Children's Use of Metacognition in Solving Everyday Problems: An Initial Study from an Asian Context

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Abstract

The aim of this study is to understand the relationship between metacognition and students' everyday problem solving. Specifically, we were interested to find out whether regulation of cognition and knowledge of cognition are related to everyday problem solving and whether students who perform better in the decision-making problem will better differentiate the various components of metacognition. Two hundred and fifty-four fifth grade students completed a survey. We found evidence to suggest the existence of two major components of metacognition. Our results also suggest that at a higher level of decision-making, knowledge of cognition and regulation of cognition were differentiated in their use by participants.

Introduction

Metacognition is an important dimension of problem solving (Gardner, 1991; Karmiloff-Smith, 1992) because it includes problem-relevant awareness of one's thinking, monitoring of cognitive processes, regulation of cognitive processes, and application of heuristics (Hennessey, 1999, 2003). Problem solving is considered as the most essential cognitive activity in everyday and professional contexts (Jonassen, 2000) and recent studies show that the ability to solve everyday problems predicts performance on the job (Cianciolo et al., 2006; Sternberg, 2005). Everyday problems, which are often characterized as ill-structured, are emergent, their solutions are unpredictable, and they require multiple criteria for evaluating solutions (Jonassen, 2000). Although Hong, Jonassen, and McGee (2003) found that metacognition is called for when solving ill-structured problems, research on the role of metacognition in solving ill-structured problems is scarce. Most research on understanding metacognition focuses on classroom settings (Everson & Tobias, 1998; Schraw & Dennison, 1994; Sperling, Howard, Miller, & Murphy, 2002) and little is known about the influence and impact of metacognition on children's problem solving ability in everyday settings. Some researchers have argued that everyday problem solving requires more complex cognitive processes than solving well-structured problems, which are mostly textbook problems. For instance, Johnson-Laird (1982) argued that everyday reasoning involves implicit inferences that depend upon general knowledge and generally go beyond the strictly necessary conclusion. A similar position was also made by Wason and Johnson-Laird (1972) that pure reasoning (also known as formal reasoning, well-structured problem solving) is a subset of practical reasoning (also known as everyday reasoning, everyday problem solving) because pure reasoning is only concerned with truth-functional issues. In contrast, practical reasoning includes both truth-functional and causal issues. This is congruent with a recent study conducted by Lin (2001) who suggested that metacognition served as a mechanism for teachers' problem solving in the everyday setting. Along the same vein, Hewitt, Pedretti, Bencze, Vailiancourt, and Yoon (2003) reported that preservice teachers reflected more deeply about their decision-making processes when they were asked to make choices about instructional situations compared to when they just analyzed somebody else's teaching.

Solving well-structured problems requires metacognition, and solving everyday problems more so. We are especially keen to focus on elementary school children's metacognition because studies in this area are limited (Sperling, Howard, Miller, & Murphy, 2002; Stipek, Feiler, Daniels, & Milburn, 1995) There is great potential in unraveling the relationship between metacognition and children's everyday problem solving. By everyday problem solving, we mean solving problems that are "frequently experienced in daily life, that are complex, and multidimensional, and that are often ill-structured as to their goals and their solutions" (Berg, Strough, Calderone, Sansone, & Weir, 1998, p. 29). Hence, understanding the role of metacognition in children's everyday problem solving may lead to the development of more effective instruction that would help children in acquiring the important skills.

In this article, we explore the relationship between children's self-reported use of metacognition and their approach to solving an everyday problem.

Literature Review

Metacognition

Metacognition is the awareness and regulation of the process of the learner's thinking. Baker and Brown (1984, p. 353) defined it as "the knowledge and control a child has over his or her own thinking and learning activities". Some argue that metacognition consists of two main components: knowledge about metacognitive resources and self-regulation of cognition (McLain, Gridley, & McIntosh, 1991). Both are critical components in problem solving, especially in solving everyday problems that may have no clear solutions and require the consideration of alternative solution paths and competing goals. In such situations, problem solvers may stand a greater chance in solving the problem if they are aware of their cognition and are able to use such awareness to control and regulate the problem solving process.

