

THE ROLE OF METACOGNITION IN EVERYDAY PROBLEM SOLVING AMONG PRIMARY STUDENTS IN KENYA

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Abstract

Metacognition is an important dimension of problem solving because it includes problem-relevant awareness of one's thinking, monitoring and regulation of cognitive processes, and application of heuristics. This study investigated the effect of Metacognition on problem solving among 150 students at Muraka Primary School, Kenya in June 2010. Students answered a 25-item self-report Metacognitive Awareness Inventory (MAI), and a 1-item multiple choice Problem solving questionnaire (PSQ). Data were analyzed using linear regression and ANOVA. Results indicated that metacognition is a good predictor of problem solving ability. Students showed significant differences in problem solving based on grade. There was also a significant difference in metacognition level based on grade. These results imply that metacognitive ability develops with age, such that the higher the grade levels the higher the metacognitive ability. Therefore, understanding the role of metacognition in children's everyday problem solving may lead to the development of more effective instruction, by teachers, which incorporates metacognitive skills to help children improve in their problem solving skills and overall academic achievement.

Key words: cognition, metacognition, problem solving.

Introduction

Research on metacognitive development was initiated in the early 1970s by John Flavell who is considered to be the "father of the field" and thereafter a considerable amount of empirical and theoretical research dealing with metacognition can be registered (Brown, Bransford, Ferrara, & Campione, 1983; Flavell, Miller, & Miller, 1993; Schneider & Pressley, 1997). From the very beginning, metacognition was broadly defined as any knowledge or cognitive activity that takes as its cognitive object, or that regulates, any aspect of any cognitive activity (Flavell et al., 1993, p.150). Moreover, it also includes executive skills related to monitoring and self-regulation of one's own cognitive activities. In a seminal article, Flavell (1979) described three major facets of metacognition, namely metacognitive knowledge, metacognitive experiences, and metacognitive skills, that is, strategies controlling cognition. Later on, Flavell (2000) divided metacognitive theory into two areas of study: knowledge and processes. Metacognitive knowledge includes understanding of how minds work in general and how your own mind works in particular. The processes of planning, monitoring, and regulating thoughts are generally known as *executive processes*, which involve the interaction of two levels: At one level is the creative, associative, wandering mind and above it is the executive, trying to keep it on task.

This theoretical framework of metacognition has been subsequently extended by various scholars such as; Ann Brown (1987) who distinguishes between knowledge about cognition, and regulation of cognition. Kluwe (1982) brought further definition to the concept

of 'metacognition' describing metacognitive activities as thinking whereby the thinking subject has some knowledge about his own thinking and that of other persons; monitors and regulates the course of his own thinking, and that the term 'executive processes' denotes both monitoring and regulating strategies. Executive *monitoring* processes involve one's decisions that help: (a) to identify the task on which one is currently working, (b) to check on current progress of that work, (c) to evaluate that progress, and (d) to predict what the outcome of that progress will be. Executive *regulation* processes are those that are "directed at the regulation of the course of one's own thinking" and they involve one's decisions that help (a) to allocate his or her resources to the current task, (b) to determine the order of steps to be taken to complete the task, and (c) to set the intensity or (d) the speed at which one should work the task (Hacker, D.J., 1997). Considerable volumes of research findings advocate the positive impact of metacognitive activity on student thinking skills (Nickerson, Perkins and Smith, 1985; Perkins and Salomon, 1989). An extensive multiple-year cross-subject approach project in the field of Metacognition; PEEL (Project to Enhance Effective Learning) in Australia, aimed at secondary school students' understanding and informed responsibility for their own learning (Gunstone, 1991). The outcomes of the project revealed that metacognition can be promoted and it can facilitate conceptual change (White and Gunstone, 1989). Significant research has also been presented by the Cognitive Acceleration through Science Education (CASE) project in the UK. Its main aim was to explore an approach that hopes to improve pupils' ability to learn, and metacognition was one of the main pillars of the intervention program employed (Adey and Shayer, 1994). Students who participated in the CASE groups generally presented better achievement two to three years after the intervention had ended, and 'general' because better achievement was reported in widely different subjects (i.e. science, mathematics and English) (Adey, Shayer and Yates, 1989). Further investigations have established the importance of metacognition in the acquisition and application of learning skills in diverse domains of inquiry (Alexander, Fabricius, Fleming, Zwahr & Brown, 2003). For example, Gardner, 1991 and Karmiloff-Smith, 1992 found metacognition to be an important dimension of problem solving 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). Most researchers working on problem-solving (Dewey, 1910; Newell & Simon, 1972; Mayer, 1991; to name a few) agree that a problem occurs only when someone is confronted with a difficulty for which an immediate answer is not available. Schunk, 2000, defines problem-solving as the effort required in achieving a goal or finding a solution when no automatic solution is available. 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. Metacognition becomes especially important in ill-defined problems as the problem solver cannot rely as much on domain-specific knowledge (Land, 2004). Thus, the focus on the problem-solving process becomes more relevant. To reflect on this process leads to a deeper understanding of the problem and to a more flexible and successful approach to solving the problem. For example, in the information collection stage, Schmidt and Ford (2003) demonstrated that metacognitive activities go hand in hand with more successful acquisition of relevant knowledge. They showed this using the real world problem of creating web pages. Chi, Bassok, Lewis, Reimann & Glaser (1989) showed that successful problem solvers more often reflect on their own problem solving. Experts compared to novices, for example, are more skilled in allocating their time during

