

METACOGNITIVE AWARENESS AND SKILL AMONGST STUDENTS STUDYING COMPUTER PROGRAMMING

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Abstract

Metacognition refers to the development and application of learning strategies and the ability to plan, control and monitor learning. Research indicates that students' metacognitive awareness and skills can influence their academic success. This study determined the extent to which students learning a computer programming module were meta-cognitively aware. The Metacognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994) was used. The MAI correlates closely to academic success and can therefore assist in identifying those students that require further academic assistance and support. The preliminary results indicate that students overestimate their academic abilities. Additionally, a metacognitive strategy intervention was developed to improve students' metacognitive skills. The intervention was classroom oriented, where explicit teaching of metacognition strategies and metacognition regulation was deliberated with students. The intervention also included an adaptation of the classroom environment to encourage "thinking about thinking". The outcomes and implications of the intervention are seen as future research.

Keywords: metacognition, metacognition awareness, metacognition skills, pedagogical intervention, teaching-and-learning

1. Introduction

Vygotsky (1986) expressed that it was important to be aware of the structure of thought processes and how to direct and control those thought processes. In other words, to perform better academically it is not sufficient to only acquire knowledge but it is equally important to acquire knowledge regarding our cognitive processes, and knowledge regarding how to control those cognitive processes (Livingston, 1997). This is known as metacognition.

The term metacognition was originally associated with scholars, such as John Flavell (1979) (Zabrocky, 2009) and Ann Brown (1988) (Brown, 1988). These scholars devised definitions of and researched metacognition extensively (Bransford, 2000; Brown, 1987; Flavell, 1987). They

understood that metacognition plays an important role in certain cognitive areas and that metacognition has the ability to affect students' academic outcomes. These cognitive areas relate to oral communication and comprehension, language acquisition and development, attention, problem solving, social cognition, self-instruction and self-control (Flavell, 1979). Flavell and Brown encouraged other scholars to research the nature and development of metacognition. Over the years various definitions regarding metacognition have been articulated and devised. However, most researchers and scholars agree that metacognition entails higher order thinking. It encompasses students consciously and actively understanding their cognitive aptitude and the ability to apply strategies to control cognitive thought processes. Such internal thought patterns extend into students daily lives where cognitive tasks are planned, regulated, co-ordinated and monitored. Additionally, alternative strategies need to be employed when current strategies cause understanding failure on the student's part (Brown, 1987; Corebima, 2009; Flavell, 1987; Gonzalez, 2013; Livingston, 1997; Schraw, 1994; Young, 2008). Students with good metacognitive skills therefore have the potential to perform better in an academic environment (Schraw, 1994).

This quantitative study firstly made use of The Metacognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994) to determine students' metacognitive awareness. The output of the MAI is a score that was used to determine metacognitive skills and self-regulation practices. Secondly, students were also asked to complete a calibration of performance judgement (Young, 2008). They predicted their abilities related to certain computer programming concepts before an assessment was completed. The predictions were correlated against their assessment mark to determine the variance between the two scores. Thirdly, based on the results of both quantitative results, a metacognitive strategy intervention was designed and developed to improve students' metacognitive skills. The intervention is an on-going study.

2. Background

Metacognition refers to students' ability to develop and apply learning strategies; and frequently plan, control and monitor their learning. Students who are meta-cognitively aware possess unique characteristics, such as the ability to (Gonzalez, 2013):

- Know themselves well;
- Understand their cognitive abilities;
- Devise learning strategies that work for them;
- Know when and how to use such strategies;
- Plan, monitor and evaluate learning;
- Control their emotions; and
- Self-motivate.

These characteristics develop over time as initially young children display only limited metacognitive skills and little monitoring of learning (Flavell, 1979). As children mature into adults, they learn to become meta-cognitively aware through the introduction of knowledge and through daily experiences (Flavell, 1979). For example, a child may realise that she is better at mathematics than her peers; or she may comprehend that she did not understand what was being said. Metacognition is a process that evolves and develops as children mature into adults. This gradual progression of gaining metacognitive skills eventually provides young adults with two metacognition skills, namely metacognitive knowledge and metacognitive regulation (Brown, 1987; Flavell, 1987; Schraw, 1994; Young, 2008).