In this study, we used the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994) and Junior MAI (Jr. MAI) (Sperling, Howard, Miller, & Murphy, 2002). The inventory reflects two main components: Regulation of knowledge and knowledge of cognition. Sperling, Howard, Staley, and DuBois (2004) found that knowledge and regulation components of metacognition were strongly related to each other. Schraw and Dennison (1994) also provided some evidence to suggest that knowledge of cognition may precede regulation of cognition when they reported that knowledge of cognition was a better predictor of performance on a reading comprehension test than the latter. On the other hand, some other studies reported that the relationships among measures of metacognition are not strong (Dennison, 1996; Tobias, Everson, & Laitusis, 1999). Our study was motivated to better understand the relationships among the components of metacognition as it has been recognized as a critical ingredient to successful learning (Brown, Bransford, Ferrara, & Campione, 1983; Flavell, 1987; Hacker, Dunlosky, & Graesser, 1998) since there remains questions about the exact relationships between the two components (Sperling, Howard, Staley, & DuBois, 2004). We believe that with this understanding we may be able to provide insights to educators who intend to incorporate everyday problem solving in instructions. Hence, the hypothesized research model in this study is shown in Figure 1. The subcomponents of knowledge of cognition and regulation of cognition are elaborated in the following sections. Specifically, we hypothesized that knowledge of cognition which comprises procedural knowledge, declarative knowledge and conditional knowledge should relate to the regulation of cognition which comprises evaluation, planning and monitoring.

Knowledge of cognition (KC) Knowledge of cognition refers to how much learners understand about their own memories and the way they learn (Sperling, Howard, Staley, & Dubois, 2004). Knowledge of cognition includes declarative (knowledge about self and about strategies), procedural (knowledge about how to use strategies), and conditional (knowledge about when and why to use strategies) (Schraw & Dennison, 1994). These subcomponents are metacognitive because they are thoughts about knowledge states and abilities (Cross & Paris, 1988). Research studies have suggested that individuals vary considerably in their knowledge of cognition (Palinscar & Brown, 1987; Schraw, 1994; Schraw & Nietfeld, 1998). The importance of knowledge of cognition is argued by Swanson (1990), who suggested that high-metacognitive-knowledge/low-aptitude children (metacognitive knowledge is similar to knowledge of cognition) performed significantly better than low-metacognitive-knowledge children with higher overall aptitude scores. In a recent study on metacognition and decision-making, Batha and Carroll (2007) found that knowledge of cognition affects university students' decision-making. Some researchers (Baker, 1989; Jacobs & Paris, 1987) also argued that knowledge of cognition is as important as regulation of knowledge.

