Research about Metacognition in Science Education: A Case of Basic Education in Thailand

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Abstract. Metacognition has been regarded as a research variable more than four decades ago with its general definition of knowing about knowing. It is genuinely difficult to study about metacognition because it is an abstract process occurred in one’s mind. A number of studies about metacognition have been conducted in an international context to derive more understanding about a metacognitive process and its benefits. There are some studies related to metacognition in the Thai context; so, it is a need to explore the current situation of metacognition research in Thailand. The metacognitive studies conducted during 2002-2016 have been intensively reviewed. The researchers found 22 research studies related to metacognition in Thailand; three, 10 and nine of them had been conducted in the primary, lower-secondary and upper-secondary levels, respectively. All metacognitive studies could be grouped into five categories: a) Impact of metacognition on other research variables (n = 9); b) Teaching strategies to enhance metacognition (n = 7); c) Developing measurement tool for metacognition (n = 3); d) Causal model of metacognition (n = 2); and e) Factors of metacognition (n = 1). Two dominant categories (16 of 22 or 72.73%) were the ‘Impact of metacognition’ and ‘Teaching strategies enhancing metacognition’ categories. Interestingly, there were five studies aimed to explore the impact of students’ developed metacognition on problem-solving skill. The teaching strategies employed to enhance students’ metacognition are diverse including 5E or 7E model, learning cycle, problem-based learning, open-ended problems, constructivist and Tri-Sik-Kha instruction.

1. Introduction

Metacognition is presently recognized as one research variable in science education context. The definition of metacognition is diverse. The most well-known definition of metacognition comes from Flavell the late 1970 that was cited by [5] as “cognition about cognitive phenomena” or “thinking about thinking” [6]. Other definitions of metacognition are “metacognition is the monitor and control of thought” [11], “Metacognition is essential for successful learning” [23] and “Metacognition is any knowledge or cognitive activity that takes as its object or regulates, any aspect of any cognitive enterprise” [22].

Flavell and his colleagues divided metacognition into two main components: Knowledge of Cognition (metacognitive knowledge) and Regulation of Cognition (metacognitive monitoring and self-regulation). Later, the third component was added, that is, Metacognitive Experiences [4]. Other researchers have addressed various components of metacognition depending on their theoretical or conceptual frameworks. Research about metacognition has taken rooted in science education context for five decades and there is one international journal specially devoted for it namely Metacognition
and Learning. Metacognition is regarded as one desirable kind of thinking for students with its benefit in promoting students’ thinking and learning achievement in various subjects and contexts.

In Thailand, metacognition is paid attention in educational context for two decades ago and there was a number of research studies related to metacognition. However, there is no study aimed to review the past studies of metacognition in the basic education context of Thailand. Consequently, the main objective of this study is to intensively review the research studies dealt with metacognition in the basic education context of Thailand during 2002-2016.

2. Literature review about review study in metacognition in science education context
From the review of literature related to metacognition in an international context. The review study about metacognition is rare. There are only two review studies and one book related to metacognition in science education. Then, we conclude the method of these studies to conduct the category in this paper.

The first review study is named “Metacognition: a literature review in science” [5]. In this study, the researchers focused metacognition as one goal in science education. It presented the definitions of metacognition stated by many researchers and the typology of metacognitive components. Also, the researchers presented the ways to assess metacognition and teacher development models regarding metacognition.

The second review study was entitled “Review of research on metacognition in science education: current and future directions” [29]. This review study presented metacognition in key trends in for 21st century and proposed a set of questions for future research. It highlighted the trends of metacognition, ways to categorize metacognition and discussion about the growth and expansion of metacognition in science education. The gap found from the review of literature is that there is no review study of metacognition in the Thailand basic education context.

3. Methods
3.1 Population and data collection
The population of this study is all research studies in metacognition reported and included in the Thailand national database so called ThailIS (Thailand Library Integrated System). After completed searching in ThailIS, we found 22 metacognitive studies conducted in Thailand during 2001 to 2016.

3.2 Data analysis
The researchers intensively read all studies in order to specify their major purposes. The major purposes of each research paper were compared with others. The research studies conducted with similar research purpose were grouped together and the category was subsequently created for them. This process was continued until the categories were exhausted.

4. Results and discussion
After review, the research about metacognition (n = 22) in the basic education content of Thailand.
The metacognitive studies in Thailand could be grouped into five categories, that is, a) Impact of metacognition on other research variables, b) Teaching strategies to enhance metacognition, c) Developing measurement tool for metacognition, d) Causal model of metacognition, and e) Factors of metacognition.