2.1 Metacognitive knowledge

Metacognitive knowledge or knowledge about cognition includes three sub categories, namely declarative knowledge, procedural knowledge and conditional knowledge. While declarative knowledge refers to students ability to understand their cognitive processes and awareness of learning strategies, procedural knowledge refers to whether a student understands which strategies are best suited to them, and whether they have the ability to make use of such strategies. However, unless the student understands when to use certain strategies, how they should be used, and is provided with an adequate academic environment, known as conditional knowledge, the other metacognitive skills may be insignificant. Additionally, these skills need to be applied in a regular, disciplined manner if students want to improve upon their academic

success. Students therefore need to regulate themselves periodically, also known as metacognitive regulation.

2.2 Metacognitive regulation

Metacognitive regulation refers to the day-to-day facilitation of learning when students are actively engaged in learning activities. It relates to coordinating cognitive learning and includes three sub categories, namely planning, monitoring and evaluating learning and learning strategies (Schraw, 1994). It is critically important for students to regulate their learning (Zabrocky, 2009) as this provides students with the ability to complete a cognitive task by: making use of strategies (planning); being mindful of their progress (monitoring); and assessing the outcome of the task and determining whether learning was achieved (evaluating) (Young, 2008). Therefore, it is important for students to plan, monitor and evaluate not only themselves, but also their learning strategies and their learning progress, as this would provide a greater opportunity to achieve academic success.

Metacognitive knowledge and regulation have, over the last four decades, been used as foundations on which various metacognition models have been built. In 1979, Flavell devised the first model, namely the Model of Cognitive Monitoring and he inspired other researchers to follow in his footsteps (Flavell, 1979).

3. Previous research

Although Flavell and Brown were initially responsible for early investigation of metacognition, they also encouraged other researchers to pursue the “...*nature and development of metacognition and of cognitive monitoring / regulation*” as they felt it could be “...*a promising new area of investigation*” (Flavell, 1979). Table 1 illustrates that metacognition has been extensively investigated and researched. From 1979 to date, many metacognitive studies have been conducted. Some studies apply to metacognition knowledge (MK), others to metacognition regulation (MR), and some include a combination of both metacognition knowledge and metacognition regulation. Whichever category is chosen as a research area, metacognition can be evaluated in two ways, namely self-report inventories or knowledge monitoring accuracy.

Table 1: Previous studies related to metacognition knowledge (MK) and metacognition regulation (MR)

Date	Researcher	Metacognition		Test type			Predictor of success? (Yes or No)
		MK	MR	Self-report inventory	Knowledge monitoring accuracy (performance judgements)		
					Local	Global	
1979	Flavell	X	X				
1988	Brown	X	X				
1994	Schraw & Dennison	X	X		X	X	
1994	Schraw & Dennison (MAI)	X	X	X			Yes
1998	Everson & Tobias		X		X		Yes
2004	Sperling, et al	X	X	X			Yes
2005	Nietfield et al		X		X	X	
2008	Young & Fry	X	X	X			Yes
2009	Zabucky et al				X	X	
2010	Laskey & Hetzel	X	X	X			
2013	Gonzalez	X	X	X			

Firstly, researchers can make use of self-report inventories to assess metacognitive skills and relate them to academic achievement (Schraw, 1994). The MAI test is one such example. This test allows students to answer questions about their learning. For example, “I ask myself periodically whether I am meeting my goals”. Scores are allocated to students’ answers and the higher the score the better the student’s metacognition. Secondly, researchers can examine metacognitive judgements in the form of monitoring accuracy, also known as calibration of performance judgements. These judgements can be assessed at a local and/or global level (Young, 2008; Zabucky, 2009). Local judgements relate to students being asked to assess how well they have done on an assessment question, just after they have answered the question. Global judgements relate to students been given an assessment in its entirety and then asked what they thought the outcome (as a whole) of their assessment would be. Therefore, a local judgement determines the average difference between the actual answer and the student’s judgement of how well they answered the question; and a global judgement is the difference between the overall test score and the student’s judgement of how well they did in the assessment (Young, 2008).

As illustrated in Table 1, many researchers evaluated metacognitive abilities either using a self-report inventory or calibration of performance judgements. For example, Schraw and Dennison (1994) were interested in the relationship between metacognitive knowledge (MK) and metacognitive regulation (MR). They measured metacognitive regulation at a local and global level and found a correlation between performance and local and global judgements. Additionally, Schraw and Dennison developed the Metacognitive Awareness Inventory (MAI) to assess metacognitive knowledge and metacognitive regulation (self-report inventory), which they referred to as the knowledge of cognition factor and the regulation of cognition factor. The MAI consists of 52 questions that look at both components of metacognition. They found that the two components were closely related, as had been suggested in research (Brown, 1987).