problem solving and realizing when they make errors (Carlson, 1997; Glaser & Chi, 1988). Engaging in metacognitive activities, problem solvers become aware of their strengths, but also of their limitations (Bransford, Brown, & Cooking, 1999) and suppressing metacognitive processes during problem solving can lead to a decrease in performance (Bartl & Dörner, 1998). Despite the multitude of studies about the role of metacognition in learning and teaching, several gaps are apparent. First, while studies on the effects of metacognitive instructional methods in reading and mathematics are relatively extensive, not much work has been done in everyday problem solving. Second, most of the investigations and interventions about the effects of metacognition in learning and teaching science have concentrated on secondary schools, colleges, and universities, but studies in elementary schools are rare. Third, no research has been done about the contribution of metacognitive instructional intervention in the schools of developing countries, characterized by large classes, limited resources, hence content-based teaching and learning. 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 in many situations including and not limited to, time allocation (whether to do homework or to play), what to buy, and social situations (how to facilitate friendships). They do so by considering the advantages and disadvantages of alternative solutions and justify those solutions. In such a problem situation, problem solvers need to identify the most relevant criteria. A lack of comparable studies in elementary schools or in developing countries prompted this study of metacognitive awareness and its impact on everyday problem solving. In this study, student participants were given an everyday decision-making type of problem to solve, that asked them on 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). The researchers believed that when a student has a high metacognitive awareness, he/she makes a better decision, and is better 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 researchers hypothesized that Metacognition is related to problem solving and that students who perform better on the metacognitive awareness scale will be better at the decision-making problem. Furthermore, the researchers believed that age is related to both Metacognition and problem solving.

Problem of Research

Metacognitive skills are a pre-requisite to problem-solving of both well and ill-defined problems. When students have knowledge and control of their own cognitive processes, learning is enhanced regardless of the domain of learning, whether reading, writing, science, mathematics, or any other activity that involves thinking. Metacognition includes the awareness about what one knows (Metacognitive knowledge), what one can do (metacognitive skills), and what one knows about his own cognitive abilities (metacognitive experience). Over-emphasis on rote-learned content and terminology still characterizes much teaching and learning at primary schools in Kenya, to the detriment of student learning yet we know that teaching and learning is all about problem solving. Traditionally, problem solving is presented by teachers simply doing the problem and then asking students to do similar problems, which more often than not is mere regurgitation of what the teachers offer. According to Hobden, 1998, typical problems are usually routine applications of formulae rather than real-life problems, and it has been assumed that students will reach conceptual understanding just through sufficient practice at problem solving. Furthermore, repetitive practice at problem solving makes students gain routine

expertise, but not adaptive expertise (Hatano & Inagaki, 1986), because they develop speed and accuracy at routine problem solving, but fail to develop the ability to reflect on what they do or to adapt to solving new problems in a flexible manner; which requires applying Metacognition. It is with this background that this study was carried out. This study investigated the effect of metacognition on everyday problem solving among primary school children in Kenya. The following research questions were addressed: 1 Does metacognition predict students' problem solving ability? 2. Does problem solving vary with grade? 3. Does metacognitive ability differ with grade level?

Research Focus

The purpose of this correlational study was to investigate the role of metacognition on problem solving and to find out if age (grade level) has an effect on the metacognitive awareness and problem solving ability.

Methodology of Research

General Background of Research

A correlational study was conducted to investigate the role of metacognition on everyday problem solving, and how both metacognition and problem solving each differs with grade level. In essence the researchers were interested in showing how students' metacognitive awareness predicts their problem solving ability. To show the effect of age, students from grade 5 through 8 participated in this study. The research questions were: 1 Does metacognition predict students' problem solving ability? 2. Does problem solving vary with grade level? 3. Does metacognitive ability differ with grade level? The researchers hypothesized that students with high metacognitive ability are good at problem solving and that students differ on metacognition and problem solving ability based on grade level.