Table 1. Categories of research about metacognition in Thailand.

| Category                                      | Educational level         | Frequency | %   |
|----------------------------------------------|----------------------------|-----------|-----|
|                                              | Primary School            | Lower-secondary | Upper-secondary | |
| a) Impact of metacognition on other research variables | 1                         | 5          | 3   | 9   | 40.9 |
| b) Teaching strategies to enhance metacognition | 1                         | 1          | 5   | 7   | 31.8 |
| c) Developing measurement tool for metacognition | 0                         | 2          | 1   | 3   | 13.6 |
| d) Causal model of metacognition              | 0                         | 2          | 0   | 2   | 9.1  |
| e) Factors of metacognition                   | 1                         | 0          | 0   | 1   | 4.6  |
| Total                                        | 3                         | 10         | 9   | 22  | 100.0|

From Table 1, there was two dominant categories of metacognitive studies in Thailand, that is, Impact of metacognition on other research variables (40.9%) and Teaching strategies to enhance metacognition (31.8%). Almost all studies about metacognition were conducted in the secondary school levels (86.36%). Interestingly, there was only three studies in metacognition conducted in a primary school level. The summary of each study related to metacognition in Thailand is presented as follows.

Category 1: Impact of metacognition on other research variables

The metacognitive studies in this category focused on the impacts of developed metacognition on other research variables.

Research 01: A study of relationship between metacognition and critical thinking of grade 6 students [20]. The purposes of this study were to study 1) the multiple correlation between subcategories of metacognition and critical thinking; and 2) the beta weight of metacognition which contributed to all subcategories and in each subcategory of critical thinking. The research instruments
were the critical thinking test and the metacognition questionnaire. The results showed that 1) the multiple correlation coefficients between the subcategories of metacognition and the sum of all subcategories of critical thinking were significant at the .01 for all values and the multiple correlation coefficients between the subcategories of metacognition and each subcategory of critical thinking were statistically significant at the .01 level for all values. 2) The beta weight values in each subcategory of metacognition positively contributed to the sum of all subcategories of critical thinking for all values. There were some subcategories of metacognition that negatively contributed to critical thinking.

Research 02: Effect of a metacognition training with attribution training to effort on problem-solving skills of grade 7 students [27]. This research conducted with the three groups: the control group, the experimental group 1 received a training on metacognition and attribution to effort and the experimental group 2 receiving a metacognition training only. The result showed that, after training, the experimental groups 1 and 2 received higher problem-solving skill scores at the .05 level of significance; while the control group received lower problem-solving skill scores.

Research 03: Grade 8 students’ scientific problem solving ability, metacognition development and scholastic achievement in work and energy topic by using metacognitive strategies [19]. The purposes of this research were: 1) to develop students’ scientific problem-solving ability by using metacognition, 2) to develop students’ metacognition by using metacognition development, and 3) to study student’s scholastic achievement in work and energy topic by using metacognitive strategies. This research used four procedures: 1) analyzing problems, 2) planning to solve problems, 3) managing problems and 4) evaluating problems. The results were: 1) metacognition helped students develop scientific problem-solving ability as students analyzed and planned to solve scientific problems; 2) 4-procedure metacognition development was applied to solve situation that they received; and 3) teaching and learning based on metacognition development affected students’ achievement.

Research 04: Learning management by using metacognition strategy to develop the scientific problem solving skills for grade 7 students [15]. The purposes of this research were: 1) to find out the efficiency of the metacognition learning plan in developing students’ scientific problem-solving skills. 2) to compare the scientific problem-solving skills and the learning achievement of grade 7 students before, during and after the metacognition learning management. The results were: 1) the efficiency of the metacognition learning plan to develop the scientific problem-solving skill for grade 7 students was at 85.86/ 81.66; 2) when students used metacognition strategy, they had higher scientific problem-solving skill and learning achievement at the .05 statistically significant level; and 3) The students satisfied with the metacognition learning management at the highest level.

Research 05: The effect of metacognitive strategy on decision making and problem solving abilities in force and motion topic for grade 9 students [13]. The purpose of this research was to study grade 9 students decision making and problem-solving abilities in science after learning through metacognitive strategy. The results showed that, after learning through metacognitive strategy., the student’s post-test average score of decision making and problem-solving abilities were significantly higher than pre-test at the .01 statistically significant level.

Research 06: Decision making and problem solving abilities in science learning through metacognitive strategy [24]. The purpose of this research was to observe and measure the decision making and problem-solving abilities of grade 9 students learned with metacognitive strategy in Force and Motion. The results presented that, after learned with metacognitive strategy, the students’ pre-test average score of decision making and problem-solving abilities were significantly higher than pre-test at the .05 statistically significant level.