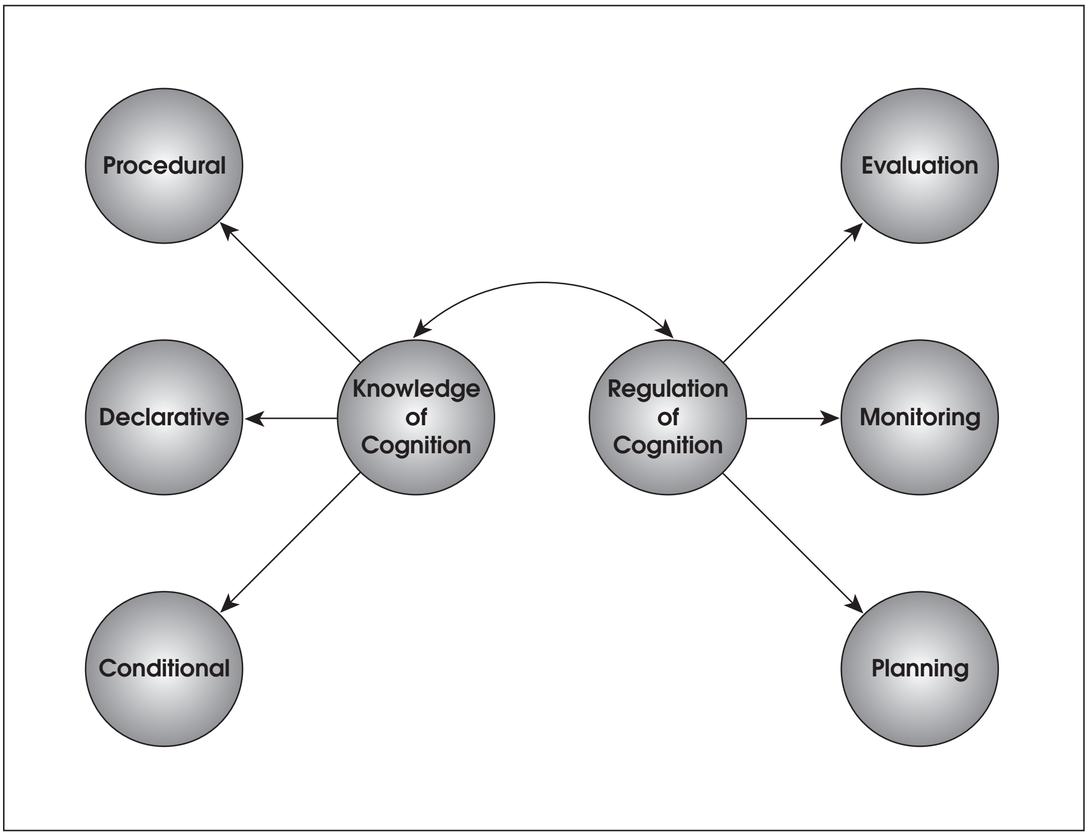

Figure 1: The hypothesized research model

Regulation of knowledge (RK) Regulation of cognition includes planning, evaluation, and monitoring. It plays a crucial role in problem solving as it enables learners to organize and monitor their thinking. It refers to the control of an individual's ongoing cognitive processes. Brown (1980) used the term executive control processes, which include planning (plans the use of strategies, organizes materials to be used), monitoring (constantly checking the use of various strategies), and evaluation. When solving everyday problems that have no defined goals and solutions, the problem solver not only needs to be aware of his or her problem solving processes but must also regulate such processes. For example, Davidson and Sternberg (1998) stated that regulation of knowledge (which they refer to as metacognitive skills) enables students to strategically encode the nature of the problem by forming mental representations of the problems; select appropriate solutions, and identify and overcome barriers to the process. Echoing the importance of regulation of cognition, Batha and Carroll (2007) found a stronger relationship between regulation of cognition ability and decision-making ability than knowledge of cognition and decision-making ability when they conducted a study on university students' decision- making ability.

Everyday problem solving

Children solve many different types of problems, ranging from textbook problems which are mostly well-structured problems and are characterized by a well defined initial state, known goal, and a finite set of rules and principles to solve, to everyday problems which mostly entail multiple solutions, multiple solution paths, or no solution at all (Jonassen, 2004; Kitchner, 1983). We argue that children's everyday problems require metacognition because such problem solving situations are highly variable and success criteria depend on how the learner clarifies and reconciles competing solutions. According to Jonassen's typology of problems (2004, 2007), there are 11 kinds of problems that vary according to their structuredness, complexity, and dynamicity. One of the problem types is decision-making, which is an everyday part of children's lives (Jonassen, 2000). Children make decisions about purchases, time allocation (whether to do homework or to play), and social situations (how to facilitate friendships).

When making a decision, children must compare and contrast the advantages and disadvantages of alternative solutions and to justify these solutions. In such a problem situation, problem solvers need to identify the most relevant criteria. The decision-making process can be very complex because the problem solvers need to consider factors such as time, cost and name another factor. Effective decision makers require the mastery of skills such as: (a) identifying a set of alternative courses of action, (b) identifying appropriate criteria, (c) assessing alternatives by criteria, (d) summarizing information about alternatives, and (e) self-evaluation (Ross, 1981).

In this study, we gave student participants an everyday decision-making type of problem to solve, and how to select a bicycle for purchase. The decision-making problem used in this study was adapted from one of the scenarios used by Amsterlaw (2006). It is hypothesized that when a student makes a better decision, he or she is able to identify a set of alternative courses of actions, identify the appropriate criteria, assess alternatives by criteria, summarize information about the alternatives and self evaluate.

The purpose of this study is to understand the relationship between metacognition and students' everyday problem solving. Specifically, two hypotheses were relevant to this study. We posited that regulation of cognition and knowledge of cognition are related to problem solving. Second, students who perform better in the decision-making problem will better differentiate the various components of metacognition (see figure 1).

Method

Participants

Data were collected from 254 5th grade students (10 years of age) of mixed abilities in an elementary school in the Asia-Pacific region. The sample included over 90% of the population of 5th graders in the school. Since this is a traditional Chinese school, the majority of the students were ethnic Chinese, with less than 5% of students of other ethnic races. Of these, 49.6% (*n*=126) were female and 50.4% (*n*=128) were male students. The students at this grade had studied the English language as part of their formal schooling for at least five years. They were able to understand printed and spoken instructions and respond to short items such as those found in the MAI. Permission was granted by the school leaders to administer a survey questionnaire to the participants. Data were collected by the first author, and at each administration of the questionnaire, specific instructions were given to the effect that participants was free to choose not to participate at any time during or after the questionnaire was administered. Due to the young age of the participants, opportunities were provided for them to ask questions about the data collection process.

Procedures

Participants completed the questionnaire in their classrooms. A total of eight classes were involved. The first author briefed participating teachers and students on the purpose and procedure of the questionnaire. To ensure consistency in data collection and respond to queries, the first author also visited these classes while the questionnaire was being administered. Participants took about 30 minutes to complete the questionnaire.

Instrument

The metacognition items used in this study were adapted from the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994). The MAI was discussed by Baker and Cerro (2000) and Pintrich, Wolters, and Baxter (2000). Factor analysis using college students as subjects supported the use of one knowledge scale (internal consistency alpha = 0.88) and one regulation scale (internal consistency alpha = 0.91) according to Schraw and Dennison (1994).

The MAI instrument consists of 52 statements to which participants respond by marking a 100 mm rating following each item. Two categories of metacognition are represented: knowledge and regulation. The knowledge component measures declarative knowledge (knowledge about self and strategies), procedural knowledge (knowledge about strategy use), and conditional knowledge (when and why to use strategies). The regulation component measures planning (goal setting), information management (organizing), monitoring (assessment of learning and strategy), debugging (strategies to correct errors), and evaluation (analysis of performance and strategy effectiveness). The instrument developers noted that the average completion time for the MAI was approximately ten minutes (Schraw & Dennison, 1994).

No reported studies were found in the literature that employed the MAI with ten year old children. The authors adapted items from the MAI to fit a problem solving scenario. In addition, we felt that children would have trouble responding to the 100 mm rating scale and provided a Likert-type scale that ranged from 1 (strongly disagree) to 5 (strongly agree). To deal with possible difficulties relating to using the MAI with our young participants, the first author was present at all administration of the survey, in order to ensure that survey instructions were given with consistency across different classes where participants were situated. Prior to the actual data collection, a briefing was conducted by the first author to the teachers and administrators from the participating school to address pertinent issues relating to the use of the MAI and subsequent data interpretation.

In the present study, 25 items were selected from the MAI for declarative knowledge, planning, evaluation, conditional knowledge, monitoring, and procedural knowledge. No items were selected from the information management and debugging scales because they seemed less applicable to the problem solving scenario. All items were measured on a 5-point scale with 1= strongly disagree and 5=strongly disagree. The instrument was administered in English, and items are shown in Table 1.

In addition, we administered a problem solving item (see table 3) for participants to report their metacognition for a decision-making (DM) type of problem. The problem portrays bicycle selection, an everyday problem solving event that elementary school children are likely to encounter. Participants selected one of four options on how they would think about the given problem. These options are hierarchically ordered according to the level of decision-making skill. For instance, selection of option A (level 4), the highest level, suggests that the participant is able to compare or weigh options, select alternatives and justify his or her decision. However, if the participant selects option D (level 1), it is likely that the he or she has considered only one alternative, has no criteria decision-making, and is not able to justify his or her decision.

Components	Number of items	Sample items
Knowledge		
Procedural	4	"I try to think in the ways that have worked in the past"
Declarative	4	"I solve the case better when I am interested in it"
Conditional	4	"I know when each plan I use will be most effective"
Regulation		
Evaluation	5	"I know how well I did after solving the cases"
Monitoring	4	"I find myself pausing regularly to check my understanding"
Planning	4	"I ask myself about the case before starting to solve the case"

Table 1: Structure of the adapted MAI

It was possible that participants might think in ways that do not conform to the four options provided in the questionnaire. To test this possibility, before the actual data collection, a separate form was administered to a group of students who did not take part in the actual data collection. These participants were shown the same decision-making problem and asked to describe how they would solve the problem. Their open-ended responses were coded using a thematic coding technique (Cresswell, 2005). Two researchers coded the responses independently and this was followed by discussions and negotiations in order to reach a consensus on cases that were difficult to be placed in a specific category. Four options emerged that match with the four options provided in the actual data collection.

The participants were asked to read an everyday decision-making problem (see Figure 2) before selecting one of the four options provided. After selecting their response for the problem, students then reported on their metacognition for their decision making.

Your parents decided to get you a bicycle for your birthday. You went to the bicycle shop to pick one but there are many different bicycles to chose from. Think about how you will pick the bicycle you want.

A. I make a list of the things I want for my bicycle, and then go to the bicycle stores to compare the bicycles in the stores to my list. I then choose the bicycle that is a closest match to my list.

B. I make a list of the things I want for my bicycle, and then go to the store and ask the store keeper whether the store has a bicycle that matches my list.

C. I ask my parents to go to the store with me and let them chose the bicycle for me.

D. I ask my friends to help me list down the important things for a bicycle. I then go to the store and find out whether the store has a bicycle that matches my list.

Figure 2: An everyday decision-making problem given to students

Results

Component	1	2	3	4	5	Mean	SD	α
1. Procedural						3.72	.75	.63
2. Declarative	.73					3.88	.71	.51
3. Conditional	.50	.53				3.85	.77	.56
4. Evaluation	.50	.46	.43			3.52	.72	.50
5. Monitoring	.50	.46	.44	.57		3.68	.74	.47
6. Planning	.58	.56	.45	.56	.54	3.74	.79	.57

Note: All correlations are significant at p<.01 (2-tailed)

Table 2: Descriptive Statistics, Alphas, and Correlation Matrix

Data (see Table 2) were normally distributed with skewness ranging from -0.25 to -1.42 with only two items (7 and 12) exceeding 1.00 for skewness. The kurtosis ranged from -0.83 to 0.83. The aggregate mean for each component is above the mid-point of 3.00 which indicates that the overall responses for all components are in the positive direction.

The overall alpha for internal consistency for the 25-item questionnaire is .86. The alpha for each component ranges from .47 to .63, indicating that the instrument used in this study has marginal reliability. All correlations are significant and they range from .43 to .73. These correlation coefficients suggested the components, although associated, are sufficiently independent.

The principal component analysis of the MAI items revealed seven factors with eigenvalues above 1, suggesting a seven factor solution. However, seven factors seemed excessive, and inspection of the scree plot suggested a two-factor solution. Nine items loaded on *regulation* and eight items loaded on *knowledge*. Together these two factors explained 30.6% of the variance extracted and the *regulation* and *knowledge* accounted for 16.4% and 14.1% of the variance respectively. The internal consistency of these two factors were .71 (9 items) and .72 (8 items) respectively.

At each level of decision-making, mean differences for knowledge of cognition and regulation of cognition were computed. Results (see Table 3) showed that all means, except for "Level 1" were significantly different at the $p<.001$ level. This suggested that at the higher level of decision-making, knowledge of cognition and regulation of cognition were differentiated in their use by the participants. Comparing effect sizes, "Level 4" has the higher percentage among the four levels ($\eta^2=.518$, $p<.001$). This suggests that the shared variance in knowledge of cognition and regulation of cognition amounted to 52%. This finding supports our prediction that students who make a better decision in the given problem, could better discriminate among the various components of metacognition. This was especially true for those who chose the highest level of decision-making response (level 4). On the other hand, it also suggested that the students, who had selected a more inferior response in their decision-making problem, were unable to realize the difference between knowledge of regulation and knowledge of cognition.

		MAI Component					
	Item*	Planning	Evaluation	Declarative Knowledge	Conditional Knowledge	Monitoring	Procedural Knowledge
1. I think I know whether I have understood the problem well	32						•
2. I set a goal before solving the problem	8	•					
3. I know what kind of information is most important when solving the problem	10			•			
4. I ask myself how well I have solved the problem once I have finished.	50		•				
5. I know when each plan I use will be most effective	35				•		
6. I find myself pausing regularly to check my understanding	34					•	
7. I can solve the problem best when I know something about the problem	15				•		
8. I ask myself if I have considered all options when solving the problem	11					•	
9. I ask myself now and then if I am meeting my goal	1					•	
10. I ask myself about the case before starting to solve the problem	22	•					
11. I think I am good at sorting out the information presented in the problem	12			•			
12. I consider several ways to solve the problem before I answer	2					•	
13. I organize my time to best solve this problem	45	•					
14. I know how well I did after solving the problem	7		•				
15. I summarize what I have learned after solving the problem	24		•				
16. I solve the problem better when I am interested in it	46			•			
17. I ask myself if I have considered all options after I solve the problem	38		•				
18. I am aware of the plans I use when solving the problem	27						•
19. I try to think in the ways that have worked in the past	3						•
20. I have a specific purpose for each plan I use	14						•
21. I ask myself whether I have considered carefully before I make a choice	49					•	
22. I can make myself to solve the problem when I need to	26				•		
23. I use different plans to solve the problem depending on situation	18				•		
24. I find myself using helpful methods naturally when I solve the problem	33						•
25. After I had solved a problem, I ask myself whether there is an easier way to solve the problem	19		•				

Note: Rated on a scale of 1=strongly agree to 5=strongly disagree
**Adapted from Schraw and Dennison (1994). Each item number corresponds with those in the MAI*

Table 3: Adapted MAI items used in this study

Discussion

This study highlights the relationship between solving everyday problems and metacognition which is vital to the understanding of how to design everyday problem solving for children

Despite great difficulties in determining the relationships between metacognition and everyday problems, this study provides insights into children's metacognition in everyday problem solving and it raises possibilities for future research. For example, the MAI, Jr. MAI and other instruments on metacognition were mainly used in domain-general contexts but we had tried to contextualize our questionnaire (based on MAI and Jr. MAI) and we found that all items correlated with the problem solving response. Hence, it is possible that our questionnaire is capable of tracing the metacognition used by children when they attempt to solve an everyday decision-making problem. This questionnaire perhaps addresses Sperling, Howard, Miller, & Murphy (2002) concern when they found that the correlations between the Jr. MAI versions and achievement are generally low. The authors suggested that it is likely that, as learners age and gain more content-specific knowledge, their strategic processes become more domain-specific, therefore a domain-general measure of metacognition loses its predictive power. Moreover, although the principal component analysis did not support our hypothesized six-factor solution, we found evidence to suggest the existence of two major components of metacognition: knowledge and regulation of cognition. The result of this study corroborated with previous studies. Although Schraw and Dennison (1994) found the presence of six factors in their study, they concluded that a two-factor solution (knowledge and regulation of cognition) fits more closely with theoretical predictions. Internal consistency of these two factors was excellent, ranging from 0.93 to 0.88. They did find a significant relationship between knowledge and regulation and on this basis the authors concluded that the MAI provided a reliable initial assessment of metacognitive awareness. Our finding suggests that children are able to distinguish these two components as different constructs. Our preliminary analyses also suggests that at a higher level of decision-making, knowledge of cognition and regulation of cognition were differentiated in their use by the participants, with Level 4 having the higher percentage among the four levels (η^2=.518, p<.001), and there is no significant mean difference for knowledge of cognition and regulation of knowledge at Level 1. This perhaps reveals the importance of the two main components of metacognition when a higher level of decision-making is concerned. These findings suggest that when incorporating everyday problem solving, teachers need to devise strategies to help students acquire and develop knowledge of cognition and regulation of cognition so that they can become effective problem solvers. Specifically, if we want our children to make better decisions in dealing with non-routine everyday problems, then we might want to provide instruction such as metacognitve strategy instruction as it has benefited poor and average decision-makers (Batha & Carroll, 2007). Such an instruction focuses on drawing participants' attention to the importance of correct strategy use and explains when and how to use strategies. Similarly, we could also consult the Critical Event Incident approach described by Lin, Schwartz and Hatano (2005). This approach helps teachers who usually confront highly variable situations to appreciate adaptive metacogntion which involves the adaption of oneself and one's environment in response to a wide range of classroom variability.

To further validate our findings, we are embarking on a funded research project to examine the different types of everyday problems that children encounter, and to design and develop a more robust instrument that will tease out the relationship of the two components including their subcomponents and everyday problem solving. We will continue to investigate whether the phenomena discovered in this study are the same for other types of everyday problems that children encounter as it is important to evaluate metacognition in order to understand individual's mental processes (Montague, 1992; Schraw & Dennison, 1994), particularly when they are solving everyday problems which are most of the time dynamic, ill-structured, and complex. Optimistically, we hope that our research will inform future classroom practices on the integration of everyday problem solving by emphasizing the criticality of metacognition.

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