Everson and Tobias (1998) assessed metacognition by way of knowledge monitoring accuracy. Students' differences between the estimates of their knowledge domain and their actual knowledge as determined by performance on a standardised verbal test were examined. They found that students' knowledge monitoring accuracy score was related to academic achievement and that the score was a good predictor of success for university.

Sperling (2004) made use of Schraw's MAI to determine students' metacognitive awareness and they found a significant correlation between the two cognition factors, namely knowledge and regulation. Interestingly, no correlation was found between the MAI scores and any other academic achievement scores, such as the Scholastic Assessment Test (SAT) scores. There was in fact a negative correlation between the SAT math score and the MAI scores.

Nietfield (2005) examined metacognitive regulation by measuring knowledge monitoring accuracy at both local and global levels. These tests were conducted throughout the semester. They found that students' global predictions regarding the outcome of assessments were more accurate than their local predictions, where students judged each individual item whilst writing a test.

Young and Fry (2008) examined Schraw's MAI to determine how the test relates to broad and single measures of academic achievement amongst students. Their aim was to make use of the MAI as a tool to identify any poor areas of metacognition and to then apply a metacognition strategy intervention. Similar to Sperling they found a correlation between the regulation of cognition factor and the knowledge of cognition factor. Young and Fry also found that the MAI was a better tool to use when comparing large-scale measures such as a semester mark, as

opposed to a single assessment mark. They found that the MAI was also a good tool to use when identifying which students had weak metacognition skills. This is particularly useful in larger classes where lecturers do not easily have contact with students. They also found the MAI useful as it allowed lecturers to flag at-risk students.

Zabrusky et al (2009) made use of calibration of performance where Taiwanese students were asked to read English literature and rate their level of understanding as well as their readiness to perform an assessment regarding the work covered (local and global judgements). These results were also compared to students within the United States of America. Both countries performed well in the sense that their calibration predictions regarding themselves were accurate.

Laskey and Hetzel (2010) examined metacognition and its relationship to the success or failure of at-risk students at university (Laskey, 2010). The Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, 1991) was used to measure metacognition. The results indicate that the at-risk students' metacognition was poor.

Gonzalez (2013) made use of the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, 1991). This scale measures the extent to which students use strategies to control and regulate their cognition. The results indicate that goals and motivation are interrelated to the choice of metacognitive strategies used by students (Gonzalez, 2013).

Overall, the findings in the research reviewed above indicate that it is important to measure metacognition awareness and skills of students, as measuring such skills can:

- Predict academic success;
- Provide an opportunity for students to reflect upon their learning in different ways;
- Indicate which students are going to need additional assistance;
- Provide a platform for lecturers to devise a metacognition strategy intervention based on students metacognition weaknesses; and
- Provide an opportunity for lecturers with large classes to reveal which students need assistance as such lecturers do not get an opportunity to get to know their students.

Given the importance of measuring metacognitive skills, this paper assesses and examines the metacognition skills of students studying a computer programming module. To the best of our knowledge, this is the first study that has assessed such students. Identifying metacognition skills can be beneficial to lecturers, as it can indicate whether students make use of learning strategies;

and whether they do plan, control and monitor their learning. In the instance of computer programming it may be of particular importance to focus on such skills as computer programming is a difficult task and students often fail computer programming modules (A. Robins, 2010). Improving students' metacognitive skills may ease the burden of learning computer programming.