Research 07: The effects of cooperative learning activities management integrated with metacognitive thinking on learning achievement and metacognitive thinking ability of grade 10 students [25]. The purpose of this research was to compare students’ learning achievement and metacognitive thinking ability after learned with cooperative learning only and learned with cooperative learning integrated with metacognitive thinking. The results revealed that the students who learned with cooperative learning integrated with metacognitive thinking has higher learning
achievement and metacognitive thinking ability than those who learned with cooperative learning only at the .05 statistically significant level.

Research 08: Development of knowledge and understanding, critical thinking, awareness, environmental conservation behaviors of grade 12 students using the good science thinking moves with metacognition techniques [7]. The purposes of this study were: to compare knowledge and understanding, critical thinking, awareness and environmental conservation behaviors of the students who learned with good science thinking moves with metacognitive techniques and those who learned with traditional teaching method. The findings revealed that the lesson plans using the good science thinking moves with metacognitive techniques had an effectiveness index of 0.7290. The students in the experimental group developed higher knowledge and understanding, critical thinking, awareness and environmental conservation behaviors (p < .001). In overall, gender did not affect different learning outcomes.

Research 09: Using problem-based learning to promote metacognition and mathematics achievement of grade 10 students [10]. The purpose of this study was to study the use of problem-based learning (PBL) in promoting grade 10 students’ metacognition and mathematics achievement. The result revealed that, after using the PBL approach, the students’ metacognition mean score was increased from a moderate level to a good level. Also, most of the students (more than 80%) had mathematics achievement mean scores higher than the minimum criteria at 60%. The mathematics achievement mean score, in overall, was 14.9 of 20 points (74.5%).

In summary, the research studies in this category shows that developed metacognition in students could affect other desirable attributes as learning achievement, critical thinking skill, problem-solving skill, decision making skill, and awareness and environmental conservation behaviors.

Category 2: Teaching strategies to enhance metacognition
The metacognitive studies in this category focused on implementing several teaching strategies and models to enhance students’ metacognition.

Research 10: Comparisons of effects of the 7E learning cycle using metacognitive moves on grade 5 students’ alternative conception in biology and basic science process skills [2]. The purpose of this study was to examine the effect of 7E learning cycle using metacognitive moves on grade 5 students’ alternative conception in biology and basic science process skills. The results showed that the 7E learning cycle using metacognitive moves helped students gain more understanding about biology concepts at the .05 level of significance. The students developed basic sciences process skills higher than the 50% criterion at the .05 level of significance. In addition, the female students evidenced more interning skills than the male students at the .05 level of significance.

Research 11: Effects on using open-ended problems to develop metacognition for grade 9 students (18). This study aimed to examine the effects of open-ended problems in helping promote problem solving ability with metacognition for grade 9 students. The results revealed that using open-ended problems could help 80.95% of the students passed the metacognition test criterion of 50%. The students also showed a “good” level of metacognition practice with mean score of 2.96.

Research 12: Development of physics learning activities to develop problem solving ability with metacognition for grade 10 students [26]. This study aimed to develop learning activities in physics subject to develop grade 10 students’ metacognition and problem-solving ability. The results showed that 80.95% of the students passed the physics problem solving ability test with criterion of 70%.

Research 13: Effects of science learning management on grade 10 students through learning cycle with metacognitive reflection and awareness [28]. The research objective was to study: 1) the interaction between types of learning management and basic scientific knowledge, scientific problem-solving ability and metacognitive ability; and 2) the effects of different learning management and basic scientific knowledge on students’ learning outcome, scientific problem-solving ability and metacognitive ability. This study presented that there was no interaction between types of learning management and basic scientific knowledge. The students who learned with the learning cycle with
metacognitive reflection and awareness (LCMRA) performed the highest learning outcome, scientific problem solving ability and metacognitive ability, followed by those learned with the learning cycle with metacognitive reflection (LCMR) and learning cycle (LC) only. The degree of student basic scientific knowledge corresponded with the degree of achieved learning outcome, scientific problem-solving ability and metacognitive ability.

Research 14: Results of 5E instructional model with metacognitive reflection strategies on science learning achievement, science concepts and metacognition of upper secondary school students [12]. This study aimed to compare the result of 5E instructional model with metacognitive reflection strategies on student’s science learning achievement. The result showed that, after learned with the 5E instructional model with metacognitive reflection strategies, the students in a bright, moderate and weak groups had higher science learning achievement, science concepts and metacognition than priori at the .01 of significance. Also, the students had science learning achievement higher than the criteria of 60%.

