Metacognition Learning (2010) 5:251–267
DOI 10.1007/s11409-010-9060-6

Metacognitive strategies that enhance critical thinking

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Received: 20 October 2009 / Accepted: 7 July 2010 /
Published online: 21 July 2010

Abstract The need to cultivate students' use of metacognitive strategies in critical thinking has been emphasized in the related literature. The present study aimed at examining the role of metacognitive strategies in critical thinking. Ten university students with comparable cognitive ability, thinking disposition and academic achievement but with different levels of critical thinking performance participated in the study (five in the high-performing group and five in the low-performing group). They were tested on six thinking tasks using think-aloud procedures. Results showed that good critical thinkers engaged in more metacognitive activities, especially high-level planning and high-level evaluating strategies. The importance of metacognitive knowledge as a supporting factor for effective metacognitive regulation was also revealed. The contribution of metacognitive strategies to critical thinking and implications for instructional practice are discussed.

Keywords Metacognition · Metacognitive strategies · Critical thinking · Individual difference · Think aloud method

A critical thinker is one who applies appropriate skills and strategies to achieve a desirable outcome (Halpern 1998). Critical thinking demands strategic use of cognitive skills that best suit a particular situation, as well as an active control of one's own thinking processes for well-justified conclusions. Psychologists and educators strive to understand what differentiates those who think critically and those who fail to do so; however, it has not been an easy task due to the complexity of human thinking processes. As a result, tests of critical thinking usually measure the end-results of thinking processes, i.e., the quality of

This paper is based on a presentation at the American Educational Research Association Annual Meeting, San Diego, CA, 13–17 April, 2009. This study was supported by a grant from the Research Grants Council of Hong Kong (Project no. CUHK 4118/04H).

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the conclusion drawn. However, such indexes of thought products give virtually no information on how the person approached the task, what strategies were used, how a conclusion was reached and what the reasoning behind was—this kind of information would reveal real-time executive processes in thinking and is crucial for our understanding of what leads to good thinking results.

To understand the differences underlying individuals' abilities to think critically, it is important to examine the approaches that people adopt to manage and execute different tasks. In fact, the need to disclose individuals' thinking processes for comparison has been emphasized by a number of scholars (e.g., Garner and Alexander 1989; Halpern 2003a; Mayer 1998; Norris 1991). In particular, the use of metacognitive strategies has been put forth as a crucial variable during thinking processes (e.g., Facione 1990; Halpern 1998; Luckey 2003; Swartz 2003). For instance, Halpern (1998) states that "when engaging in critical thinking, students need to monitor their thinking process, checking whether progress is being made toward an appropriate goal (and) ensuring accuracy…. Metacognitive monitoring skills need to be made explicit and public so that they can be examined" (p. 454). Facione (1990) also emphasizes the importance of self-consciously monitoring "one's cognitive activities, the elements used in those activities and the results educed" (p. 10). In Swartz's (2003) reflection on teaching methods that facilitate critical thinking, there is the claim that "thinking about their thinking has dramatic effects on students' learning and is usually not a difficult or complicated task for even primary-level children" (p.237).

Despite these assertions, there has been limited empirical research that directly examines individual differences in the use of metacognitive strategies during critical thinking. The foremost reason is perhaps that it is methodologically difficult to collect direct data on ongoing cognitive processes that are complex in nature, with independent and clearly defined elements being teased out for analysis. The current study adopted a think-aloud method to examine metacognitive strategies as they occurred during thinking. This paper discusses what think-aloud protocols reveal regarding the differential use of metacognitive strategies among students with similar levels of cognitive ability, intellectual tendency and academic achievement but with different levels of critical thinking performance.

Conception of metacognition

Metacognition is often simplified as thinking about thinking or cognition about cognition. Flavell first introduced the term metacognition, in which he referred as "one's knowledge concerning one's own cognitive processes or anything related to them" (Flavell 1976, p.232). Cognitive psychologists (e.g., Miller 2000; Newell and Simon 1972) have referred metacognition as the "executive control" system of the human mind and as higher-order cognitions that supervise a person's thoughts, knowledge and actions (Weinert 1987). Such supervision is achieved through perception of what is known or unknown, knowledge of oneself as a thinker and regulation of how one goes about thinking a problem. In simple terms, metacognition describes the awareness and control of one's own thoughts.