4. Computer programming

Computer programming, also known as software development, can be defined as the process of developing an algorithm to complete a particular task. The tasks are normally problems that need to be solved. The result of these tasks is the formulation of a program. A program is a detailed step-by-step set of instructions, also known as a sequence of actions, which tells the computer exactly what to do (Zelle, 2002). The process of creating a program can be broken down into a number of stages (Zelle, 2002) as these stages (numbered A to F) make it more manageable to create a program. The stages are:

- A. **Formulate requirements** – the computer programmer must understand what the problem is that needs to be solved. In understanding the problem, the programmer will be able to determine accurate solutions to the problem.
- B. **Determine specifications** – the computer programmer must be able to describe exactly *what* the program will do.
- C. **Create the design** – the computer programmer must now describe *how* the program will work. Tools, such as algorithms, pseudo code, flowcharts and Input-Process-Output (IPO) charts are valuable sources.
- D. **Implement the design** – the computer programmer translates the design that is written in pseudo code, a flowchart, and/or an IPO chart into a computer programming language, such as Java, Python or C⁺⁺, to name a few.
- E. **Test / Debug the program** – the computer programmer must compile the program to verify if there are any syntactical errors in the program, fix them and re-compile the program. This cycle should continue until the program is error / bug-free¹. Once the program is error free the computer programmer must then execute (run) the program to

¹ The term bug originated due to a moth that managed to find its way inside a computer

verify that it produces accurate results. If the program does not produce accurate results it means that the program contains logical errors.

- F. **Maintain the program** – the computer programmer can make changes to the program to produce other results as programs evolve as users' needs change.

According to The Joint Task Force on Computing Curricula, the Association for Computing Machinery and the IEEE-Computer Society, computer programming is a prerequisite to the study of most Computer Science or Information Technology courses (ACM, 2012). These organisations (ACM, 2012) state that “.....*to effectively use computers to solve problems, students must be competent at reading and writing programs in multiple programming languages*”. This means that novice computer programmers must be able to:

- Design and analyse algorithms (problem solving);
- Select appropriate paradigms (programming constructs);
- Utilise modern development tools (programming languages); and
- Utilise testing tools (integrated development environments or IDE's).

Competency in these areas, means that novice computer programmers have learnt the fundamental concepts and skills related to the software development (computer programming) process (ACM, 2012). For students entering university these tasks may seem daunting.

4.1 Difficulties faced by students learning computer programming

The skills expected for computer programming are complex. These skills include the ability to:

- Solve problems (Development-OECD, 2004; Mead, 2006);
- Articulate a problem into a programming solution (Garner, 2005; Lahtinen, 2005);
- Construct mechanisms and explanations (Soloway, 1986);
- Combine syntax and semantics into a valid program (Winslow, 1996);
- Understand larger entities of a program instead of smaller details (Lahtinen, 2005);
- Apply fundamental computer programming concepts (Garner, 2005; A. Robins, Rountree, J., Rountree, N., 2003);
- Understand abstract concepts (Lahtinen, 2005);
- Formulate schemas that facilitate categorizing and processing information (Mead, 2006); and
- Properly estimate their level of understanding (Lahtinen, 2005).

4.2 Computer programming and metacognition

In order to develop good computer skills students must think critically and logically, as they are constantly engaging problems in a creative and reflective manner. These skills are higher order thinking skills (HOTS), which include the ability to create, apply, analyse and evaluate. Students are expected to think in a critical, logical, reflective, metacognitive and creative manner (King, 2000). According to Blooms Revised Taxonomy, computer programming falls into the higher order thinking skills range, namely “Creating” (Anderson, 2001; Churches, 2008). Computer programming has been allocated the highest HOTS level and this means that many students may find it difficult to complete tasks at such a challenging level.

Cognitive thinking at the highest HOTS level means that students are forced to think meta-cognitively and metacognition not only becomes “thinking about thinking” but also forms part of the “thinking” process. For example, unless students acquire *strategies* on how to develop programs, and *regulatory skills* to plan programs, these students may find it difficult to develop computer programs. Table 2 below describes the higher order thinking skills required to solve a problem and develop a computer program. During each stage, numbered A to F metacognitive skills are needed.

Table 2: Higher order thinking skills (HOTS) and metacognition

Stage	Higher order thinking skills required	Metacognitive skill
A	Solving problems given a real-world, ill-defined problem requires higher order thinking. Students are expected to understand what they are reading, evaluate and interpret it correctly, have insight into the unspoken text and solve the problem cognitively.	MK / MR
B	Once the problem has been solved cognitively, students must be able to describe in as much detail as possible what the program must do. This means that students must “think ahead” and start planning what computer programming constructs can be used to develop a solution and solve the problem.	MK / MR
C	Students are expected to translate their ideas into computer-related sources, such as pseudo code and flowcharts. This is an extremely difficult task as it requires students to think in an abstract manner.	MK / MR
D	Students are expected to again translate from pseudo code or flowcharts into a computer programming language, such as Java. Students must now completely rely on abstract thought processes to produce a solution.	MK / MR
E	Testing a solution requires insight into real-world scenarios as students must make use of a dataset to test the solution. Students must be able to evaluate their solution objectively.	MK / MR
F	Students are expected to make changes to the solution if and when needed.	MK / MR

Higher order thinking skills include the ability to think meta-cognitively. For example (Flavell, 1979):

- What strategies are likely to be effective in solving a problem;
- Which problems have been solved before, where the solution is similar to the present problem; and
- What planning is needed before the solution can be developed.