Research 15: Development of metacognition by using constructionist activities in the topic of evolution for grade 12 [21]. The purposes of this research were: 1) developing grade 12 students’ metacognition by using the constructionist activities in the topic of evolution; 2) find the approach to develop grade 12 students’ metacognition by using the constructionist activities. The result indicated that the constructionist activities could develop grade 12 students’ metacognition in a high level. This was occurred from the characteristic of constructionist activities as working with multiple formats, a teacher allowing students to discuss and share ideas both in and outside the classroom.

Research 16: Effects of instruction based on Tri-Sik-Kha principle for developing grade 10 students’ metacognition in the Ecosystems and Human and Sustainable Environment topic [17]. This study applied the Tri-Sik-Kha principles to design instruction to help develop grade 10 students’ metacognition. The result showed that the instruction based on Tri-Sik-Kha principles could develop the students’ metacognition. The student average score of metacognition was very high at 70.35%.

In summary, the researchers tried to apply several teaching strategies, that is, the 5E and 7E learning cycle, open-ended problems, constructionist activities, and Tri-Sik-Kha principle, in order to help promote students’ metacognition. Also, the effect of those teaching strategies on students’ metacognition was positive.

**Category 3: Developing measurement tool for metacognition**

The metacognitive studies in this category focused on the development of research tool for measuring metacognition in students.

Research 17: Development of metacognition test for Level 3 students [14]. This study aimed to construct a metacognition test for Level 3 students and investigate its quality. The results showed that the metacognition test for Level 3 students was consisted of six tests, that is, Test 1: A Metacognition Knowledge (Person), Test 2: A Metacognition Knowledge (Task), Test 3: A Metacognition Knowledge (Strategy), Test 4: A Metacognition Experience (Planning), Test 5: A Metacognition Experience (Monitoring), and Test 6 A Metacognition Experience (Assessment).

Research 18: Development of metacognition test in science subject for grade 9 students [9]. This study had two objectives: 1) to develop a metacognition test in science subject for grade 9 students; and 2) to examine the quality of a developed metacognition test. This study showed that the metacognition test in science subject for grade 9 students was consisted of 24 items. The metacognition test was consisted of four situations and each situation had six open-ended questions. The questions aimed to test six components of metacognition including Self-awareness, Task Awareness, Strategy Awareness, Planning, Monitoring, and Evaluating. The Index of Consistency of the metacognition test and its components was ranged from 0.67 to 1.00. The Index of Consistency of content and appropriateness of language was ranged from 0.67 to 1.00. Also, the difficulty and discrimination index of metacognition test were ranged from 0.22 to 0.44 and 0.44 to 0.88, respectively. Also, the reliability of metacognition test was very high at 0.93.
Research 19: Construction of metacognition test for Level 4 students [1]. The purposes of this study were to create a metacognition test and examine its quality regarding the discrimination index and construct validity by means of factor analysis and reliability. The results showed that the metacognition test for Level 4 students was qualified. That is, the Awareness, Planning, Self-evaluation aspects had discrimination index ranged between .402-.731, .279-.561 and .326-.620, respectively. The construct validity of the metacognition test being analyzed by the factor analysis showed that the Awareness, Planning, Self-evaluation aspects had the factor loadings ranging between .480-.799, .353-.667 and .394-.712, respectively. The external reliability of Awareness, Planning, Self-evaluation aspects were .861, .816 and .842, respectively. The reliability of metacognition test as a whole was very high at .940. In this case, there was no interaction found between gender and class level of the students.

In summary, the researchers created the research tool for measuring metacognition in secondary students including Levels 3 and 4. The created tools were mainly quantitative and the researchers tried to established the quality of tools in quantitative way.

**Category 4: Causal model of metacognition**

The metacognitive studies in this category focused on the explanation of causal model of metacognition in students.

Research 20: Development of a causal model of metacognition of lower secondary school students [3]. This research aimed to study the metacognition level of lower secondary school students and develop a causal model of metacognition of lower secondary school students. The results showed that, in general, the lower secondary school students had high level of metacognition, especially in awareness and planning. The causal model of metacognition of lower secondary school students fit to the empirical data and accounted for 64% of variance in the student’s metacognition.

Research 21: Causal model of self-efficacy and metacognition affecting efficacy and outcome expectancy of lower secondary students [8]. This research focused in developing and validating a causal model of self-efficacy and metacognition affecting efficacy and outcome expectancies of lower secondary school students. The results indicated that the causal model was consistent with the empirical data. The variables in the model accounted for 78% and 79% of the total variance in efficacy expectancy and outcome expectancy, respectively. Self-efficacy had the highest direct effect on students’ efficacy expectancy and outcome expectancy.