Sample of Research

A convenience sampling technique was employed to sample 150 students, which is the total population for upper primary grades from Muraka primary School, Kakamega District, Kenya. (Males = 69, Female = 81; ages ranged from 10 to 17 years and mean age = 12years; 5th graders=42, 6th graders= 38, 7th graders= 31, and 8th graders=39) in the month of June, 2010. In the Kenyan education system, primary school has 8 grades starting with grade 1 through grade 8. Grades 1 through 4 are collectively called lower primary, while grades 5 through 8 are the upper primary. The sample (n=150) was 30.1% of the total school population. The school is highly homogeneous in terms of ethnic groups (tribes). It is predominantly Luhya 492 (98.7%) and other tribes 6 (1.2%). The total population is 498 students. This sample is representative of the Luhya community in which 99% of the population is Luhya tribe and one percent non-Luhya. Social economic status (SES) was sought from analysis of documents at the principal's office and it showed that Low SES= 98(65.3%), Middle SES= 42 (28%), and High SES= 10 (6.7%).

Instrument and Procedures

A Metacognitive Awareness Inventory Junior Version (MAI, Jr. Version) which was developed by Sperling & Howard, (2002) and adapted by Chwee Beng Lee (2009) for use in Asia (see Appendix) was used in the present study because it contains items that measure how metacognition can predict everyday problem solving. Theory shows two components

of metacognition as being regulation of cognition and knowledge of cognition. These components of Metacognition have the following subscales: For knowledge of cognition we have: Declarative knowledge (DK), Procedural knowledge (PK), and Conditional knowledge (CK). For regulation of cognition we have: Planning (P), Evaluation (E), and Monitoring (M). The MAI is a self-reporting 25-item, 5-point Likert type scale whose responses ranged from 1=Strongly Agree, 2=Agree, 3=Undecided, 4=Disagree, to 5=Strongly Disagree. The Problem-Solving Questionnaire (PSQ) was used to measure problem solving ability (see Appendix). The PSQ is a single item multiple choice scale with four options ranging from option A to D. Option A represents very high problem solving ability and option D represents low problem solving ability. To evaluate how metacognition predicts problem solving ability, the composite score of metacognitive awareness was computed and used as a continuous independent variable. To explore the effect of grade level on problem solving ability, students were grouped into four groups based on their score on the PSQ. Students who selected option A were classified as very high problem solving level group; option B as high problem solving group; option C as average problem solving group; and option D as low problem solving group. Prior to study, the lead researcher visited the school to seek permission from the school principal to conduct the study. Before administration of the instruments, the lead researcher and 4 teachers from the school explained the purpose of the study to the students and informed them that participation was entirely voluntary. The students were told that they were free to withdraw from the study at any time without penalty. For the purpose of confidentiality and anonymity, students were assigned identification numbers which were used instead of their names. Thereafter, the instructions were carefully read to the students and they were told to feel free to ask for assistance on any items that were difficult to understand. Both the MAI and PSQ were answered in 30 minutes.

Data Analysis

Prior to conducting analyses to address the main research questions, descriptive statistics (mean and percentages) were conducted to check for data entry errors. Cronbach's alpha coefficient was used for internal consistency of the items as used on the Kenyan sample. To investigate the structure of the MAI scale, Exploratory Factor Analysis was conducted using promax rotation to examine factor structure. The model tested was based on the hypothesized 6-factor structure by Lee, C., et al, 2009 and Akpınar, et al, 2009. To address the research questions, linear regression and ANOVA analyses were conducted. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity were conducted to test whether the data were factorizable.

Results of Research

Descriptive Statistics

A total number of 150 primary students participated in this study. The distribution by gender was male=69 (46%) and female= 81 (54%), and by grade we had grade 5= 42 (28%), grade 6= 38 (25.3%), grade 7= 31 (20.7%), and grade 8= 39 (26%). Students' age ranged from 10-14 years= 105 (70%) and 14-19 years = 45 (30%). Levene's test of homogeneity was non-significant ($p=0.908$), hence not violated. Skewness and kurtosis of the items were analyzed and all items were found within normality criteria. Reliability analysis revealed an internal consistency of $\alpha = 0.789$. This is on average a good estimate of internal consistency. Item-total statistical analysis revealed only one item (OPTIONS) was not very important because when deleted from the analysis there was no variation in the cronbach's alpha. For Exploratory factor analysis (EFA) produced a 6-factor solution with eigenvalues greater than one that explained

47% of the sample variance. From the communality output the lowest explained variance by the items was 33% while the highest was 64%. This meant that all the items in the MAI scale were well explained for. The item loadings were all very high with a loading greater than 0.3 (Appendix 2). The six factors fall under the sub-scales: Planning (P), Monitoring (M), Evaluation (E), Declarative knowledge (DK), Procedural Knowledge (PK), and Conditional Knowledge (CK).