Metacognition has often been conceptualized as comprising two components (Brown 1987; Flavell 1979): the *knowledge* component refers to knowing one's cognitive processes, such as knowledge about oneself as a thinker, characteristics of existing task and about which strategies are required to carry out for effective performance; the *regulation* component refers to the actual strategies one applies to control cognitive processes, such as planning how to approach a task, monitoring understanding and comprehension, and evaluating progress and performance. According to Flavell (1979), metacognitive

knowledge refers to acquired knowledge that can be used to control cognitive processes, which are to be further divided into three categories: knowledge of person variables, task variables and strategy variables. In addition, Brown (1987) added metacomprehension, i.e. to know that you understood a question as an important category of metacognitive knowledge. Through regulation, individual makes use of such knowledge to modify and improve intellectual performance. That is, metacognitive knowledge provides the basis for effective regulation (i.e. how and when planning, monitoring and evaluating ought to be carried out). Thus, the knowledge and the regulation components supplement each another and are both essential for optimal performance (Livingston 1997; Schraw 1998). For instance, in Pressley and colleague's (1998) study, it was found that students were more proficient in their use of strategies as they acquire more knowledge about the nature of different strategies and under what circumstances a particular strategy should be employed. Similarly, Davidson and Sternberg (1998) has argued that metacognitive knowledge allows problem solver to better encode and represent the givens in a problem context and therefore better performance. In various other studies, it was found that having metacognitive knowledge, such as knowing what factors affect one's thinking (person variables), how to make sense of a problem or how different problems demand different cognitions (task variables) and knowing when and why to use a skill (strategy variables) facilitate metacognitive regulation (e.g., Anderson 1991; Pintrich and De Groot 1990; Schraw and Dennison 1994; Swanson 1990). Having only an awareness for the need to apply metacognitive strategy is not enough for good performance; one must also know when, how and which strategy to use at different contexts.

Another distinction that must be made is one that distinguishes metacognitive activities and cognitive activities. The border between what is metacognitive and what is cognitive has been unclear, and many have acknowledged the two may be mutually dependant on each other and thus cannot be entirely separated (Flavell 1979; Livingston 1997; Veenman 2006). In fact, the same activity may be invoked for either purpose depending on its goal (Ward and Traweek 1993). The principle difference lies in the *goal* of the activity: cognitive activities help to acquire, retain and transfer knowledge for task execution, whereas metacognitive activities allow one to regulate and govern task execution (i.e. how a task is carried out to ensure satisfactory level of performance).

Vygotsky (1962) and Piaget (1964) both argued that children at a very young age develop awareness of their own minds which in turn guides their thoughts, as they grow older they demonstrate an increased awareness of their thinking processes and capacity to exercise such metacognitive ability to guide their thoughts. By late childhood, children show competence in evaluating their attempts to solve problems with strategies (Dembo 1994). Older children also tend to show monitoring activity during reading comprehension (Myers and Paris 1978). It was found that metacognitive activities that enable children's reflection on what, why, how and when they knew about an idea were related to more advanced argumentation skills in children (Mason and Santi 1994). As the awareness of the source, upholding and reliability of one's claims and beliefs about a particular topic forms the basis of a reasoned argument. Metacognition has also been frequently linked to reading comprehension; various studies have consistently found that skilled readers pay more attention to important information in texts, and engage in comprehension monitoring and revision more often (Palincsar and Brown 1984; Paris and Jacobs 1984; Schmitt and Hopkins 1993; Yang 2002). Metacognition is no doubt a core component in various forms of higher-order thinking. An understanding of how our cognition functions allows us to develop related knowledge and skills in comprehension, argumentation, reasoning and various forms of higher-order thinking.

Metacognition and critical thinking

Definition of critical thinking varies. Nevertheless, the existing literature shares the consensus that critical thinking involves cognitive, dispositional and metacognitive components; together they denote good critical thinking performance (Ennis 1987; Facione 1990; Halpern 1989). The cognitive component has been represented by the mental capability to comprehend a problem as well as the ability to apply cognitive skills to make sound judgments. Cognitive skills acknowledged as central to critical thinking range from a few to many; typically these include analyzing arguments, recognizing logical fallacies, distinguishing warranted and unwarranted claims, identifying understated assumptions and skills in scientific analytical reasoning (Beyer 1984; Dick 1991; Halpern 1998). On the other hand, a person's disposition exerts an influence on the patterns of one's intellectual activity. Enjoyment of thinking, an open attitude, a careful approach in thinking and a mind-set for truth are essential for a person to reach sound judgments (Facione 1990; Ku and Ho 2010).