In summary, the causal models of metacognition presented in the studies in this category fit to the empirical data. However, these studies focus on the causal models of metacognition of lower secondary school students.

**Category 5: Factors of metacognition**

The metacognitive study in this category focused on the factors of metacognition in students.

Research 22: Factors affecting metacognition of grade 6 students using the multilevel analysis [16]. This study aimed to study the relationship between the student and classroom levels and metacognition of grade 6 students’ metacognition and to construct the predictive equation of the factors affecting the metacognition. The results were as follows. The student level factors positively affected students’ metacognition were students’ learning goals, achievement motivation, confidence in self-performance, parental support, parental educational expectations, teaching quality, learning aptitude, child-centered instruction, teacher personality and learning environment. The classroom level factor positively affected students’ metacognition was child-centered instruction.

In summary, there are many factors that can affect students’ metacognition. These factors may be internal factor (e.g. personality) and external factors (e.g. classroom environment).

5. Discussion

There are 22 research studies during 2001 to 2016 dealt with metacognition in the basic education context of Thailand. Almost all studies about metacognition were conducted in the lower- and upper-
secondary school levels (86.36%) rather than the primary school level. The very small number of studies in primary school level may be dealt with the limitation of cognitive development of primary school students with their ages ranged from seven to 12 years old. According to Piaget’s cognitive development, there are four stages of cognitive development: Sensorimotor stage, Pre-operational stage, Concrete operational stage and Formal operational stage. The students in primary school level are mainly in the Concrete operational stage (age ranged from 7 to 11 years old) that is the beginning of logical or operational thought. Consequently, a majority of research about metacognition in the basic educational context in Thailand deals with the secondary school students (ages ranged from 13 to 18 years old) because these students are mainly in the Formal operational stage (age 11 years and over). In this stage, Piaget stated that people develop the ability to think about abstract concepts and logically test hypotheses. Up to this, there is a need for more studies related to metacognition in primary school students (grades 1 to 6). One interesting research question is that what is the most suitable grade level for developing metacognition in students.

Another interesting issue is about the type of research participants. The major research participants are students more than pre-service and in-service teachers. Thus, there is a need for more studies with pre-service and in-service teachers. Particularly, there is a need of research aimed to prepare pre-service teachers or help in-service teachers in deriving in-depth understanding about metacognition and develop their ability to design and conduct the learning activities to enhance metacognition in their students in real classroom contexts.

The final issue is about the research methodology and tool in studying about metacognition. In Thailand, the metacognitive studies commonly employ the quantitative approach methodology and tools in conducting research and collecting data. The researchers usually employ the same or similar research quantitative tool and get the similar research findings. So, in Thai context, we need more metacognitive studies that employ different research methodology and tools. The researchers should consider to employ more qualitative research methodology and tools in their research. This will contribute more in-depth findings about metacognition in the Thai context.

6. Conclusions
The review of research about metacognition in the basic education context of Thailand during 2002 to 2016 shows some interesting issues as follows. First, there are five categories associated with metacognitive research in Thailand including a) Impact of metacognition on other research variables, b) Teaching strategies to enhance metacognition, c) Developing measurement tool for metacognition, d) Causal model of metacognition, and e) Factors of metacognition. Among these, two dominant categories are the ‘Impact of metacognition on other research variables’ and ‘Teaching strategies to enhance metacognition’ categories. Second, there is a lack of metacognitive research in a primary school level. Since 2002, there are only three studies on metacognition conducted in the primary school level. Third, the targeted participants of metacognitive research in Thailand focus on students rather than pre-service and in-service teachers.

7. Implications
This review study presents a need to develop more tools for measuring metacognition in different groups such as students, pre-service and in-service teachers. Regarding students, we need to develop tools for measuring metacognition in different levels ranged from primary, lower-secondary, upper-secondary to tertiary levels. Also, the research topic about causal model of metacognition and its associated factors is interested to study further. We hypothesized that the causal model of metacognition and its associated factors may be specific for different groups of participants. Particularly to research in students, there still be a need for more studies on metacognition for students in primary school level. In addition, there is a need for more research to enhance teachers’ ability to design the lessons appropriated for promoting metacognition in their students. The teacher professional development on teaching to promote metacognition should be developed to suit specific educational contexts. More importantly, ‘sooner is better’, the pre-service teachers should be educated
about metacognition and teaching to promote metacognition. Therefore, it demands the design of teacher education course as ‘Metacognitive Teaching and Learning’ for pre-service teachers in university or teacher colleges.

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