Given that computer programming requires higher order thinking skills, such as metacognition, the researchers were interested in the correlation between the metacognition scores, specifically the MAI and the semester mark, to validate students' metacognitive abilities.

5. Methodology

5.1 Participants

First year students at a university in Johannesburg, South Africa studying a computer programming module took part in the study. The students were asked to complete the voluntary Metacognitive Awareness Inventory (MAI) during class time. The MAI was delivered face to face and 93 students completed the MAI.

5.2 Material

The MAI (Schraw, 1994) with permission of the first author was used to measure students metacognitive awareness. The MAI which has been tested for validity and reliability (Schraw, 1994) consists of 52 statements, which students' rate as being false or true on a five point Likert scale. The two components of metacognition discussed above are represented within the scale, metacognitive knowledge and metacognitive regulation. Within the MAI these are referred to as the knowledge of cognition factor and the regulation of cognition factor. Within the inventory there are 17 questions related to the knowledge of cognition factor for a possible point total of 85. There are 35 questions related to the regulation of cognition factor for a possible point total of 175. The factor scores are calculated by adding the scores on questions related to each of the factors. Higher scores correspond to greater metacognitive knowledge and greater metacognitive regulation. In addition to the knowledge of cognition score and the regulation of cognition score a MAI total score is derived by summing responses to all 52 questions. The instrument was designed for use on adult populations.

5.3 Procedure

Students were asked to consent to complete the MAI and to provide their names on the MAI so their semester mark could be associated with their score on the MAI. Students were not provided incentive in the form of additional points to complete the MAI as this extra credit would skew their semester marks and confound the results of the study.

6. RESULTS

6.1 Correlations between MAI and measure of academic achievement

As illustrated in Table 3 for the 93 respondents the mean MAI score was 198.78. The mean score for the knowledge of cognition factor and regulation of cognition factor was 66.11 and 132.35 respectively.

Table 3: Means (M) and Standard Deviations (SD) of the MAI

	M	SD
MAI Total	198.78	20.48
Knowledge of Cognition Factor	66.11	7.76
Regulation of Cognition Factor	132.35	14.82

In order to determine if there were relationships between the knowledge of cognition and the regulation of cognition factors, as well as correlations between scores on the MAI and achievement measures of semester marks Pearson's Rho, nonparametric correlation analysis was completed. There was a significant correlation between the knowledge of cognition factor and the regulation of cognition factor, as illustrated in Table 4, where $r = X$, $p < 0.01$.

Table 4: Correlations between MAI scores and other measures of Achievement

	Semester mark	MAI Total	Regulation Factor	Knowledge Factor
Semester mark	1.00	-.021	-.075	-.023
MAI Total	-.021	1.00	.856**	.939**
Knowledge of Cognition Factor	-.075	.856**	1.00	.662**
Regulation of Cognition Factor	-.023	.939**	.662**	1.00

** Correlation is significant at the .01 level

* Correlation is significant at the .05 level

Breaking this down into the two factors, namely the knowledge of cognition factor and regulation of cognition factor, a correlation was found between each of these and the MAI score. Interestingly, there was no correlation between the MAI score and the semester mark.

6.2 Correlations between calibration of performance judgements and academic achievement

In addition to measuring achievement using the MAI scores, students were also asked to provide a calibration of performance judgement. The judgement was performed in the following manner. One hundred and four students were asked to predict the extent to which they understood certain computer programming concepts. In total, the students were asked 6 questions and the calibration of performance judgement took place just before writing the assessment. Students' calibration of performance judgements were scored, where 1 point was allocated if a student said that they did understand a concept and zero points allocated if a student said that they did not understand a concept. These questions correlated directly to questions asked in the assessment. Therefore, if the student provided the correct answer in the assessment, again 1 point was allocated and if they did not answer correctly zero points was allocated.

Figure 1: Example: calibration of judgement scores

Student		Questions						Score	Difference	Status
		1	2	3	4	5	6			
A	Assessment answer	1	0	1	0	0	1	3		
	Calibration of judgement answer	1	1	1	0	0	1	4	-1	poor
B	Assessment answer	1	1	1	0	0	1	4		
	Calibration of judgement answer	1	1	0	0	0	1	3	1	
C	Assessment answer	0	1	0	0	0	0	1		
	Calibration of judgement answer	1	1	1	1	1	1	6	-5	poor
D	Assessment answer	0	0	0	0	0	0	0		
	Calibration of judgement answer	1	1	1	1	1	1	6	-6	poor

As illustrated in Figure 1, the two scores were totalled and the difference between the two scores was determined. For example, if student A received a total of 4 for the calibration of performance judgement score but received a 3 for the assessment score, this meant that student A scored negatively, as $3 - 4 = -1$. In other words, these students were under the impression that they understood the computer programming concepts. However, their predictions or judgements about their learning were inaccurate. A score of zero or more meant that they judged their ability more accurately. For example, if student B received a total of 5 for the judgement score but received a 6 for the assessment score, this meant that student B scored positively, as $6 - 5 = 1$. Table 5 illustrates that most students over-estimated their abilities, where 93.27% of students had poor judgements. In other words, their “thinking about thinking” or metacognition skills are inaccurate. Interestingly, these results are in contrast to students MAI scores, where the mean MAI was 76.46%. Further investigation is necessary to determine (a) why the MAI score and the

semester mark varied to such a degree; and (b) how lecturers can assist students with improving their ability to predict learning better.

Table 5: Calibration of performance judgement (CPJ)

	M	% of students – poor judgement	% of students – good judgement
CPJ score total	-2.52		
CPJ score percentage		93.27	7.28

6.3 Discussion

The purpose of the study was to further explore the MAI and its relationship to broad measures of academic achievement. As was expected and found in previous research (Schraw, 1994; Young, 2008) there was significant correlation between the knowledge of cognition factor and the regulation of cognition factor. These results also provide support for the validity of the MAI as it relates to academic measures. However, significant correlations were not found between the MAI and broad measures of academic achievement, such as the semester mark.

This study indicates that there are areas of concern. For example, the majority of students have poor predictions of learning; and there is a wide variance between the MAI score and the semester mark. The researchers propose a teaching intervention to:

- Develop metacognitive strategies;
- Teach such strategies explicitly to students during classroom discussions; and
- Establish a metacognitive-friendly environment.

It is hoped that by developing and teaching metacognitive strategies to students explicitly, in an environment that encourages discussion and collaboration, students may be motivated to apply such strategies to their learning.

6.3.1 Metacognitive strategies for computer programming

According to Blakey and Spence (1990) the basic metacognitive strategies (seen as A, B, C in Table 6) are (Blakey, 1990):

- Connecting new information to former knowledge (A);
- Selecting thinking strategies deliberately (B); and
- Planning, monitoring and evaluating thinking processes (C).

Based on these strategies, the following tools have been selected to assist students. Firstly, as illustrated in Figure 2, a metacognition strategy card was designed to assist students in developing a strategy while developing a computer program. The card provides students with a

range of questions that could assist them when developing computer programs. For example, which programming constructs must I make use of; or do the results of the solution look realistic?

Figure 2: Metacognition strategy card

<u>Question</u>	<u>Yes ? No</u>	<u>Description</u>	
Am I able to describe the problem?			
Am I able to describe a solution for the problem?			
<u>Question</u>	<u>Construct</u>	<u>Identify</u>	
Which programming constructs are needed to solve the problem?	Inputs		
	Processes	Calculations	
		If/else statements	
		FOR loop	
		WHILE loop	
Outputs			
<u>Question</u>	<u>Yes ? No</u>	<u>Description</u>	
Am I able to trace my solution?			
What results do I get?			
Are they accurate?			
Do they look realistic?			

Secondly, as illustrated in Figure 3, students complete, on a weekly basis, a questionnaire on reflective thinking. This questionnaire allows them to reflect on their weekly assessment mark. For example, did I get the mark I was hoping for? How can I improve on my mark? What did I get correct? What did I not get correct? What do I need to focus on this week so that I can improve in the next test?