Table 1. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.651
Bartlett's Test of Sphericity	Approx. Chi-Square	689.341
	df	300
	Sig.	0.000

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.651 (see Table 1), which is above the cut-off of 0.6, conventionally held as a critical value. Bartlett's Test of Sphericity is statistically significant [$\chi^2 (150) = 689.341, p < 0.0001$] (Table 1), showing that factor analysis was suitable for this data set, and the strength of the relationship among the variables is fairly strong, given the relatively small sample size.

Question 1: Does metacognition predict students' problem solving ability?

Linear regression was conducted and results showed that overall metcognition can only account for 3.8% of variation in students' problem solving skills indicating that there could be other factors that could explain about 96% of variation in problem solving that cannot be explained by students' metacognitive abilities. The predictor model was significant $p < 0.05$ indicating that the regression model used in this case predicts problem solving skills significantly well.

Table 2. Summary Table of Linear regression.

Model	Sun of squares	df	Mean squares	F	p-value.
Regression	7.544	1	7.544	5.829	0.017
Residual	191.530	148	1.294		
Total	199.073	149			

- a. Predictors: (Constant), Overall metacognition score
- b. Dependent Variable: How to choose right bicycle

Results (Table 3) show that overall students' metacognition score makes a significant contribution $p < .05$ to predicting problem solving skills. From the ANOVA Table 2, we see that there is a linear relationship between how well students perform on a problem solving task and metacognition ($F = 5.829, p = 0.017$).

Table 3. Summary Table of Linear regression.

Model	Unstandardized	Coefficients	Standardized	Coefficients	t-value	p-value
Constant	B	SE	B	9.720	0.000	
Overall	3.805	0.391				
Metacognition scor	-.017	.007	-.195	-2.414	.017	

Dependent Variable: Problem Solving

Question 2: Does problem solving vary with grade?

A One-way ANOVA was conducted (Table 4) and the results revealed statistically significant mean differences in problem solving based on grade ($p < 0.0001$, $df = 3$, at $\alpha = 0.05$). After the significant results $F(3, 150) = 7.724$, $p < 0.0001$, a follow-up post-hoc Tukey's HSD test revealed that grades 7 and 8 were significant at $\alpha = 0.05$ indicating that at higher grades students tend to be better at problem solving.

Question 3: Does metacognitive ability differ with grade?

A One-Way ANOVA was also conducted (Table 4) and there was a statistically significant difference in metacognition level based on grade ($p = 0.002$, $df = 3$ at $\alpha = .05$).

Table 4. Summary tables for Analysis of Variance.

Outcome variable	df	F-ratio	p-value
Problem solving	3	7.724	0.000
Level of Metacognition	3	5.161	0.002

Dependent Variables: Problem Solving and Metacognition

Similarly, following up the significant ANOVA results for metacognition, $F(3, 150) = 5.161$, $p = 0.002$, post-hoc Tukey's HSD revealed that grade 8 was the most statistically significant, implying that at a higher grade level, students have higher metacognitive ability than those at a lower grade level.

Discussion

This study contributes to the limited research on influence of Metacognition on everyday problem solving in primary schools. Muraka Primary is a low-achieving school and the results indicated that students with high Metacognition level were better problem solvers than those with low Metacognition level. This is consistent with many studies (Gardner, 1991, Karmiloff-Smith 1992, Hennessey, 1999, 2003, Hong, Jonassen, and McGee, 2003, Schmidt and Ford 2003, Chi, Bassok, Lewis, Reimann & Glaser 1989, Bransford, Brown, & Cooking, 1999, Bartl & Dörner, 1998, Amsterlaw 2006) that showed a similar trend.

It is encouraging to note that students who participated in the study all scored highly on

the MAI scale, with an average of 2.00 which translate to “Agree”, based on our Likert scale.

Results of how Metacognition predicts problem solving ability were statistically significant and this can be interpreted in the context of broader metacognitive changes taking place during middle childhood. Students at higher grade level were better at both metacognition awareness and problem solving ability. This finding concurs with theory about metacognition and development. Metacognition improves with age and therefore we expect older students to score highly on a metacognitive scale than younger students and likewise older students will be better problem solvers than younger students. Developmental and comparison studies have shown that highly skilled and mature readers exceed poor and young readers in metacognitive measurement (e.g. Garner, 1980; Paris & Jacobs, 1984). Some theories posit that increasing Metacognition contributes to developmental change in decision making (reasoning) (Kuhn, 2000b; Moshman 1998). Applied to present findings, children’s strategies of solving of everyday problems, such as planning, monitoring, and evaluation may depend on them having such knowledge in the first place. In theory, such a relationship makes sense because when children encounter problems, they must really appeal to some metalevel knowledge about how to arrive at a solution. Without this they would be unable to regulate their decision making hence problem solving. 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 metacognitive 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. