: Set up your expectation in this class"*. The system provided examples of answers of the

MetaQs (*Example answers of Q1, To be able to solve MWP by myself, to use it in my carrier, to improve my grade, to make my parents proud of me, to be able to enter to a good faculty, etc.; Example answers of Q2, can understand more about MWP. can interpret context problem into math notation, can apply MWP in daily life problem, etc.*) and suggested the students choose or use their own opinions.

Figure 6-4. The atmosphere of the extra period.

II) *Observation phase*: MathReflect was applied in this phase. The students could access to this phase only if they made a response to MetaQ via MrA in the previous phase. The activities/tasks in this phase included composing QAS, completing InDi and answering MetaQ. After the students entered the first page in this phase, MWP was shown with the direction to inform them to read the problem carefully. And, there was a question raised, "*Do you completely understand the problem?*" They could respond to this question by clicking on the buttons, YES or NO. If they go for YES, QAS constructing page appears, otherwise, the list of possibilities of difficulties (e.g. *don't know the meanings of some words in the problem, cannot imagine about the situation, don't understand the situation in the problem*) were suggested as examples together with the direction for telling them to answer MetaQ. MetaQ raised here was

"*What do you think it is the reason that you cannot understand the problem clearly? (Choose from the list or state your own opinion)*". They could only move on to QAS constructing page only if they submitted their response to MetaQ via MrA.

a) *Procedure in QAS constructing page*: The students had tasks to match questions and answers then put them in an appropriate order. If they could compose it correctly, then made a response to MetaQ (*Which question in the sequence is difficult for you?*) via MrA to get permission to access to the next page. Conversely, incorrect QAS had no permission to access the next page. If students think they cannot do it, they can click for a hint to see a solution and follow it, however, this action would be recorded and made them could not move over this task. If the class period was over before they finish the task, they needed to start to compose that QAS from the beginning next time they logged-in into the system.

b) *Procedure in InDi completing page*: The students had tasks to select appropriate Information Tags and Reasons from the provided lists for existing information. The same as in QAS constructing page, the students could move over this page for the next step only if they completed InDi correctly and already made a response to MetaQ (*Which #box of information that is difficult to remind?*) via MrA.

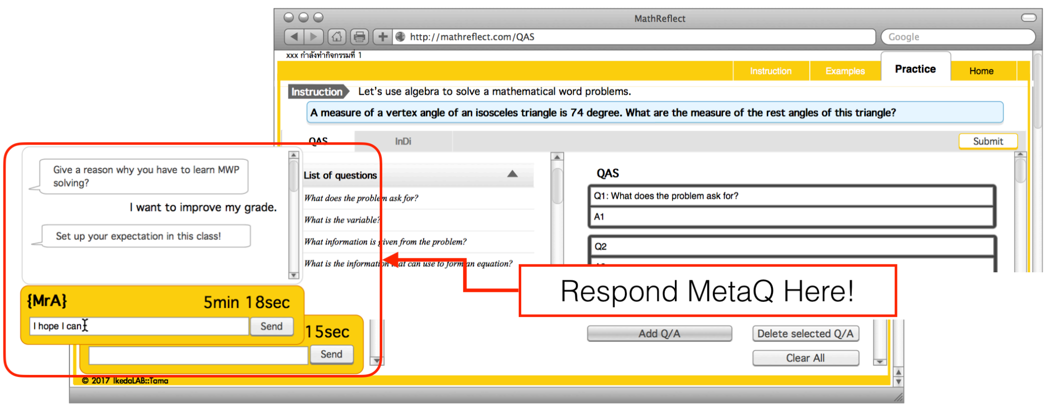


Figure 6-5 Web interface of MathReflect at QAS Constructing Page.

The students could finish Observation phase only if they could compose QAS and completed InDi without following a solution suggested by the system. The same problem was re-occurred until they could make it themselves. Then a new problem was shown until they could complete an unseen problem without clicking for a solution. The system then delivered these MetaQs:

1. Evaluate your competency in solving MWP from observing this QAS and InDi as, poor, average, or excellent
2. Please indicate your difficulties in learning MWP solving (Choose from above list or state your own opinion)
3. What might make you give up to improve your performance in learning MWP solving? How to prevent or resolve it?

The students needed to answer all questions to complete the phase. The numbers of periods that students took to finished this phase varied depending on individual performance.

III) *Experiencing phase*: Google Classroom was used in this phase. The students accessed to Google Classroom to do MWP exercise while they could also access to MathReflect any time to see their completed QASs and InDis. The students had to answer MetaQ before and after solving MWP (MetaQ before solving MWP: *Read the question carefully, evaluate your confidence to complete this problem as percentage, before writing a solution*, MetaQ after solving MWP: *After your try, evaluate your solution in percentage of completion*). After finished few problems, they were asked to respond to these MetaQs;

1. Criticize your own difficulties in learning MWP solving.
2. What might make you give up to improve your performance in learning MWP solving? How to prevent or resolve it?

After each period, the students got an assignment to complete an exercise about what they stated in each period about their difficulties in solving MWP. The teacher played a role as a supporter when students needed further explanation.

6.5. Data Collection Instruments

To perform the investigation, a MWP test and a questionnaire for classifying a learner who has gained S2SRL in MWP learning (Q-L2SRL) were conducted before and after the intervention. The investigation was taken place about one month after conducting the pretest.

6.5.1. MWP test

MWP test was conducted to access students' performance in solving MWP. The MWP pretest was used in the screening process. Then, the pretest and posttest were not used to analyze the change of the subjects, but the subjects were considered and compared among different groups. The posttest is composed of 6 MWPs. The problems were selected and modified from the student textbook that they normally used in the school. Three problems are MWPs using one variable (including one problem which requires hidden knowledge) and the other three problems are MWP using two variables (Problem 4 is more difficult than Problem 5 and Problem 6 is a challenging problem). The English translations of all six problems of the posttest are shown below.

The MWP Posttest

1. If the sum of a number and 231 is equal to 756, please find that number.
2. Mom gave Kapom a 1000Baht banknote to pay for the electric bill. How much of the electric charge, if Kapom received 121.50Baht back after the payment?
3. A measure of a base angle of an isosceles triangle is 21 degree. What are the measures of the rest angles of this triangle? (*To solve this problem, it requires special knowledge about properties of a triangle, requires special knowledge*)
4. The total numbers of oranges and apples is 77. If the number of oranges is 13 more than the numbers of apples, please find the number of apples.

5. A collection of 155 coins, consisting of 1Baht coins and 5Baht coins, has a value of 395Baht. Please find how many coins of each kind are there?
6. The sum of the ages of father and son is 83 and a mother is 42 years old. If 4 years ago the father's age is two times the son's, how old is the son now? (*Challenge problem*)

6.5.2. Q-L2SRL

Q-L2SRL has been especially developed for this research. The items in Q-L2SRL cover all categories in the three aspects of UL and ASL, mentioned in section 3.4. As a result, there were 16 items in Q-L2SRL, see its English translation in Table 6-1. The questionnaire was composed in 4 point Likert-type scale (1 = I don't agree at all, 2 = I don't agree, 3 = I agree, and 4 = I strongly agree) which allows the students to express their consensus how much they agree or disagree with a particular statement.

A reliability analysis was carried out on Q-L2SRL comprising all 16 items. Cronbach's alpha showed the questionnaire has good internal consistency ($\alpha = 0.95$). All items appeared to be worthy of retention, resulting in a decrease in the alpha if deleted. Moreover, it also has adequate test-retest reliability ($r(43) > 0.85$, $p < 0.0001$ over a three-week period) for all 16 items.

Besides MWP test and Q-L2SRL, students' answers to metacognitive questions attaching with MWP test as shown in section 6.2 were also considered. Moreover, their learning behavior was also taken into account.

Table 6-1 shows all 16 items of the Q-L2SRL and their Pearson's correlation values from the test-retest reliability.

Item codes	Questionnaire items	r	p-value
UL-STM-A	I am (began to be)* curious about the source of my feeling to learn MWP.	0.896	0.000
UL-STM-G	I am (began to be) curious about my goal of MWP learning.	0.971	0.000
UL-STM-M	I am (began to be) curious about my reason why should I have to learn MWP.	0.943	0.000
UL-SUT-K	I am (began to be) curious about what I know in learning MWP.	0.954	0.000
UL-SUT-P	I am (began to be) curious about my understanding of MWP principle.	0.954	0.000
UL-SUT-D	I am curious (began to be) about my difficulty in MWP learning.	0.960	0.000
UL-SUP-S	I am (began to be) curious about the appropriate strategy to achieve my goal in MWP learning.	0.931	0.000
UL-SUP-C	I am (began to be) curious about the source of my distraction in learning MWP.	0.886	0.000
ASL-STM-A	I am (began to be) curious to find the benefit/application of learning MWP to make me feel easy in learning MWP learning.	0.870	0.000
ASL-STM-G	I am (began to be) curious about how to encourage myself to achieve the goal I set for learning MWP.	0.908	0.000
ASL-STM-M	I am (began to be) curious to figure out my reason why should I have to learn MWP.	0.902	0.000
ASL-SUT-K	I am (began to be) curious about how to update my background knowledge to meet the knowledge required for learning MWP.	0.850	0.000
ASL-SUT-P	I am (began to be) curious about finding a method to improve my understanding of MWP principle.	0.951	0.000
ASL-SUT-D	I am (began to be) curious about finding the way to resolve my difficulty in MWP learning to be able to improve my performance.	0.947	0.000
ASL-SUP-S	I am (began to be) curious about finding my own effective strategy to achieve my goal in MWP learning.	0.881	0.000
ASL-SUP-C	I am (began to be) curious about how to concentrate on the process during learning MWP.	0.869	0.000

*The phrase in the parenthesis is used for the posttest.

CHAPTER 7
Experimental Result and Analysis

This chapter reports the result from the previous chapter. The data collected from the investigation is summarized and analyzed using statistical technics. Then it will be presented in various forms of representations. Finally, those results are discussed and the conclusion of the finding is made.

7.1. Introduction

As mentioned, to achieve the research goal, these followings questions must be answered:

1. Can CREMA really support learners to gain S2SRL in MWP learning?
2. How does CREMA work in a practical environment?
   2.1. Is MetaQ a factor in CREMA to support learners to gain S2SRL?
   2.2. Can computer support really enhance training effect in CREMA?

The explanation of the investigation is explained in the previous chapter. In the investigation, these following data were collected: MWP test, Q-L2SRL questionnaire, metacognitive questions, and class observations, by comparing these following groups of students:

1) *Control Group 1* (CTRL): students in this group learnt MWP solving by the traditional method.
2) *Control Group 2* (CTRL+MetaQ): students in this group learnt MWP solving by the traditional method combining with the intervention of MetaQ.

3) *Experimental* G*roup* (CREMA): students in this group learnt MWP solving via computer application implemented from CREMA.

There were some students that did not attend the classes properly. Then, the total numbers of students in each class that finally could take into account were 33 (13male, 20female), 34 (16male, 18female), and 34 (12male, 22female) students in CTRL, CTRL+MetaQ, and CREMA respectively. In the rest section of this chapter, the results and their statistical analysis from each instrument are reported and discussed.

7.2. Analysis of the result from Q-L2SRL

The differences of means and standard deviations from the Q-L2SRL pretest and posttest are shown in Table 7- 1 and 2. In Figure 7-1, the interval plot shows the comparison of the means of the Q-L2SRL pretest among the three groups, by performing a one-way analysis of variance (ANOVA) on the means of the Q-L2SRL pretest and for all 16 items of the questionnaire, it showed that there was no significant difference ($Fs(2,98) < 2.54$; $Ps>0.083$), see Appendix A, among the three groups which were selected.

From Figure 7-2, it can be seen that the means of the Q-L2SRL posttest among the three groups are different. The mean of the Q-L2SRL posttest of CREMA is greater than the other groups and of CTRL+MetaQ is greater than CTRL. A one-way ANOVA showed that the effect of training methods was significant, $F(2,98) = 128$, $p < .0001$. Post-hoc analyses using Tukey's HSD indicated that there were significant differences between the means of the Q-L2SRL posttest of the students in CREMA vs. CTRL ($p < .0001$), CREMA vs. CTRL+MetaQ ($p < .0001$), and CTRL vs. CTRL+MetaQ ($p < .0001$).

When considered in each item of the questionnaire, see Table 7- 1 and 2, it can be seen that the means of the Q-L2SRL posttest of CREMA are greater than of CTRL+MetaQ and CTRL and the means of the Q-L2SRL posttest of CTRL+MetaQ are greater than of CTRL, for all 16 items. A one-way ANOVA showed the significant difference among these comparisons for all 16 items. Post-hoc analyses using Tukey's HSD indicated that there were significant differences between the means of the Q-L2SRL posttest of the students in CREMA vs. CTRL (*ps* < .0001), CREMA vs. CTRL+MetaQ (*ps* < .001), and CTRL vs. CTRL+MetaQ (*ps* < .05), for all 16 items, see Appendix B.

Table 7- 3 and 4 show the differences of frequencies of students who gave positive responses to the Q-L2SRL for all 16 items. For example, 85% in the first row of Table 7- 3 means there were 85% of the students (31 from 34 students) in CREMA rated they were agreed or strongly agree that they began to be curious about the source of their feeling to learn MWP. From Table 7- 3 and 4, we can see that the frequencies in CTRL+MetaQ and CREMA increased in all 16 items of the Q-L2SRL pretest and posttest, and the frequencies of CREMA were greater than of CTRL+MetaQ for all 16 items in the Q-L2SRL posttest. In CTRL, the frequencies slightly increased in these following items: UL-SUT-K, P, D, ASL-SUT-K, P, and ASL-SUP-S.

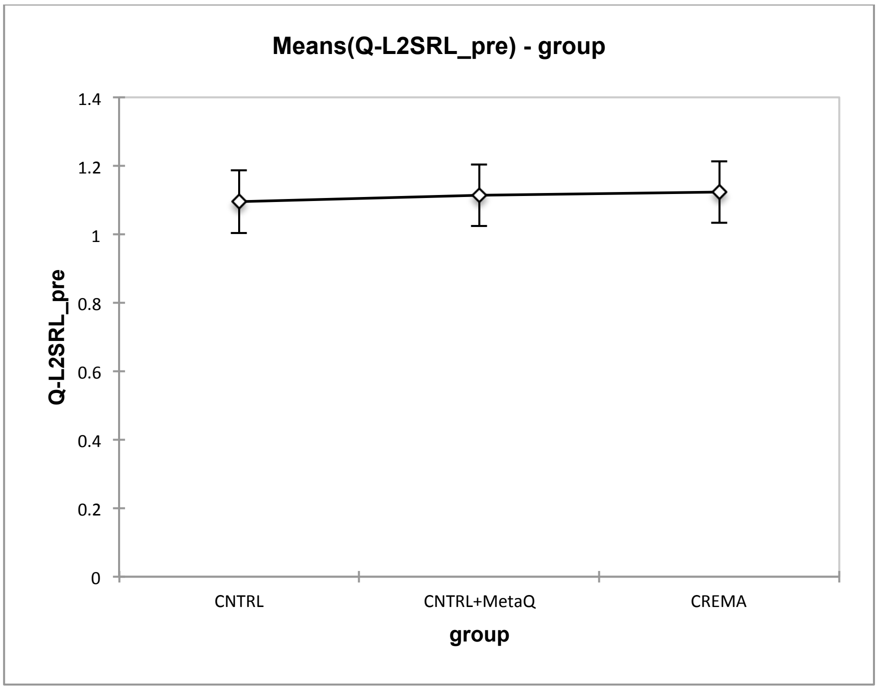


Figure 7-1. The interval plot of the comparison of the means of the Q-L2SRL pretest.

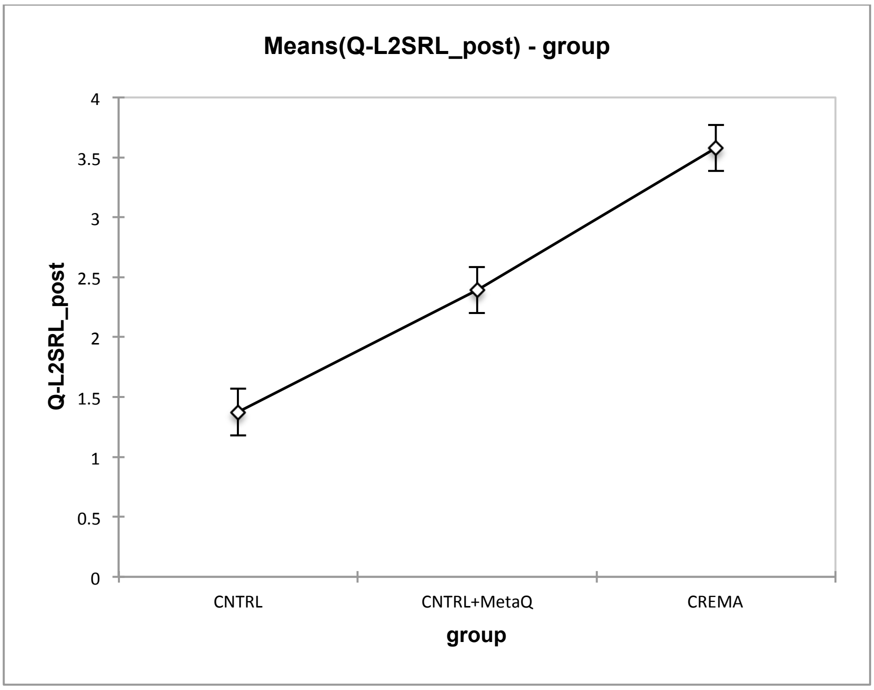


Figure 7-2. The interval plot of the comparison of the means of the Q-L2SRL posttest.

Table 7-1 shows the means and standard deviations of the Q-L2SRL pretest and posttest in individual items of UL.

			Pretest (Range 1-4)						Posttest (Range 1-4)					
			CTRL (n=33)		CTRL+ MetaQ (n=34)		CREMA (n=34)		CTRL (n=33)		CTRL+ MetaQ (n=34)		CREMA (n=34)	
Aspects	**Categories**	**Item codes**	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Stimulus	Attitude	UL-STM-A	1.03	0.17	1.06	0.24	1.06	0.24	1.03	0.17	2.32	0.81	**3.29**	0.72
	Goal	UL-STM-G	1.18	0.39	1.15	0.36	1.12	0.33	1.15	0.36	2.68	0.91	**3.68**	0.53
	Motivation	UL-STM-M	1.21	0.48	1.26	0.51	1.15	0.36	1.39	0.61	2.62	0.65	**3.53**	0.61
Self-understanding toward task	Background knowledge	UL-SUT-K	1.21	0.48	1.15	0.36	1.15	0.44	1.61	0.97	2.79	0.88	**3.71**	0.52
	Self-understanding of principle of topic	UL-SUT-P	1.18	0.46	1.21	0.54	1.18	0.52	1.55	0.87	3.06	1.01	**3.71**	0.52
	Self-difficulty	UL-SUT-D	1.15	0.44	1.15	0.36	1.15	0.44	1.91	1.28	2.71	0.8	**3.76**	0.5
Self-understanding toward learning process	Strategy	UL-SUP-S	1.15	0.44	1.09	0.29	1.15	0.44	1.27	0.63	2.91	1.06	**3.62**	0.55
	Concentration	UL-SUP-C	1.12	0.33	1.15	0.36	1.12	0.33	1.15	0.36	2.68	0.84	**3.44**	0.56

M = mean, SD = standard deviation

Table 7-2 shows the means and standard deviations of the Q-L2SRL pretest and posttest in individual items of ASL.

			Pretest (Range 1-4)						Posttest (Range 1-4)					
			CTRL (n=33)		CTRL+ MetaQ (n=34)		CREMA (n=34)		CTRL (n=33)		CTRL+ MetaQ (n=34)		CREMA (n=34)	
Aspects	**Categories**	**Item codes**	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Stimulus	Attitude	ASL-STM-A	1.00	0.00	1.00	0.00	1.00	0.00	1.09	0.29	1.97	0.94	**3.32**	0.64
	Goal	ASL-STM-G	1.00	0.00	1.00	0.00	1.00	0.00	1.18	0.39	2.12	1.04	**3.65**	0.54
	Motivation	ASL-STM-M	1.00	0.00	1.00	0.00	1.00	0.00	1.33	0.48	2.1	0.75	**3.38**	0.6
Self-understanding toward task	Background knowledge	ASL-SUT-K	1.06	0.24	1.06	0.24	1.06	0.24	1.61	0.93	2.15	0.86	**3.74**	0.51
	Self-understanding of principle of topic	ASL-SUT-P	1.06	0.24	1.06	0.24	1.06	0.24	1.58	0.9	2.06	0.89	**3.76**	0.5
	Self-difficulty	ASL-SUT-D	1.03	0.17	1.03	0.17	1.03	0.17	1.42	0.61	1.94	0.78	**3.82**	0.46
Self-understanding toward learning process	Strategy	ASL-SUP-S	1.09	0.29	1.09	0.29	1.09	0.29	1.52	0.87	2.18	0.97	**3.5**	0.56
	Concentration	ASL-SUP-C	1.03	0.17	1.03	0.17	1.03	0.17	1.21	0.48	2.03	0.83	**3.35**	0.69

M = mean, SD = standard deviation

Table 7-3 shows frequencies (in percent) of students who gave positive responses on Q-L2SRL of each group in individual items of UL.

			Pretest (%)			Posttest (%)		
Aspects	**Categories**	**Item codes**	CTRL (n=33)	CTRL+ MetaQ (n=34)	CREMA (n=34)	CTRL (n=33)	CTRL+ MetaQ (n=34)	CREMA (n=34)
Stimulus	Attitude	UL-STM-A	0	0	0	0	53	**85**
	Goal	UL-STM-G	0	0	0	0	62	**97**
	Motivation	UL-STM-M	3	3	0	6	71	**94**
Self-understanding toward task	Background knowledge	UL-SUT-K	3	0	3	**27**	74	**97**
	Self-understanding of principle of topic	UL-SUT-P	3	6	6	**24**	76	**97**
	Self-difficulty	UL-SUT-D	3	0	3	**33**	74	**97**
Self-understanding toward learning process	Strategy	UL-SUP-S	3	0	3	9	71	**97**
	Concentration	UL-SUP-C	0	0	0	0	74	**97**

Table 7-4 shows frequencies (in percent) of students who gave positive responses on Q-L2SRL of each group in individual items of ASL.

			Pretest (%)			Posttest (%)		
Aspects	**Categories**	**Item codes**	CTRL (n=33)	CTRL+ MetaQ (n=34)	CREMA (n=34)	CTRL (n=33)	CTRL+ MetaQ (n=34)	CREMA (n=34)
Stimulus	Attitude	ASL-STM-A	0	0	0	0	41	**91**
	Goal	ASL-STM-G	0	0	0	0	35	**97**
	Motivation	ASL-STM-M	0	0	0	0	32	**94**
Self-understanding toward task	Background knowledge	ASL-SUT-K	0	0	0	**30**	38	**97**
	Self-understanding of principle of topic	ASL-SUT-P	0	0	0	**27**	35	**97**
	Self-difficulty	ASL-SUT-D	0	0	0	6	26	**97**
Self-understanding toward learning process	Strategy	ASL-SUP-S	0	0	0	**24**	38	**97**
	Concentration	ASL-SUP-C	0	0	0	3	35	**88**

7.3. Analysis of the Results from MWP test

Table 7-5 shows differences of means and standard deviations of the MWP pretest and posttest. The means of the three selected groups were equal according to a one-way ANOVA, $F(2, 98) = 0.02, p = 0.98$, see Table C1-1 in Appendix C. After the training, the means of the three groups became unequal according to a one-way ANOVA, $F(2, 98) = 4.797, p = 0.010$. Pairwise comparisons of the means of MWP posttest using Tukey's HSD procedure indicated only one significant comparison: the students in CREMA ($M = 15.12$) significantly ($p = 0.007$) outperformed the students in CTRL ($M = 10.18$). The other comparisons were not significant (ps > 0.17), see Table C2-2 in Appendix C.

Considering in more fine-grained detail of the MWP posttest, their comparisons of the means of the individual MWP items are illustrated by the bar chart in Figure 7-3. A one-way ANOVA was conducted against the six items the MWP posttest, see Table C2-3 – 8 and C1-3 – 8 in Appendix C. It found that there were significant differences in Problem 3 and 6, $F(2, 98) = 35.744, p < 0.001$ and $F(2, 98) = 9.375, p < 0.001$, respectively. Pairwise comparisons of the means of the MWP posttest item 3 and 6 using Tukey's HSD procedure indicated the significant comparisons in these following pairs: in the MWP posttest item 3, the students in CREMA significantly ($p < 0.0001$) outperformed the students in CTRL and CTRL+MetaQ; in the MWP posttest item 6, the students in CREMA significantly ($p < 0.0001$) outperformed the students in CTRL, see Appendix C.

Table 7-5 shows the average scores from the MWP pretest and posttest of each group.

		CTRL (n=33)		CTRL+ MetaQ (n=34)		CREMA (n=34)	
MWP test	**Full score**	M	SD	M	SD	M	SD
Pretest	18	1.03	0.81	1.029	0.63	1	0.7
Posttest	36	10.18	5.1	12.62	5.7	**15.12**	8.28

M = mean, SD = standard deviation

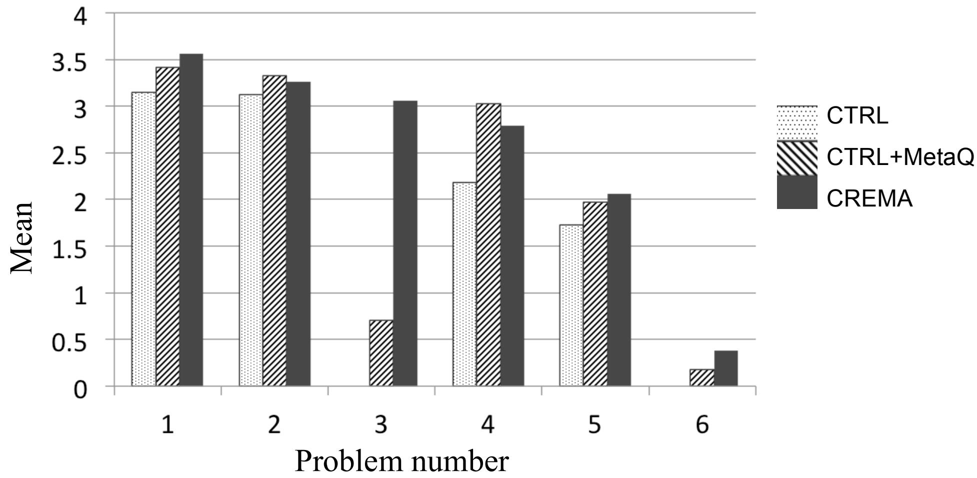


Figure 7-3. The bar chart of means comparisons of each item of the MWP posttest.

7.4. The Results from Metacognitive Questions in the MWP test

Table 7-6 shows the differences of frequencies of students who precisely expressed their difficulties in solving MWP in the MWP pretest and posttest against all groups. All students in CREMA could state their difficulties and reasons why they failed to solve the problems. About 32% of students in CTRL+MetaQ could express their difficulties and none of the students in CTRL could do this task (e.g., students wrote only I don't understand, I cannot remember, It is too difficult, or left it blank).

Table 7-6 shows differences of frequencies of students who precisely expressed their difficulties in solving MWP in the pretest and posttest of MWP among the three groups.

Number of students who can express their difficulties	CTRL (n=33)	CTRL+MetaQ (n=34)	CREMA (n=34)
Pretest	0	0	0
Posttest	0 (0%)	11 (32.4%)	34 (100%)

7.5. The Analysis of Q-L2SRL vs MWP test

This section reports regression analysis of the MWP posttest score and all 16 items of Q-L2SRL. In summary, from the analysis shows that there were significant correlation between all variables in Q-L2SRL and their MWP posttest scores, (Fs(1, 99) > 14, *p*s < .001, R^2s > .11), see Table 7-7 and Figure 7-4 to 7-9.

Table 7-7 Summary of Simple Regression Analyses for MWP performance and Q-L2SRL (N = 101).

Items	*B*	*SE B*	β	*F(1,99)*	*p*
UL-STM-A	2.185	1.121	0.362	14.94	0.0002
UL-STM-G	2.141	1.222	0.387	17.40	< 0.0001
UL-STM-M	2.212	1.073	0.351	13.91	0.0003
UL-SUT-K	2.244	1.178	0.391	17.83	< 0.0001
UL-SUT-P	2.196	1.222	0.396	18.46	< 0.0001
UL-SUT-D	2.194	1.183	0.384	17.10	< 0.0001
UL-SUP-S	2.199	1.249	0.406	19.52	< 0.0001
UL-SUP-C	2.04	1.135	0.342	13.14	0.0005
ASL-STM-A	2.351	1.140	0.396	18.44	< 0.0001
ASL-STM-G	2.303	1.242	0.423	21.54	0.0001
ASL-STM-M	2.607	1.050	0.405	19.39	< 0.0001
ASL-SUT-K	2.277	1.197	0.403	19.18	< 0.0001
ASL-SUT-P	2.293	1.221	0.414	20.49	< 0.0001
ASL-SUT-D	2.151	1.210	0.385	17.19	< 0.0001
ASL-SUP-S	2.618	1.159	0.449	24.95	< 0.0001
ASL-SUP-C	2.392	1.116	0.395	18.27	< 0.0001

B = unstandardized beta, *SE B* = standard error for the unstandardized beta,
β = standardized beta

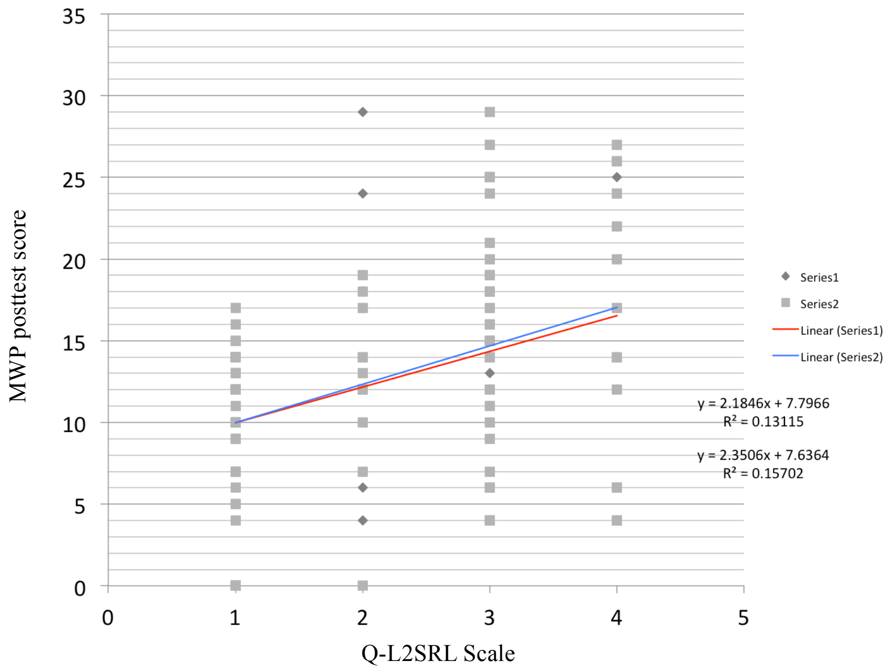


Figure 7-4 A scatterplot of UL-STM-A (red) and ASL-STM-A (blue) vs MWP posttest score.

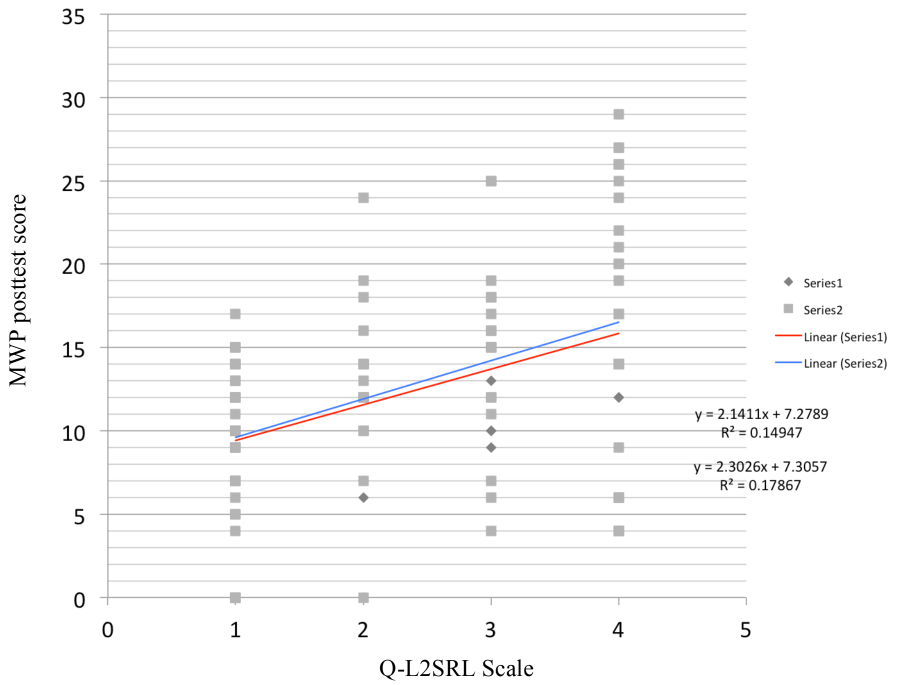


Figure 7-5 A scatterplot of UL-STM-G (red) and ASL-STM-G (blue) vs MWP posttest score.

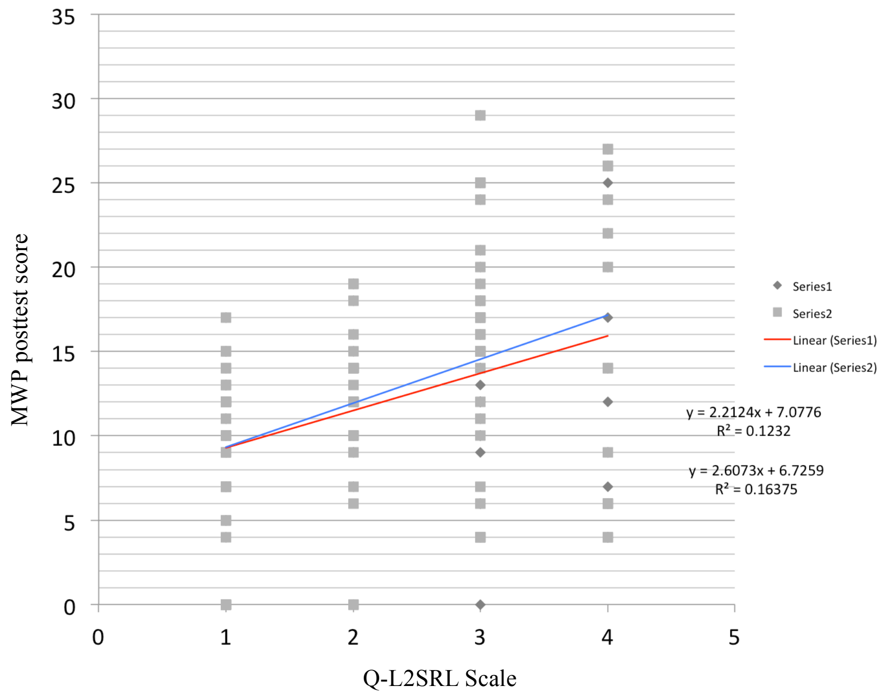


Figure 7-6 A scatterplot of UL-STM-M (red) and ASL-STM-M (blue) vs MWP posttest score.

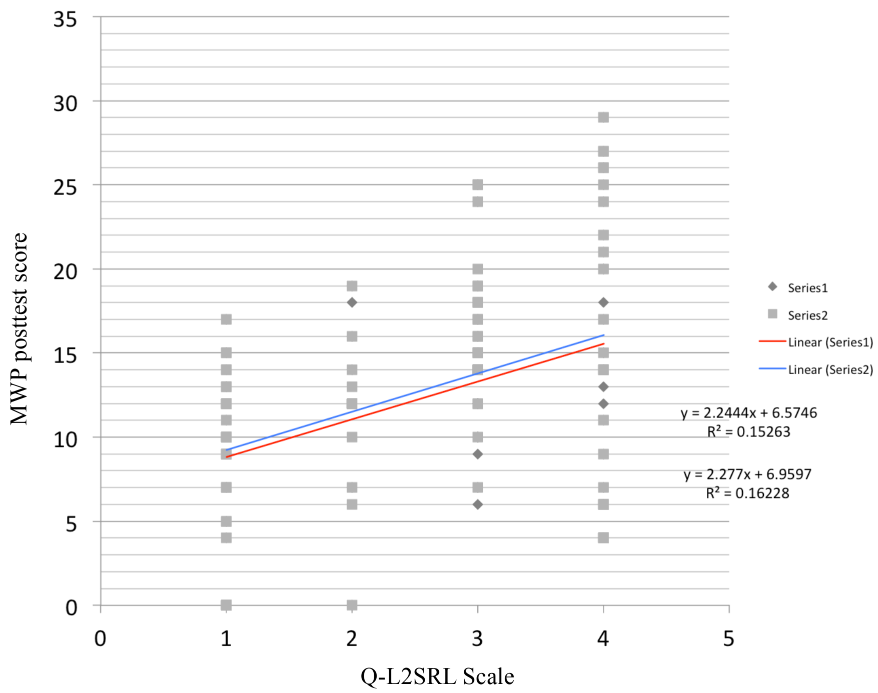


Figure 7-7 A scatterplot of UL-SUT-K (red) and ASL-SUT-K (blue) vs MWP posttest score.

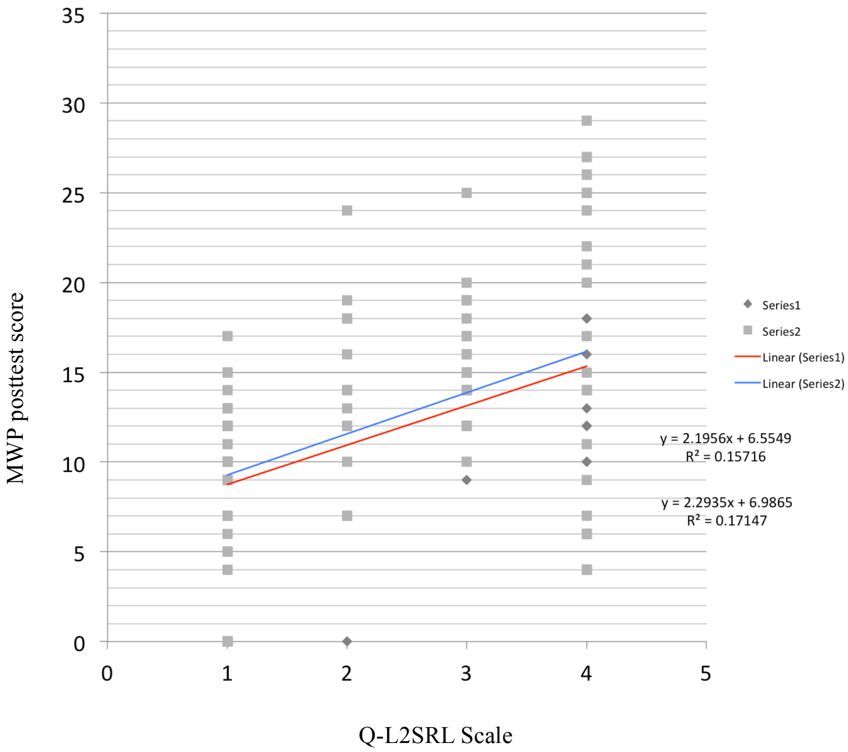


Figure 7-8 A scatterplot of UL-SUT-P (red) and ASL-SUT-P (blue) vs MWP posttest score.

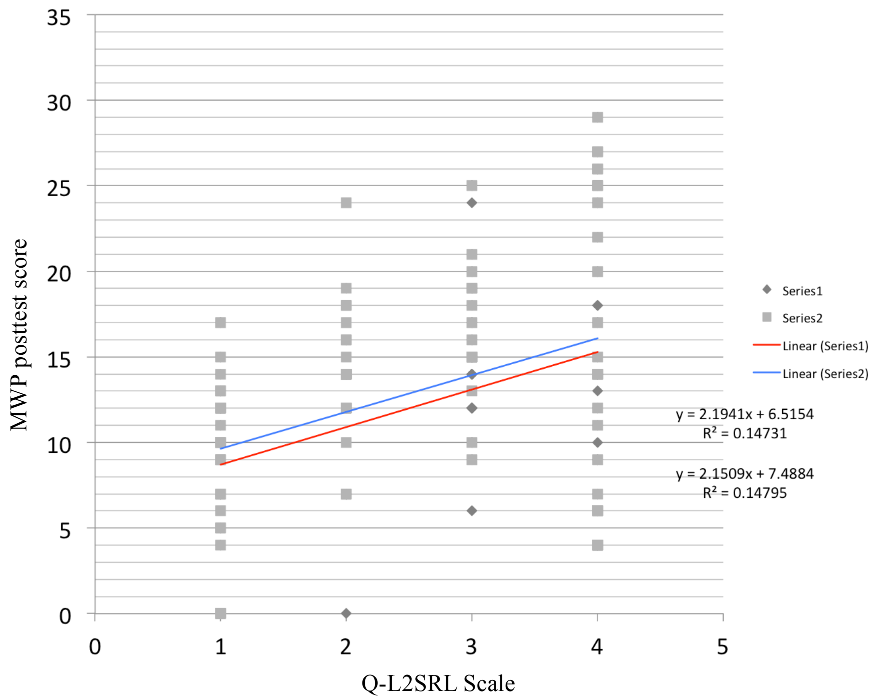


Figure 7-9 A scatterplot of UL-SUT-D (red) and ASL-SUT-D (blue) vs MWP posttest score.

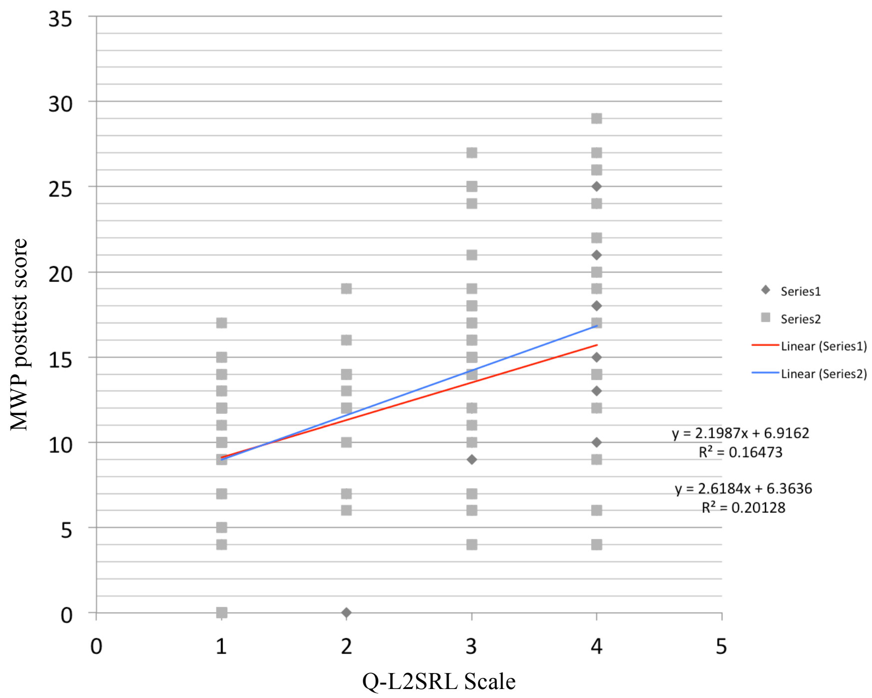


Figure 7-10 A scatterplot of UL-SUP-S (red) and ASL- SUP-S (blue) vs MWP posttest score.

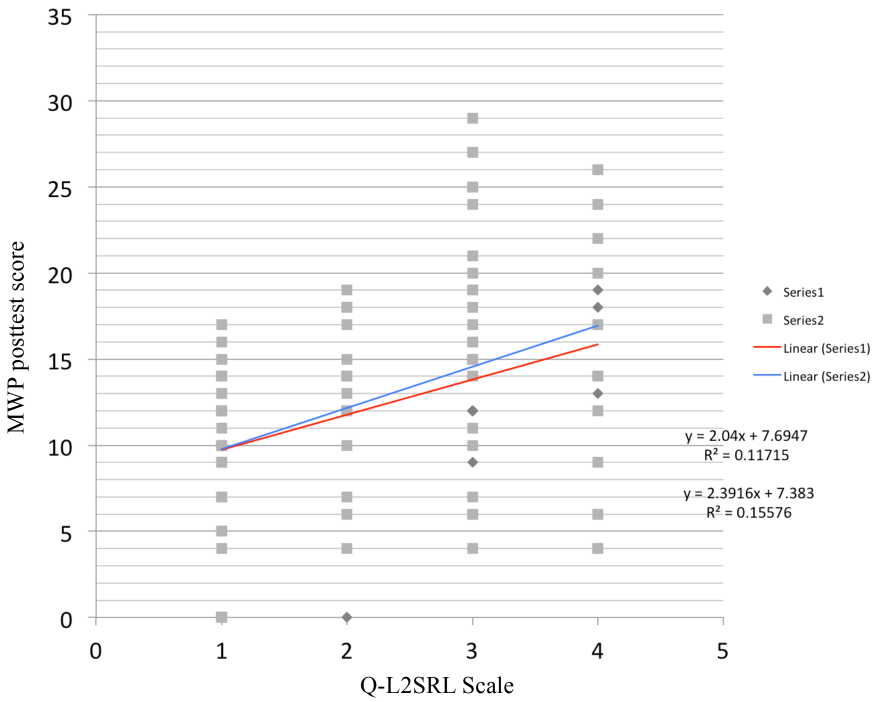


Figure 7-11 A scatterplot of UL-SUP-C (red) and ASL- SUP-C (blue) vs MWP posttest score.

7.6. Discussion

From the research questions: (i) Can CREMA really support learners to gain S2SRL in MWP learning?; and (ii) How does CREMA work in a practical environment?

To answer the first question, the questionnaire, Q-L2SRL, was developed to access whether students have gained S2SRL in MWP learning, i.e., whether students began to be curious about their own understanding and awareness of self-improvement in MWP learning after having trained from the environment influenced by the proposed model, CREMA. The questionnaire, Q-L2SRL, was applied on the class of students who learnt MWP with the environment implemented by applying CREMA as a framework (CREMA) and the class of students who learnt MWP solving in the traditional method (CTRL). The result from the comparison revealed that the proposed model, CREMA, is effective for encouraging students to become curious about their own understanding and awareness of self-improvement in MWP learning for all considered aspects in Table 3-6 in section 3.4.

Next, I demonstrate and express the answer to the second question. First about the effectiveness of MetaQ—metacognitive questions and motivative statements, as I described CREMA in chapter 4, MetaQ is the main support in the proposed model, CREMA. It appears in all phases of the model, CREMA. There are studies showed the benefits of training learning skills using metacognitive questions and answers (Jacobse & Harskamp, 2009; Mevarech & Kramarski, 2003). To confirm the effectiveness of MetaQ, the class of students who learnt MWP solving in traditional method combining MetaQ (CTRL+MetaQ) was considered against CTRL. The result showed that MetaQ was a factor that affects students to gain S2SRL in MWP learning.

Secondly, I claimed that computer technology was another key factor to enhance students' learning sense and to empower methodology to facilitate learning objects in CREMA. The comparison between CTRL+MetaQ and CREMA could confirm this claim. From the class observation, I could demonstrate the claim that the students in CREMA individually received MetaQ related with what they were focusing in and they had equal chance to respond MetaQ and got suggestion related directly to their behaviors from the system, whereas, the students in CTRL+MetaQ received the same MetaQ when the teacher delivered at the same time, in this case, some students might think about MetaQ, some played with friends and did not listen to the teacher and concentrate on class content, because a number of students in class, it made the teacher could not take care of individual students effectively. This could be an explanation why there are more frequencies of the number of students in CREMA gave positive responses than the number of students in CTRL+MetaQ, as the result shown in Table 7-3 and 4.

Thirdly, when we considered the comparisons of the MWP posttest. Students in CREMA were outstanding from the other groups with the significant difference in the comparison with CTRL. There is no significant difference between the comparisons of CTRL+MetaQ vs CREMA and CTRL vs CTRL+MetaQ. This might be because the groups of subjects were low-performance students and the short training period, the subjects were quite weak in Mathematics and lacked of background knowledge in several areas needed for solving MWP (e.g., reading comprehension, basic calculation proficiency, etc.), they needed more time for practicing and improving their skills. However, all students in CREMA could state their difficulties and reasons why they failed to solve the problems contrasting with the other groups. This showed that they have gained a basic skill to clarify their self-difficulties which can be used to develop their MWP learning performance. It can be explained by that, only in CREMA, QAS and InDi were applied as a representation to support the students to gain more understanding in MWP solving process and help them to be able to clarify their self-difficulties in the tasks, this would help them to set their sub-learning goal to fulfill their difficulties.

7.7. Conclusion

In conclusion, the implementation of the proposed model, CREMA, could effectively support learners to gain Seed skill to become self-regulated learners in MWP learning, in which MetaQ played a key role in CREMA while appropriate emerging Optional supports (Explanation, think representation, practice) could enhance the effect of MetaQ. And by integrating with computer and technology, it could enhance learners' learning sense and to empower methodology to facilitate learning objects, while

MWP involves a process which benefits training metacognition in which we could use its benefit to prepare learning process representation. The finding of the research reveals an alternative direction to support self-regulation by promoting S2SRL which is a basic skill for learners to simulate and grow self-regulated learning skills. I recognize the need to define and examine components of CREMA that are linked to qualities of mutual engagement and learners' learning. Moreover, I recognize the need to understand more about how MetaQ are integrated with different supports in different advanced technology environments. However, further research is needed to investigate the long-term of support effect. What support could be involved in the model to empower its effectiveness and support learners to become more independent in learning and change their status from passive learners to be active learners?

CHAPTER 8
Dissertation Conclusion

This chapter makes the general conclusion of the overall dissertation from the first chapter. Then, the impact and contribution of the research study are appealed. Finally, the study limitation and suggestion of the future are revealed.

8.1. Conclusion

This dissertation started from my interest in students' difficulties in solving MWP, from my own experience in the educational field. I found the evidence from standard tests (e.g., TIMSS, PISA, etc.) that it is not only my students having difficulties with MWP learning but it is a common problem worldwide. I explained in the chapter one and two that solving MWP required metacognitive skills. From the literature reviews, students rarely take the time to monitor and regulate the use of cognitive strategies, even if they understand the calculations embedded in the word problem. This causes them to skip or misinterpret information from the problem and choose inappropriate solutions. Then, these made them involved in the trouble of constructing a problem model from a problem context. The skills to monitor and regulate the use of cognitive strategies are involved in metacognitive skill—which is necessary to support students to structure their problem-solving process in MWP as well as in real life. It was found that solving MWP having a room to applied metacognitive skills, I considered this as an advantageous feature of MWP which could be employed as a medium to train metacognition instead of using a real-life problem, which is ill-defined and unstructured. Due to complexity and implicitness of metacognition combining with an unstructured problem, it might be quite complicated and could cause frustration in novice learners.

To avoid producing cognitive load and frustration which is a cause of demotivation in novices or young learners and to encourage them to become familiar with and be able to perform metacognitive skill, I do believe that there should be an implicit meta-level thinking skill which could be alike an assisting ladder to support them to step up to the stage of self-regulated learners. I would name that implicit skill as S2SRL. S2SRL refers to a very basic skill to be able to develop into metacognitive skills. It is defined in this study as a skill in which learners are curious on their own understanding and awareness of self-improvement in their learning before learners can perform metacognitive questions by themselves to reflect their own cognition for planning, monitoring, and doing self-evaluation. To encourage learners to be curious on their own understanding and awareness of self-improvement in their learning or to gain S2SRL, it is necessary to motivate and facilitate them to have the clear process of a given task in their mind. Later, they can use those in their mind as their cognitive target to perform meta-level thinking.

To perform a research in education field, there is no rule of common definitions. Due to the implicitness and the abstraction of metacognition, it causes the definition of metacognition and its related terms still remain quite blurred and confused, even though there have been a number of researches on this topic. It is not a good idea to assume that readers will have a common understanding with the researchers on the meanings and borderlines of terms especially in an area where definitions can easily make confusion. In this dissertation, the goal of training metacognitive skills is to help learners to be comfortable with applying meta-level thinking on their cognitive process and become self-regulated learners who can automatically monitor and regulate their learning processes and be aware of their difficulties to achieve their tasks. From this exposition of training metacognition, there was a curiosity of what are required skills of self-regulated learners in MWP learning. In chapter three, the process of providing the description of the required skills of self-regulated learners in MWP learning for this dissertation was explained. According to the proposed required skills of self-regulated learners in MWP learning, S2SRL in MWP learning is precisely defined in this chapter.

In this dissertation, S2SRL in MWP learning is referred to a basic skill that learners can further develop to be the required skills of self-regulated learners in MWP learning. That is, learners are curious on their own "*understanding of MWP learning*" and "*awareness of self-improvement in MWP learning*" before learners can perform metacognitive questions by themselves to reflect their own cognition for planning, monitoring, and doing self-evaluation. "*Understanding of MWP learning*" and "*awareness of self-improvement in MWP learning*", here, are considered in 3 aspects (Stimulus, Self-understanding toward task, Self-understanding toward learning process) of the required skills of self-regulated learners in MWP learning as shown in Table 3-6 in section 3.4.

Based on the terminology definition of S2SRL, to achieve my desire to design an environment for encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning, instead of just proposing a specific environment, there is more impact to create a framework for designing a required environment. Thus, CREMA has been developed to be a framework for designing an environment to encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning. The construction detail of CREMA and the theory behind its design were explained in chapter four. This raised the research problems that "can the proposed framework really support learner to gain S2SRL?" And "how does it work in a practical environment?"

In order to answer the recent research questions, a learning environment, implemented by applying CREMA as a framework, was prepared (Chapter 5). The investigation to evaluate the effectiveness of and investigate the implementation of CREMA was performed by comparing three classes of low-performance students of grade-9 were assigned into three different learning groups: (i) a group of students who learnt MWP with our proposed method by implementing CREMA, (ii) a group of students who learnt MWP in traditional method combining MetaQ, and (iii) a group of students who learnt MWP in traditional method. The methodology of the investigation was explained in chapter six. The chapter seven, then, revealed the result from the investigation that the implementation of the proposed model, CREMA, could effectively support learners to gain S2SRL in MWP learning, in which MetaQ played a key role in CREMA while appropriate emerging Optional supports (Explanation, think representation, practice) could enhance the effect of MetaQ. And by integrating with computer and technology, it could enhance learners' learning sense and to empower methodology to facilitate learning objects, while MWP involves a process which benefits training metacognition in which we could use its key features to prepare a representation of learning process.

8.2. Research Impact and Contribution

8.2.1. Originality of the research

In this dissertation, there are four major novelties are emphasized:

1) I introduced the term, S2SRL, as the basic skills to be able to develop into self-regulated learning skills. It is the initial state to promote to learners for developing themselves to become self-regulated learners.
2) I expressed the key features of MWP for utilizing it as a medium to promote meta-level thinking, i.e., MWP solving has an *'explicit form of solution process'* which is a good feature to support monitoring and to create representation framework to externalize problem-solving process. Moreover, its *'complexity of solution process'* and *'many explicit operators at each step'* are beneficial features to support metacognitive training, in which the former feature promotes reflectively analyzing the thinking process and the latter feature is good to promote regulation of making decision criteria.
3) I proposed QAS and InDi as media for facilitating and supporting learners to acquire their self-difficulties in MWP learning.
4) I proposed CREMA to encourage learners to use intrinsic comprehension of metacognitive questioning to acquire S2SRL in MWP learning. The concept of the proposed model, CREMA, is to support/facilitate learners learn how to learn MWP and get used to utilize metacognitive questioning and answering by delivering appropriate metacognitive questions with

Optional supports (Explanation, thinking process representation, practice) at the right time and events together with enhancing them to reflect on clearer process of problem solving by graphical representation.

8.2.2. Contribution to knowledge science society

Due to the implicitness of metacognition and the complication of its training process, it makes training learners self-regulation becomes more complicated. For knowledge science society, this research provides an alternative framework to deal with implicit knowledge to determine 'how could we manage and utilize the knowledge of dealing with implicit skills such as metacognition?' From the research goal to find a framework for designing an environment for encouraging learners to use intrinsic comprehension of metacognitive questioning to acquire Seed Skill to become a self-regulated learner in MWP learning, the knowledge in this dissertation is "the methodology to encourage learners to use intrinsic comprehension of metacognitive questioning to acquire Seed Skill to become a self-regulated learner in MWP learning". In the dissertation, I indicated the important to precisely clarify the related terminologies in the studies (e.g., metacognition, self-regulation, factors of self-regulated learners, etc.) to enable the management on the knowledge and become the benefit for sharing the knowledge.

8.2.3. Contribution to academic society

This dissertation integrates the various disciplines and techniques in three different areas: education, psychology, and information science. So, it could have the potential to contribute to the field. The finding of the research might contribute an alternative direction to support self-regulation by promoting S2SRL which is a basic skill for learners to simulate and grow self-regulated learning skills. The need to define and examine components of CREMA that are linked to qualities of mutual engagement and learners' learning and the need to understand more about how MetaQ are integrated with various supports in different advanced technology environments are recognized. CREMA could be an alternative framework for educators to develop their own learning environment to promote self-regulation in MWP learning. In addition, S2SRL in MWP learning might be an alternative framework for other researchers to develop an idea to promote self-regulation in other domain. Another contribution is that the research result would give some benefits for establishing the deep understanding in promoting metacognition in the educational research and community.

8.3. Limitation and Future work

Even though under the constraints of this dissertation, the implementation of CREMA as a framework for promoting S2SRL in MWP learning was successfully proved, however, due to the limitation of time and resource during the research process, there are still some points should be improved to enhance the existing accomplishment.

Long-term of support effect

Sine the research was performed in quite a short period which could be investigated only the initial state of learners' change. However, further research is needed to investigate the long-term of support effect. What support could we involve in the model to empower its effectiveness and support the learners become more independent in learning and change their status from passive learners to be active learners?

Data collection process and development of a learning environment from CREMA

In this dissertation, various platforms were combined to follow CREMA to represent the learning environment for supporting learners to gain S2SRL in MWP learning. Due to the incompletion of the system implementation and the students' financial status that they had no personal computers of their own, all assignment and activities could not be performed via computer environment some activities still use manual implementation combining with MathReflect system. Complete system implementation and data collection algorithm would help a lot to enable us to have more data to be analyzed and interpreted in more various aspects of studies, such as detail of students behavior during using the system, etc.

Observing different groups of students

A next recommendation would be to further study how metacognition influences performance for different subsamples of students. In this study, only low-performance students were investigated. Most designs of the environment was designed to suit the behavior of this group of students. To be able to interpret several groups of learners various group of types of students should be involved.

Including teacher to metacognitive training

The further recommendation is to involve teachers in research studies about training metacognition to connect finding from research to real classrooms. The finding in this dissertation showed that when researchers supervise if the computer program is implemented well, the proposed training could affect students' awareness of their understanding and self-improvement in MWP learning. Nevertheless, it could not show how teachers can manage this kind of environment.

LIST OF PUBLICATIONS

Student name: DUANGNAMOL Tama

Title of dissertation: Computer-Supported Meta-Reflective Learning Model via Learning Mathematical Word Problem to Acquire Seed Skill to Become a Self-Regulated Learner
(自己調整学習スキルの基礎を形成するリフレクティブ学習モデルに基づく数学文章題学習環境)

- ***Papers published in journals***

[1] Duangnamol, T., Supnithi, T., Srijuntongsiri, G., & Ikeda, M., Computer-Supported Meta-Reflective Learning Model via Mathematical Word Problem (MWP) Learning For Training Metacognition, Research and Practice in Technology Enhanced Learning. (In press).

- ***Oral presentations at conferences***

[2] Duangnamol, T., Supnithi, T., Srijuntongsiri, G., & Ikeda, M., Analyzing a Practical Implementation of Training Metacognition through Solving Mathematical Word Problems. The 25th International Conference on Computers in Education, pp.204-209, December 4-8, 2017, Christchurch, New Zealand.

[3] Duangnamol, T., Supnithi, T., Suntisrivaraporn, B., & Ikeda, M., Facilitating Metacognitive Skill using Computer-Supported Multi-Reflective Learning: Case Study of MWP Solving. The 23rd International Conference on Computers in Education, pp.124-133, November 30-December 4, 2015, Hangzhou, China. (Nominated as the best over all paper award)

[4] Duangnamol, T., Suntisrivaraporn, B., Supnithi, T. and Ikeda, M. Circuitously Collaborative Learning Environment to Enhance Metacognition in Solving Mathematical Word Problem, The 22nd International Conference on

Computers in Education, pp.251-253, November 30-December 4, 2014, Nara, Japan. (poster presentation)

[5] Duangnamol, T., Suntisrivaraporn, B., Supnithi, T. and Ikeda, M. Engaging Reflective Thinking in Learning Mathematics Word Problem by Chatbot as Personal Tutoring Agent, the 2nd Asian Conference on Information Systems, pp.239-246, October 31 – November 2, 2013, Phuket, Thailand.

- ***Domestic conference proceedings***

[6] Duangnamol, T. & Ikeda, M. (2016). Supporting Metacognition in a Collaborative Environment via Solving Mathematics Word Problem Solving, the 6th Forum in Knowledge Co-creation, March 12–13, 2016, Kanazawa, Japan. (poster presentation)

- ***Others***

[7] Duangnamol, T., Suntisrivaraporn, B., Supnithi, T. and Ikeda, M. Circuitously Collaborative Learning Environment to Enhance Metacognition, Doctoral Student Consortium Proceeding of the 22nd International Conference on Computers in Education, pp.1-4, December 1, 2014, Nara, Japan.

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APPENDIX A: Statistical test by One-way ANOVA of the Q-L2SRL pretest

Table A-1. Analysis of variance (Q-L2SRL_pre):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.014	0.007	0.100	0.905
Error	98	6.907	0.070		
Corrected Total	100	6.921			

Computed against model Y=Mean(Y)

Table A-2. Analysis of variance (UL-STM-A):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.018	0.009	0.187	0.830
Error	98	4.734	0.048		
Corrected Total	100	4.752			

Computed against model Y=Mean(Y)

Table A-3. Analysis of variance (UL-STM-G):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.069	0.035	0.266	0.767
Error	98	12.703	0.130		
Corrected Total	100	12.772			

Computed against model Y=Mean(Y)

Table A-4. Analysis of variance (UL-STM-M):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.236	0.118	0.567	0.569
Error	98	20.398	0.208		
Corrected Total	100	20.634			

Computed against model Y=Mean(Y)

Table A-5. Analysis of variance (UL-SUT-K):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.094	0.047	0.255	0.775
Error	98	18.045	0.184		
Corrected Total	100	18.139			

Computed against model Y=Mean(Y)

Table A-6. Analysis of variance (UL-SUT-P):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.017	0.008	0.032	0.968
Error	98	25.409	0.259		
Corrected Total	100	25.426			

Computed against model Y=Mean(Y)

Table A-7. Analysis of variance (UL-SUT-D):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.000	0.000	0.001	0.999
Error	98	16.772	0.171		
Corrected Total	100	16.772			

Computed against model Y=Mean(Y)

Table A-8. Analysis of variance (UL-SUP-S):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.084	0.042	0.271	0.763
Error	98	15.242	0.156		
Corrected Total	100	15.327			

Computed against model Y=Mean(Y)

Table A-9. Analysis of variance (UL-SUP-C):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.017	0.009	0.076	0.927
Error	98	11.309	0.115		
Corrected Total	100	11.327			

Computed against model Y=Mean(Y)

Table A-10. Analysis of variance (ASL-STM-A):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.058	0.029	0.995	0.373
Error	98	2.853	0.029		
Corrected Total	100	2.911			

Computed against model Y=Mean(Y)

Table A-11. Analysis of variance (ASL-STM-G):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.250	0.125	1.957	0.147
Error	98	6.265	0.064		
Corrected Total	100	6.515			

Computed against model Y=Mean(Y)

Table A-12. Analysis of variance (ASL-STM-M):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.404	0.202	**2.539**	**0.084**
Error	98	7.794	0.080		
Corrected Total	100	8.198			

Computed against model Y=Mean(Y)

Table A-13. Analysis of variance (ASL-SUT-K):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.055	0.027	0.328	0.721
Error	98	8.143	0.083		
Corrected Total	100	8.198			

Computed against model Y=Mean(Y)

Table A-14. Analysis of variance (ASL-SUT-P):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.055	0.027	0.328	0.721
Error	98	8.143	0.083		
Corrected Total	100	8.198			

Computed against model Y=Mean(Y)

Table A-15. Analysis of variance (ASL-SUT-D):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.132	0.066	0.894	0.412
Error	98	7.234	0.074		
Corrected Total	100	7.366			

Computed against model Y=Mean(Y)

Table A-16. Analysis of variance (ASL-SUP-S):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.139	0.070	0.943	0.393
Error	98	7.227	0.074		
Corrected Total	100	7.366			

Computed against model Y=Mean(Y)

Table A-17. Analysis of variance (ASL-SUP-C):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.132	0.066	0.894	0.412
Error	98	7.234	0.074		
Corrected Total	100	7.366			

Computed against model Y=Mean(Y)

APPENDIX B: Statistical test by One-way ANOVA of the Q-L2SRL posttest

Table B1-1. Analysis of variance (Q-L2SRL_post):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	81.576	40.788	128.045	**< 0.0001**
Error	98	31.217	0.319		
Corrected Total	100	112.794			

Computed against model Y=Mean(Y)

Table B2-1. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (Q-L2SRL_post):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.198	15.922	2.380	**< 0.0001**	Yes	1.869	2.526
CREMA vs CNTRL+MetaQ	1.184	8.647	2.380	**< 0.0001**	Yes	0.858	1.509
CNTRL+MetaQ vs CNTRL	1.014	7.351	2.380	**< 0.0001**	Yes	0.686	1.343
Tukey's d critical value:			3.366				

Table B1-2. Analysis of variance (postUL-STM-A):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	86.293	43.146	107.129	**< 0.0001**
Error	98	39.470	0.403		
Corrected Total	100	125.762			

Computed against model Y=Mean(Y)

Table B2-2. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-STM-A):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.264	14.598	2.380	**< 0.0001**	Yes	1.895	2.633
CREMA vs CNTRL+MetaQ	0.971	6.306	2.380	**< 0.0001**	Yes	0.604	1.337
CNTRL+MetaQ vs CNTRL	1.293	8.339	2.380	**< 0.0001**	Yes	0.924	1.662
Tukey's d critical value:			3.366				

Table B1-3. Analysis of variance (postUL-STM-G):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	108.103	54.051	128.804	**< 0.0001**
Error	98	41.125	0.420		
Corrected Total	100	149.228			

Computed against model Y=Mean(Y)

Table B2-3. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-STM-G):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.525	15.950	2.380	**< 0.0001**	Yes	2.148	2.902
CREMA vs CNTRL+MetaQ	1.000	6.365	2.380	**< 0.0001**	Yes	0.626	1.374
CNTRL+MetaQ vs CNTRL	1.525	9.633	2.380	**< 0.0001**	Yes	1.148	1.902
Tukey's d critical value:			3.366				

Table B1-4. Analysis of variance (postUL-STM-M):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	76.809	38.405	98.066	**< 0.0001**
Error	98	38.379	0.392		
Corrected Total	100	115.188			

Computed against model Y=Mean(Y)

Table B2-4. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-STM-M):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.135	13.964	2.380	**< 0.0001**	Yes	1.772	2.499
CREMA vs CNTRL+MetaQ	0.912	6.007	2.380	**< 0.0001**	Yes	0.551	1.273
CNTRL+MetaQ vs CNTRL	1.224	8.002	2.380	**< 0.0001**	Yes	0.860	1.588
Tukey's d critical value:			3.366				

Table B1-5. Analysis of variance (postUL-SUT-K):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	74.177	37.088	56.355	**< 0.0001**
Error	98	64.496	0.658		
Corrected Total	100	138.673			

Computed against model Y=Mean(Y)

Table B2-5 Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-SUT-K):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.100	10.592	2.380	**< 0.0001**	Yes	1.628	2.572
CREMA vs CNTRL+MetaQ	0.912	4.634	2.380	**< 0.0001**	Yes	0.444	1.380
CNTRL+MetaQ vs CNTRL	1.188	5.993	2.380	**< 0.0001**	Yes	0.716	1.660
Tukey's d critical value:			3.366				

Table B1-6. Analysis of variance (postUL-SUT-P):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	3	86.084	28.695	44.094	**< 0.0001**
Error	97	63.124	0.651		
Corrected Total	100	149.208			

Computed against model Y=Mean(Y)

Table B2-6. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-SUT-P):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.160	10.683	2.380	**< 0.0001**	Yes	1.679	2.642
CREMA vs CNTRL+MetaQ	0.647	3.224	2.380	**0.005**	Yes	0.169	1.125
CNTRL+MetaQ vs CNTRL	1.513	7.483	2.380	**< 0.0001**	Yes	1.032	1.995
Tukey's d critical value:			3.366				

Table B1-7. Analysis of variance (postUL-SUT-D):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	58.136	29.068	34.781	**< 0.0001**
Error	98	81.904	0.836		
Corrected Total	100	140.040			

Computed against model Y=Mean(Y)

Table B2-7. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-SUT-D):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	1.856	8.306	2.380	**< 0.0001**	Yes	1.324	2.387
CREMA vs CNTRL+MetaQ	1.059	4.775	2.380	**< 0.0001**	Yes	0.531	1.586
CNTRL+MetaQ vs CNTRL	0.797	3.567	2.380	**0.002**	Yes	0.265	1.328
Tukey's d critical value:			3.366				

Table B1-8. Analysis of variance (postUL-SUP-S):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	96.630	48.315	79.833	**< 0.0001**
Error	98	59.310	0.605		
Corrected Total	100	155.941			

Computed against model Y=Mean(Y)

Table B2-8. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-SUP-S):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.345	12.335	2.380	**< 0.0001**	Yes	1.893	2.797
CREMA vs CNTRL+MetaQ	0.706	3.741	2.380	**0.001**	Yes	0.257	1.155
CNTRL+MetaQ vs CNTRL	1.639	8.622	2.380	**< 0.0001**	Yes	1.187	2.091
Tukey's d critical value:			3.366				

Table B1-9. Analysis of variance (postUL-SUP-C):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	90.766	45.383	116.837	**< 0.0001**
Error	98	38.066	0.388		
Corrected Total	100	128.832			

Computed against model Y=Mean(Y)

Table B2-9. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postUL-SUP-C):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.290	15.034	2.380	**< 0.0001**	Yes	1.927	2.652
CREMA vs CNTRL+MetaQ	0.765	5.059	2.380	**< 0.0001**	Yes	0.405	1.124
CNTRL+MetaQ vs CNTRL	1.525	10.013	2.380	**< 0.0001**	Yes	1.163	1.887
Tukey's d critical value:			3.366				

Table B1-10. Analysis of variance (postASL-STM-A):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	84.920	42.460	92.184	**< 0.0001**
Error	98	45.139	0.461		
Corrected Total	100	130.059			

Computed against model Y=Mean(Y)

Table B2-10. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-STM-A):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.233	13.462	2.380	**< 0.0001**	Yes	1.838	2.627
CREMA vs CNTRL+MetaQ	1.353	8.219	2.380	**< 0.0001**	Yes	0.961	1.745
CNTRL+MetaQ vs CNTRL	0.880	5.304	2.380	**< 0.0001**	Yes	0.485	1.274
Tukey's d critical value:			3.366				

Table B1-11. Analysis of variance (postASL-STM-G):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	104.015	52.007	101.522	**< 0.0001**
Error	98	50.203	0.512		
Corrected Total	100	154.218			

Computed against model Y=Mean(Y)

Table B2-11. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-STM-G):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.465	14.095	2.380	**< 0.0001**	Yes	2.049	2.881
CREMA vs CNTRL+MetaQ	1.529	8.810	2.380	**< 0.0001**	Yes	1.116	1.943
CNTRL+MetaQ vs CNTRL	0.936	5.351	2.380	**< 0.0001**	Yes	0.520	1.352
Tukey's d critical value:			3.366				

Table B1-12. Analysis of variance (postASL-STM-M):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	72.140	36.070	92.783	**< 0.0001**
Error	98	38.098	0.389		
Corrected Total	100	110.238			

Computed against model Y=Mean(Y)

Table B2-12. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-STM-M):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.049	13.448	2.380	**< 0.0001**	Yes	1.686	2.412
CREMA vs CNTRL+MetaQ	1.294	8.558	2.380	**< 0.0001**	Yes	0.934	1.654
CNTRL+MetaQ vs CNTRL	0.755	4.955	2.380	**< 0.0001**	Yes	0.392	1.118
Tukey's d critical value:			3.366				

Table B1-13. Analysis of variance (postASL-SUT-K):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	82.486	41.243	66.520	**< 0.0001**
Error	98	60.761	0.620		
Corrected Total	100	143.248			

Computed against model Y=Mean(Y)

Table B2-13. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-SUT-K):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.129	11.066	2.380	**< 0.0001**	Yes	1.671	2.587
CREMA vs CNTRL+MetaQ	1.588	8.316	2.380	**< 0.0001**	Yes	1.134	2.043
CNTRL+MetaQ vs CNTRL	0.541	2.812	2.380	**0.016**	Yes	0.083	0.999
Tukey's d critical value:			3.366				

Table B1-14. Analysis of variance (postASL-SUT-P):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	89.128	44.564	72.714	**< 0.0001**
Error	98	60.061	0.613		
Corrected Total	100	149.188			

Computed against model Y=Mean(Y)

Table B2-14. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-SUT-P):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.189	11.442	2.380	**< 0.0001**	Yes	1.734	2.644
CREMA vs CNTRL+MetaQ	1.706	8.984	2.380	**< 0.0001**	Yes	1.254	2.158
CNTRL+MetaQ vs CNTRL	0.483	2.525	2.380	**0.035**	Yes	0.028	0.938
Tukey's d critical value:			3.366				

Table B1-15. Analysis of variance (postASL-SUT-D):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	107.472	53.736	135.432	**< 0.0001**
Error	98	38.884	0.397		
Corrected Total	100	146.356			

Computed against model Y=Mean(Y)

Table B2-15. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-SUT-D):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.399	15.587	2.380	**< 0.0001**	Yes	2.033	2.766
CREMA vs CNTRL+MetaQ	1.882	12.321	2.380	**< 0.0001**	Yes	1.519	2.246
CNTRL+MetaQ vs CNTRL	0.517	3.358	2.380	**0.003**	Yes	0.151	0.883
Tukey's d critical value:			3.366				

Table B1-16. Analysis of variance (postASL-SUP-S):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	68.673	34.336	51.230	**< 0.0001**
Error	98	65.684	0.670		
Corrected Total	100	134.356			

Computed against model Y=Mean(Y)

Table B2-16. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-SUP-S):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	1.985	9.921	2.380	**< 0.0001**	Yes	1.509	2.461
CREMA vs CNTRL+MetaQ	1.324	6.666	2.380	**< 0.0001**	Yes	0.851	1.796
CNTRL+MetaQ vs CNTRL	0.661	3.306	2.380	**0.004**	Yes	0.185	1.137
Tukey's d critical value:			3.366				

Table B1-17. Analysis of variance (postASL-SUP-C):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	78.383	39.192	83.043	**< 0.0001**
Error	98	46.250	0.472		
Corrected Total	100	124.634			

Computed against model Y=Mean(Y)

Table B2-17. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (postASL-SUP-C):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant	Lower bound (95%)	Upper bound (95%)
CREMA vs CNTRL	2.141	12.752	2.380	**< 0.0001**	Yes	1.741	2.540
CREMA vs CNTRL+MetaQ	1.324	7.944	2.380	**< 0.0001**	Yes	0.927	1.720
CNTRL+MetaQ vs CNTRL	0.817	4.868	2.380	**< 0.0001**	Yes	0.418	1.217
Tukey's d critical value:			3.366				

APPENDIX C: Statistical test by One-way ANOVA of the MWP pretest and posttest

Table C1-1. Analysis of variance (MWP_pretest):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.020	0.010	0.020	0.980
Error	98	49.940	0.510		
Corrected Total	100	49.960			

Computed against model Y=Mean(Y)

Table C2-1. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (MWP_pretest):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CNTRL vs CREMA	0.030	0.174	2.380	0.984	No
CNTRL vs CNTRL+MetaQ	0.001	0.005	2.380	1.000	No
CNTRL+MetaQ vs CREMA	0.029	0.170	2.380	0.984	No
Tukey's d critical value:			3.366		

Table C1-2. Analysis of variance (MWP-Posttest):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	3	458.549	152.850	3.600	**0.016**
Error	97	4118.006	42.454		
Corrected Total	100	4576.554			

Computed against model Y=Mean(Y)

Table C2-2. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (MWP-Posttest):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CREMA vs CNTRL	4.966	3.119	2.380	**0.007**	Yes
CREMA vs CNTRL+MetaQ	2.530	1.600	2.380	0.250	No
CNTRL+MetaQ vs CNTRL	2.437	1.530	2.380	0.281	No
Tukey's d critical value:			3.366		

Table C1-3. Analysis of variance (post-MWP-1):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	2.843	1.421	0.754	0.473
Error	98	184.860	1.886		
Corrected Total	100	187.703			

Computed against model Y=Mean(Y)

Table C2-3. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (post-MWP-1):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CREMA vs CNTRL	0.407	1.214	2.380	0.448	No
CREMA vs CNTRL+MetaQ	0.147	0.441	2.380	0.898	No
CNTRL+MetaQ vs CNTRL	0.260	0.775	2.380	0.719	No
Tukey's d critical value:			3.366		

Table C1-4. Analysis of variance (post-MWP-2):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	0.723	0.362	0.185	0.831
Error	98	191.574	1.955		
Corrected Total	100	192.297			

Computed against model Y=Mean(Y)

Table C2-4. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (post-MWP-2):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CNTRL+MetaQ vs CNTRL	0.202	0.592	2.380	0.825	No
CNTRL+MetaQ vs CREMA	0.059	0.173	2.380	0.984	No
CREMA vs CNTRL	0.143	0.420	2.380	0.907	No
Tukey's d critical value:			3.366		

Table C1-5. Analysis of variance (post-MWP-3):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	172.841	86.421	35.744	**< 0.0001**
Error	98	236.941	2.418		
Corrected Total	100	409.782			

Computed against model Y=Mean(Y)

Table C2-5. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (post-MWP-3):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CREMA vs CNTRL	3.059	8.050	2.380	**< 0.0001**	Yes
CREMA vs CNTRL+MetaQ	2.353	6.239	2.380	**< 0.0001**	Yes
CNTRL+MetaQ vs CNTRL	0.706	1.858	2.380	0.157	No
Tukey's d critical value:			3.366		

Table C1-6. Analysis of variance (post-MWP-4):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	12.779	6.390	2.257	0.110
Error	98	277.439	2.831		
Corrected Total	100	290.218			

Computed against model Y=Mean(Y)

Table C2-6. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (post-MWP-4):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CNTRL+MetaQ vs CNTRL	0.848	2.061	2.380	0.103	No
CNTRL+MetaQ vs CREMA	0.235	0.577	2.380	0.833	No
CREMA vs CNTRL	0.612	1.489	2.380	0.301	No
Tukey's d critical value:			3.366		

Table C1-7. Analysis of variance (post-MWP-5):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	1.968	0.984	0.387	0.680
Error	98	249.398	2.545		
Corrected Total	100	251.366			

Computed against model Y=Mean(Y)

Table C2-7. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (post-MWP-5):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CREMA vs CNTRL	0.332	0.851	2.380	0.673	No
CREMA vs CNTRL+MetaQ	0.088	0.228	2.380	0.972	No
CNTRL+MetaQ vs CNTRL	0.243	0.624	2.380	0.807	No
Tukey's d critical value:			3.366		

Table C1-8. Analysis of variance (post-MWP-6):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	2	2.455	1.228	9.275	**0.000**
Error	98	12.971	0.132		
Corrected Total	100	15.426			

Computed against model Y=Mean(Y)

Table C2-8. Group / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (post-MWP-6):

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
CREMA vs CNTRL	0.382	4.301	2.380	**0.000**	Yes
CREMA vs CNTRL+MetaQ	0.206	2.333	2.380	0.056	No
CNTRL+MetaQ vs CNTRL	0.176	1.985	2.380	0.121	No
Tukey's d critical value:			3.366		