On the contrary, there has been fewer research investigating the metacognitive component in critical thinking. The use of metacognitive strategies has been frequently discussed at the conceptual level as an important factor affecting critical thinking (e.g., Halpern 1998; Paul 1993; Tishman et al. 1992; Tsai 2001). Metacognitive strategies are thought to invoke behaviors that enable students to supervise and control their thinking processes. Thus, it has been argued that students need to be trained and examined on the use of these strategies (Halpern 1998, 2003b; Luckey 2003; Swartz 2003). Commonly suggested metacognitive strategies used in critical thinking fall under three categories: planning, monitoring, and evaluating. Examples of *planning* activities include those aiming at the determination of procedures that direct thinking, the selection of appropriate strategies, and the allocation of available resources (King 1991; Schraw 1998). *Monitoring* refers to an ongoing awareness of task comprehension (Schraw 1998). Monitoring activities include checking task information to validate comprehension, allocating attention to important ideas, and pointing out informational ambiguities (Luckey 2003; Swartz 2003). *Evaluating* strategies involve the examination and correction of one's cognitive processes (Facione 1990). These include evaluating one's reasoning, goals and conclusions (Schraw 1998) as well as making revisions when necessary. In sum, a critical thinker is one who is in charge of his thinking processes, while metacognitive strategies enable such control to take place.

Assessing metacognitive strategies with the think-aloud method

How to measure thinking-related variables accurately has long been an issue of concern. Although a number of self-report measures of metacognition have been developed (e.g., Everson et al. 1991; Koch and Eckstein 1995; Pintrich et al. 1991; Schraw and Dennison 1994), they bring along problems such as participants failing to recall a cognitive process and failing to be aware of how the cognitive process relates to their thought products (Garner and Alexander 1989). Such problems hinder the validity of the data that we gather, as metacognitive activities are being assessed before or after the thinking process rather than *during* the process. Other suggested methods include examining verbal reports, eye movements, and underlined text (Garner and Alexander 1989; Norris 1991). Similarly, these methods disallow individuals' actual thought processes to be revealed and followed through. In fact, any non real-time measurement that requires participants to recall their

cognition after task completion would give an incomplete picture of the actual thinking process.

Among the various methods suggested, the think-aloud procedure, wherein participants are asked to say aloud everything that goes through their mind while completing a task, has drawn positive attention. Ericsson and Simon (1993) argue that compared to other verbal reports, asking participants to verbalize thoughts during a task reflects thinking processes more directly. It has been considered "a very direct method to gain insight into the knowledge and methods of human problem-solving" (Someren et al. 1994, p.1), and it offers a way of accessing rich information that is unattainable through other means. Concerns have been raised regarding whether the process of thinking would be interrupted, altered or incompletely reviewed under the think aloud procedures (Garner and Alexander 1989; Nisbett and Wilson 1977). Ericsson and Simon (1984) argued that verbalizing one's thought would not alter the course of thinking nor would it affect the nature of the on-going cognitive activities, as the procedures do not involve participants interpreting their own thinking. Hence, think-aloud protocols are considered reliable because thinking aloud takes place almost simultaneously with the thinking process which allows thinking activities to be closely followed while keeping the risk of losing information minimal (Schellings et al. 2006). Bannert and Mengelkamp (2008) have found that students' learning performance was not affected by being asked to think-aloud and Veenman et al. (1993) have reached similar conclusions in their study. A number of other studies have also established the validity of using think-aloud protocols to examine comprehension, reading skills and strategies (e.g., Laing and Kamhi 2002; Magliano et al. 1999; Magliano and Millis 2003; Pressley and Afflerbach 1995; Schellings et al. 2006; Zwaan and Brown 1996); other studies have employed the think-aloud method to assess decision-making (e.g., Ryan et al. 2009), reasoning (e.g., Lucas and Ball 2005) and clinical judgment (e.g., McAllister et al. 2009; Offredy and Meerabeau 2005). These serve to support Ericsson and Simon's (1993) argument that thinking aloud does not interfere with cognitive processes.

The present study

Our study aimed at examining metacognitive strategies as they occurred during thinking using the think-aloud method, with a focus on comparing the use of these strategies by people with different levels of critical thinking performance. The investigation was based on the proposition that individuals with differential use of metacognitive strategies would differ in their thinking performance, even though they might have comparable levels of cognitive ability, intellectual tendency and educational achievement.

Method

Participants

The participants were ten Chinese undergraduates (seven females and three males) at a university in Hong Kong, ranging in age from 20 to 23 years (M=21.20). They were divided into high critical thinking performance and low critical thinking performance groups (five in each group), based on their performance in an earlier study (Ku and Ho 2010) examining the cognitive ability, thinking disposition, academic achievement, and critical thinking performance of 137 undergraduates. The ten participants demonstrated

comparable cognitive ability (based on the Verbal Comprehension Index of the Wechsler Adult Intelligence Scale—Third Edition;WAIS-III, Chinese Edition 2002), thinking disposition (based on scores from a Concern for Truth Scale; Ku and Ho 2010), and academic achievement (GPA). However, they displayed different levels of critical thinking performance as measured by the Halpern's Critical Thinking Assessment Using Everyday Scenarios (HCTAES; Halpern 2007). Using the Mann-Whitney *U*-test for analyzing data from two independent groups with very small sample sizes, it was found that except for the HCTAES scores ($U=25$, $p<.01$), there were no significant differences between the two groups on all the other variables (Table 1). This suggested that the difference in critical thinking performance between the two groups could not be attributed to ability, dispositional, or educational factors.

Thinking tasks

The participants' use of metacognitive strategies was assessed using six thinking tasks. Five were scenario-based open-ended problems set in authentic contexts, selected from the HCTAES. Tasks with greater complexity and discrepancies in scores between the two groups in the earlier study were selected. These tasks tapped a variety of critical thinking skills including hypothesis testing, verbal reasoning, argument analysis, understanding likelihood, and decision-making. The sixth task was developed to assess participants' argument analysis skills in relation to a controversial issue requiring complex two-sided reasoning.

Task one In this task, the respondent was to come up with relevant criteria for making a decision regarding which program to join for a specific purpose. The objective of the task was to determine if the respondent was aware of the necessary information needed when evaluating the relative benefits of comparable programs, as well as whether the respondent was able to distinguish between fact and opinion.

Task two The respondent was to analyze and decide whether he or she would join a campaign to lobby for a stated cause. The task assessed if the respondent was able to recognize the ambiguity embedded in the proposed campaign.

Table 1 Means for individual difference variables and critical thinking performance

Variable	Range[a]		Mean		*U*-value
	All participants in an earlier study ($N=137$)	All participants in an earlier study ($N=137$)	High performers in current study ($n=5$)	Low performers in current study ($n=5$)	
Cognitive ability (VCI)	83–131	105.93	105.20	104.80	13.5
Thinking disposition (Concern for Truth)	26–57	47.56	49.60	50.8	13
Critical Thinking Performance (HCTAES)	52–147	115.32	133.00	106.80	25**
Academic Achievement (Cumulative GPA)	1.71–3.70	3.01	2.96	3.06	15

VCI Verbal Comprehension Index of WAIS-III. *Concern for Truth* Concern for Truth Scale. *HCTAES* Halpern Critical Thinking Assessment Using Everyday Situations

[a] Mean for VCI = 100. Possible range of scores for Concern for Truth = 12 to 60. Possible range of HCTAES scores = 0 to 194

**$p<.01$

Task three The respondent was asked to comment on the feasibility of a proposal that aimed to give the city a new look. The objective of this task was to assess if the respondent could articulate strong arguments and differentiate between opinion, reason, and conclusion.

Task four The respondent was to identify likely flaws in a claim that the human race would face a major crisis in future. The objective was to determine if the respondent could identify faulty assumptions in the claim, which would lead to unsound conclusions.

Task five This task presented a scenario where one was facing a major decision which would result in potential benefits and harms. The respondent was asked to think of ways to facilitate the decision-making process. This task assessed the respondent's ability to weigh the costs and benefits, identify the need to seek further information, and to come up with reasonable actions.

Task six This task involved a controversial issue about whether long-term drug patent is acceptable. Drug patents allow pharmaceutical companies to be the sole producer and freely set the price for a newly developed drug for at least 20 years. This arrangement safeguards the profit of the company and encourages the development of new drugs. Yet it also results in high drug prices which are not affordable by many who need the medicine. Therefore there has been a debate on whether this patent arrangement should be kept, with reasonable arguments supporting both sides of the debate. A pilot study with 15 postgraduate students showed that the numbers of people voting for or against the arrangement were comparable (53.33% and 46.67%, respectively). Also the arguments for the two sides of the debate were rated as equally convincing; $t(14)=.36$, n.s. In the present study, participants were asked to decide their position for this issue so that their thinking process in face of a complex and difficult issue could be revealed.

Procedure

Pilot testing of the task procedures were conducted on three undergraduates. After these students completed all procedures, we interviewed them to find out if they had encountered any ambiguities or difficulties in the process. Their responses helped to finalize the think-aloud procedures.

The ten participants were assessed individually. They were told that the session would be audio-taped, and informed consent was obtained. General instructions for the think-aloud procedure were given based on the work of Someren et al. (1994). Participants were instructed to say whatever came to their mind as they carried out the tasks, without first judging the relevancy. The researcher prompted the participants by saying "please keep on talking" only when they had stopped for more than 10 s. Participants were encouraged to take as much time as they needed on each task. Each participant was first asked to practice thinking aloud on two sample tasks. This step provided participants with an opportunity to practice verbalizing their thoughts and allowed the researcher to train them in the proper way to do so.