Figure 3: Reflective thinking questionnaire

REFLECTIVE THINKING

What mark did I get for my test that was written on the week prior to this week?

What mark was I hoping to get?

How can I improve my mark?

What are the concepts that I learnt this week that I know well?

What are the concepts that I learnt this week that I DO NOT know well?

Make a list of programming concepts that I need to know that will enable me to do well in the test on Friday

Thirdly, as illustrated in Figure 4, students complete a plan-of-action worksheet weekly. This sheet assists them in planning and monitoring their learning for the week.

Figure 4: Plan of action sheet

PLAN OF ACTION FOR THE WEEK
Did I complete all the exercises and problem solving as outlined in the weekly learning activity?

If the answer was “yes” that means that I can now focus on revising the exercises / problem solving for the test on Friday
Write down a plan of action to do this

If the answer is “no”, you must ask yourself the following:
Did I finish my exercises?

If the answer was “yes” that means that I can now focus on whether I completed my problem solving
If the answer is “no”, you must ask yourself the following:
Write down your plan of action to complete the exercises?

If you have completed the exercises but not the problem solving the same applies, you need a plan of action to complete the problem solving

Table 6 illustrates which metacognitive strategies are reflected in the metacognitive score card, the reflective thinking questionnaire and the plan-of-action worksheet.

Table 6: Metacognitive strategies applied by students

Computer programming Metacognitive strategy	A	B	C
Metacognitive score card	√	√	√
Reflective thinking			√
Plan-of-action		√	√

Table 6 illustrates that the:

- Metacognitive score card provides students with an opportunity to:
 - Identify whether they had seen the problem before (A);
 - Identify which computer programming constructs were needed for this particular problem (B); and
 - Plan and structure the solution using a template that explicitly indicates computer programming constructs needed (C).

- Reflective thinking questionnaire provided students with an opportunity to:
 - “Think about thinking” or reflect on their weekly achievement and
 - How to rectify problems and set goals (C).
- Plan-of-action worksheet provided students with an opportunity to:
 - Set goals on how to complete tasks for the week (B, C).

Merely providing students with a set of metacognition strategies may be insufficient. Explicit teaching of such strategies may be required.

6.3.2 Teaching Metacognitive strategies explicitly

These strategies are taught explicitly to students before during and after classroom activities have taken place. Such teaching takes place in a collaborative manner, where students either pair (Preston, 2005) up with one another or students collaborate with one another in small groups. Groups discuss various metacognitive strategies openly. For example, a student may express that time management is an issue; or that they felt they had learnt the work, but still performed badly. Solutions are discussed in collaboration with fellow students, tutors and the lecturer. Teaching metacognitive strategies assists students to (Blakey, 1990):

- Identify “what you know” and “what you don’t know”;
- Talk about thinking;
- Keep a thinking journal;
- Plan and self-regulate;
- Debrief the thinking process; and
- Self-evaluate.

Teaching metacognition strategies needs to be done in an environment that promotes an awareness of thinking (Blakey, 1990). Therefore, the environment must be conducive to thinking reflectively.

6.3.3 Establish a metacognitive environment

Students exposed to a learning environment that promotes openness, discussion and relaxation are more inclined to express their feelings and emotions than students who are not (Jenkins, 2001). Consequently, the classroom was rearranged to accommodate open discussion. The class size was reduced by half and students collaborated in small groups (ten students to a group). Students face each other, get to know each other, have opportunities to discuss various learning

aspects with each other, and form camaraderie within the group. Once this was established, students readily spoke about their learning strategies, goals, and suggested ways in which to improve learning.

7. Conclusion

The results of the study are promising. Given the positive correlations between the MAI and knowledge of cognition and regulation of cognition factors, they can be used as a tool for lecturers to identify students in need of direct instruction related to metacognition. Additionally, the item analysis, in combination with the calibration of performance judgement results, may be useful tools to further assess students' metacognitive abilities. This may be especially useful for large classes as well as online classes, where lecturers have little opportunity to get to know students. Lecturers can monitor students with low MAI scores and use the MAI results to determine areas of metacognitive knowledge and regulatory skills students use or do not use while learning.

In the future, the goals will be to examine the MAI score more closely in order to understand why there is a wide variance between the MAI score and the semester marks. Also, the extent to which the metacognition teaching intervention assisted students will be more closely examined.

8. References

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