Protocol coding

Spoken protocols were collected on audio tapes and were transcribed into text by helpers who were not informed of the purpose of the study. The transcribed protocols were segmented based on pauses as well as linguistic structure (Brown and Smiley 1977, as cited in Thoreson et al. 1997; Someren et al. 1994). Segmenting was done by listening to the audio recordings as well as reading the text because it was less reliable to perform the

segmenting based on text alone. All segments were numbered, and segments belonging to the same "thought structure" were grouped into a single unit for easier coding (Someren et al. 1994). A thought unit is one that contains a complete idea regardless of the number of pauses (Schellings et al. 2006; Whitney and Budd 1996). For instance, *"I think I may not..."* and *"I think I may not recommend this program to my friend"* would be coded as one thought unit despite the five-second pause in-between.

The development of the coding scheme used to analyze the think-aloud scripts had gone through two stages. In the first stage, we first examined metacognitive strategies proposed by various researchers (i.e. Ertmer and Newby 1996; Garner and Alexander 1989; King 1991; Luckey 2003; Mayer 1998; Sternberg 1998; Swartz 2003), and we then organized those commonly-suggested strategies into groups according to three dimensions: planning, monitoring, and evaluating. In general, the three dimensions captured and described typical metacognitive activities: regulating one's cognition by planning what to do, checking comprehension of information, and evaluating task approach with a conscious goal to improve performance. A description of each dimension was given together with copious exemplars to familiarize the coders with possible responses that could fall under each dimension. Further instructions and examples were included to help coders to distinguish metacognitive and cognitive activities. The coding scheme was then tried on five protocols collected from the pilot tests with two independent coders. Discrepancies in coding were discussed and resolved with subsequent revisions made to improve the reliability of the coding scheme.

A major revision after trying out the coding scheme on pilot protocols was to further distinguish participants' responses into high and low-level strategies under each dimension. In examining the pilot protocols, it was found that although two participants might engage in similar frequencies of metacognitive activities, the quality of their responses could be different. For example, comments such as *"Maybe this rule applies to something else?"* and *"I think this rule also applies to verbal violence."* would both be coded as metacognitive activities. However, the quality of the second comment was not the same as the first, since it went beyond simple questioning. The first comment demonstrated awareness of the need to check for an alternative interpretation, whereas the second comment demonstrated awareness as well as the recognition of a specific alternate interpretation. In Thoreson et al.'s (1997) study, which examined reading comprehension processes using think-aloud procedures, the authors shared similar observations and found that coding these comments separately better reflected readers' cognitive processing. Therefore for the present study, we also decided to distinguish between comments that represented mere awareness of problems and those that represented recognition of alternatives by coding them into low and high level strategies. Low-level strategies were characterized by mere questioning or awareness (e.g., *What should I do next?*), or simple paraphrasing (e.g., *This paragraph states that graffiti has been a serious problem.*) that was not followed by any solution or improved action. The low-level strategies typically demonstrated an awareness of the need to regulate or adjust one's thinking but without a clear indication of the actual execution of effective strategies. High-level strategies, on the other hand, embody specific steps that would help resolve confusion, enhance understanding, or make improvements. The final coding scheme employed for the present study is given in Table 2.

Inter-rater reliability

The ten protocols were independently coded by two coders blind to each participant's final critical thinking group assignment. Initial percent agreement was found to be 80%. Disagreements were then sorted through by discussion between the coders.

Table 2 Coding scheme for metacognitive strategies

Dimension	Description	Strategy level	Sample responses
Planning	Comments on preparation for task execution. The participant inquires about or identifies procedures and requirements of a task.	Low	"What is the task goal?" "What should I do next?"
	Comments indicating an awareness of the need for planning are coded as low-level strategies.	High	"The task requires me to first make a prediction and then provide an explanation."
	Comments specifying actual planning actions are coded as high-level strategies.		"I should read this paragraph one more time before I do anything."
Monitoring	Comments related to task comprehension. The participant checks or points out own understanding/lack of understanding as well as known/unknown information.	Low	"I don't think I understand this paragraph." "What information is missing?"
	Comments indicating the need to check for one's understanding are coded as low-level strategies.	High	"I know a real patient would have a different reaction to the doctor's opinion."
	Comments clearly pointing out known or ambiguous information are coded as high-level strategies.		"The question does not give me the average food consumption in different countries."
Evaluating	Comments representing assessments of own thoughts and performance in relation to the task goal. The participant indicates recognition of a problem or error.	Low	"I think my interpretation of the text is inaccurate." "My answer maybe too brief."
	Comments that represent the recognition of a problem but without any further attempt to improve or to correct are coded as low-level strategies.	High	"I've generated three hypotheses, the first one seems more correct."
	Comments that represent evaluations that lead to improvements or revisions of one's thoughts are coded as high-level strategies.		"I think what I just said only answers the question partially, it needs to be further elaborated."

Scoring of critical thinking performance

The answers to the first five thinking tasks were scored using the original scoring scheme of the HCTAES. The total score for each item varies. A typical item may range from 0 to 4 points. The scoring scheme gives objectives and exemplars of possible responses for each score point. Each item was scored by two trained raters and discrepancies were resolved with discussion. The scoring scheme for the selected five tasks evaluate participant's ability to distinguish between fact and opinion, identify flaws in reasoning, recognize faulty assumptions in the claim, weigh the costs and benefits to come up with reasonable judgments.

For the sixth task, a marking scheme was constructed which focuses on the participant's ability to generate supporting arguments with sound reasoning, to tackle counterarguments with rational rebuttals, and to reach clear conclusions based on a thorough evaluation of arguments on both sides. The sum of scores for the six tasks formed the critical thinking performance score, with a possible range of 0–25.

Results

The average amount of time spent on the tasks by the high and low performance groups was 27 min 28 s (ranging from 17 min 1 s to 39 min 19 s) and 20 min 55 s (ranging from 12 min 41 s to 30 min 12 s), respectively. Overall, the participants in the high performance group spent more time on the tasks. In the high performance group, there were a total of 407 coded units, 163 (40%) were coded as consisting of metacognitive strategies, while 70 (25%) out of 276 units in the low performance group were coded as such.

A comparison of the critical thinking performance scores between the two groups with a *U*-test indicated a significant group difference ($U=31.5$, $p<.05$), with the high performance group ($M=19.8$) scoring better than the low performance group ($M=12.8$). This confirmed that the two groups differed in their critical thinking performance.

Mean frequencies for each type of strategy were presented in Table 3. *U*-test results further showed that the high performers produced significantly more high-level planning strategies ($U=23$, $p<.05$) and high-level evaluating strategies ($U=22$, $p<.05$) than the low performers.

Qualitative analysis of metacognitive strategy use

Differences that corresponded to the observed frequencies and statistical analysis results were evident when we looked qualitatively at participants' think-aloud protocols. Their use of metacognitive strategies under each of the three dimensions is illustrated below.

Planning dimension Planning activities are directed toward the preparation for task execution & thought processes. We observed three categories of planning activities commonly employed by the participants: (1) inquiring task nature, e.g., "*What do I have to do in this task?*", (2) inquiring task procedure, e.g., "*What should I do first?*", and (3) commenting on one's ability or inability, e.g., "*I do not know much about this.*" Comments in these categories were coded as low-level if no specification of proceeding steps followed. In contrast, comments specifying actual planning actions were coded as high-level strategies.

Table 3 Mean frequencies of metacognitive strategies for high and low performance groups

Metacognitive strategy	Mean		*U*-value
	High performance group ($n=5$)	Low performance group ($n=5$)	
All strategies	27.6	11.4	19.5
Planning	6.2	3	17
Low-level	1.4	1.8	15.5
High-level	4.8	1.2	23*
Monitoring	9.8	5.2	19
Low-level	1	0.4	16
High-level	8.8	4.8	15.5
Evaluating	11.6	3.2	19
Low-level	4.2	2.0	17
High-level	7.4	1.2	22*

*$p<.05$

Across the tasks, participants from the high and low performance groups did not differ much in low-level planning activities. What differentiated the two groups was their use of high-level planning strategies. In particular, the high performers obviously made more comments that showed specifications of task procedures besides simple self-questioning of what should be done. For instance, in the task where participants were asked to judge for or against the drug patent arrangement, a high performer made this comment: "*…this is such a long passage; I should slow down and allow myself more time to think about it*." She went on reading aloud the rest of the text, and then summarized, "*There are viewpoints representing pros and cons*." She paraphrased the viewpoints in the passage and then commented, "*This is interesting, and this could be a good debate topic. I should address both sides. Um, probably start with the cons as they seem more apparent.*" In contrast, a low performer showed awareness of the need to plan, but no actual planning followed. Instead, he immediately drew a conclusion to the issue: "*So, what do I do next, where to begin? Um, I think, I think if the drug patent prevents the pharmaceutical companies from making lower-priced drugs, then it must be a bad thing.*" In fact, we have also observed that high-level planning activities were most frequently seen in the drug-patent task. Perhaps the complex and controversial nature of the task would require more cognitive efforts to plan one's thoughts around generating arguments and/or counterarguments.

In sum, our observation in the present study suggested that participants were similarly attentive to the need to plan, yet the high performers followed through on the need, whereas the low performers jumped right to the conclusion without seeing the need to think about both pros and cons. Those who were more skilled in thinking did not bypass the process of planning, instead sophisticated planning strategies were frequently employed to determine the step or the sequence of steps needed to tackle the task. Despite being equally aware of the need to plan, low performers did not come up with effective strategies, which might be an indication of insufficient procedural knowledge. Overall, the protocols highlighted the fact that recognizing the need for planning was not enough; procedural knowledge was necessary to conceptualize concrete actions.

Monitoring dimension We coded those activities aimed at checking and validating one's comprehension of the task as monitoring strategies. Low-level monitoring strategies were those that demonstrated the need to check for one's understanding (e.g., "*What does this sentence mean?*"), whereas responses that clearly pointed out important or ambiguous information were coded as high-level strategies (e.g., "*The passage does not tell us the total number of people who joined the program*.").

Although differences between the groups' use of monitoring strategies did not reach statistically significant levels, we observed a tendency for high performers to engage in more monitoring activities, especially at the high level, than low performers (*M*s=8.8 and 4.8, respectively). In particular, high performers generally made more attempts to confirm their lack of understanding (e.g., *"I do not understand this passage."*) than low performers.

Furthermore, we found that when high performers recognized what was not known or understood, they were more likely to re-assess their approach to task, i.e., monitoring was typically followed by evaluating. There appeared to be a relationship between monitoring and evaluating strategies. For example, in a task that required a judgment concerning the likelihood of a food crisis happening in future, a participant from the high performance group commented, "*The passage does not specify how the amount of food production is calculated and what types of food are counted or not counted.*" After this checking and pointing out of the unknown (high-level monitoring), she re-assessed the weight she had put on a claim made in the passage, as it had been based on unknown information: "*Then I*

shouldn't really trust what is being said here, namely, that in 80 years people on earth will run out of food" (high-level evaluating).

In contrast, low performers typically took no action to re-evaluate their task approach despite knowing that they had not comprehended the information well. For instance, one participant from the low performance group commented on the drug patent issue by first paraphrasing the information provided in the task: *"Before drug patents were put into effect, other pharmaceutical companies could produce generic drugs with the same chemical compositions and the same biochemical and physiological effects. As they were cheaper, they could lower the prices of patented drugs*." A sentence later, he concluded: "*I do not understand what this means*." This represented low-level monitoring, an awareness of the lack of understanding, which was clearly metacognitive in nature. However, no self-evaluation of task approach followed that would help overcome the problems arising from this lack of understanding. In fact, this participant later gave an incorrect interpretation of the influence of drug patents, which eventually led to a judgment based on faulty reasoning. This observed relationship between monitoring and evaluating suggests that monitoring alone may not result in better thinking. Effective monitoring depends on whether monitoring activities leads to a re-examination of how one should approach the task (i.e., evaluating strategies).

Evaluating dimension Evaluating activities are those characterized by a strategic self-assessment of one's reasoning, thought products and task progress. For instance, making a conscious examination of how one makes sense of the task is an evaluating strategy: "*I think my earlier interpretation of the rule is incorrect*." Comments that represented the recognition of a problem but without any further attempt to improve or to correct were coded as low-level strategies. Alternatively, comments representing evaluative activities that actively led to an improvement or revision of one's thoughts were coded as high-level strategies. It was apparent from the strategy frequencies (Table 3) that the greatest difference observed between the high performance group and the low performance group was on the evaluating dimension, especially high-level evaluating strategies (M=7.4 versus M=1.2).

By way of illustration, in a task that asked participants to explain how they would decide between two weight-loss programs, we observed that although participants from both groups were able to come up with some relevant criteria for making a decision, often the high performers would stop periodically to engage in evaluating activities before concluding their thoughts, whereas the low performers were more likely to jump right to the conclusion. Low-level evaluating strategies employed by the high performers included "*I think I have made a sound judgment"* and *"I think what I just said only partially answers the question."* In addition, there were obviously more high-level self-evaluations that led to revisions of thoughts: *"I do not think the figures provided by the sales person are trustworthy, so perhaps I should not ask how the figures are calculated? Um…Yes, I think I should ignore the figures completely and simply compare the actual content of the two programs."*; *"I think asking about the total number of people who have successfully lost weight after joining each program is more important than knowing the average weight loss."*

Thus skilled thinkers paid more attention to reviewing their reasoning and conclusions during on-going execution of tasks to make sure their performance met the task goals. They were also more prepared to change their approach when problems were identified. In contrast, review and revision were less seen among the low-performance group. Their metacognitive activities focused more on repeating known information to monitor understanding, with little effort at checking one's task approach.

Discussion

Metacognition has been put forth as an important component of critical thinking. Studies have examined the relationships between the two (e.g., Akama 2006; Antonietti et al. 2000; Berardi-Coletta et al. 1995; Coutinho et al. 2005). Others also have argued for its role in thinking and learning (e.g., Garner and Alexander 1989; Halpern 2003a; Mayer 1998; Norris 1991). The aim of the current study was to examine the use of metacognitive strategies during on-going critical thinking processes. We proposed the effective use of metacognitive strategies to be an important factor contributing to critical thinking performance, explaining at least in part why the high-performing group in this study did better on thinking tasks than their peers with comparable levels of cognitive ability, thinking disposition and academic achievement. The results clearly supported this proposition and threw light on how these strategies affected thinking performance.

The role of metacognition in critical thinking

The results have provided evidence that skilled thinkers displayed distinct strengths in their ability to plan specific steps that guide thinking (high-level planning) and to revise their approach upon evaluation (high-level evaluating). Both would lead to enhanced performance in thinking. Low-level strategies demonstrate an awareness of the need to check the steps necessary for task execution, comprehension of related information, and task progress. However, mere questioning or paraphrasing of information with no further execution of the necessary strategies indicates confusion rather than solution (Thoreson et al. 1997). Only high-level metacognitive strategies would help resolve confusion and improve performance.

This distinction of levels of metacognitive strategies in the current study echoes Bereiter and Scardemalia's (1987) differentiation of knowledge-telling and knowledge-transforming activities of novice and skilled writers. The authors observed that less experienced writers tended to do more restating of information, while more skilled writers adopted a problem-solving model in writing. Similarly, in Thoreson et al.'s (1997) study examining reading comprehension processes using think-aloud procedures, it was found that after revising the coding scheme to include only transforming responses that represented active and accurate integration of passage content, the variance in comprehension score accounted for by the use of comprehension strategy rose from 20% to 49%. In the present context of thinking about a problem, checking how one is doing need to be accompanied by the knowledge and execution of proper thinking steps in order for improvements to be made.

Metacognitive knowledge and metacognitive regulation

As mentioned in the earlier literature review, metacognition includes two components: knowledge and regulation. The knowledge component refers to acquired knowledge about cognitive processes, while the regulation component refers to the actual strategies one applies to control cognitive processes (Brown 1987; Flavell 1979). It has been suggested that the two components are distinct from each other because an individual might engage in regulatory activities without having the necessary knowledge of the specific cognitive strategies required (Sternberg 1998). On the other hand, during regulation, individual relies on knowledge about their cognitive processes, task characteristics and strategies to improve intellectual performance. In line with previous findings (e.g., Anderson 1991; Pintrich and De Groot 1990; Schraw and Dennison 1994; Swanson 1990), the current finding that high-level strategies are more relevant for superior thinking performance supports the proposition that

metacognitive knowledge provides the basis for effective regulation (i.e. how and when planning, monitoring and evaluating ought to be carried out). High-level strategies reflect both metacognitive knowledge and metacognitive regulation, whereas low-level strategies reflect a lack of metacognitive knowledge and therefore ineffective regulation. Only individuals who have sufficient metacognitive knowledge would be able to go beyond mere awareness and engage in specific regulatory activities that would lead to an improvement in task performance. The importance of metacognitive knowledge has in fact been emphasized in earlier studies. For example, Swanson (1990) reported that high levels of metacognitive knowledge about problem-solving were related to better problem-solving in children. Specifically, it was alleged that high metacognitive strategies compensated for participants' overall ability by providing knowledge about cognition.

This observation has important implications for the enhancement of metacognitive ability as a component of critical thinking instructional programs. While participants should be encouraged to reflect on their own cognitive activities through checking and questioning to build up the habit of metacognitive regulation, it is also important to explicitly teach the related metacognitive knowledge when necessary. Without the support of metacognitive knowledge, metacognitive regulation will not be effective in enhancing thinking performance.

Summary and conclusion

Despite the small-scale examination, important insights about metacognition and critical thinking have been generated. Our study has highlighted the benefits of examining individuals' on-line thinking processes to achieve a better understanding of factors behind thinking performance. By comparing the thinking processes of two groups of participants matched on cognitive ability, thinking disposition, and academic achievement, the importance of metacognitive strategies in critical thinking was demonstrated.

Clear patterns of differences in the use of metacognitive strategies were identified between those who performed well on critical thinking tasks and those who performed less well. The findings indicated that while the two groups might not differ as much in the frequencies of their checking and self-questioning behaviors, high performers displayed distinctly better abilities to plan for specific steps in thinking and to revise their task approach after identifying problems. This points to the importance of metacognitive knowledge as a supporting factor in effective metacognitive regulation. The implication for practice is that while teachers and trainers of critical thinking should help students establish the habit of self-checking their understanding and task approach, related metacognitive knowledge should also be imparted when necessary.

Further studies are needed to consolidate the present findings with larger samples, using tasks that tap on different domains of knowledge and thinking skills. It would also be desirable to examine think-aloud protocols together with results from self-report measures of metacognitive activities. This would further enhance our understanding of the extent to which individuals vary in metacognitive ability as well as their awareness of it, which would have important implications for related teaching and training.

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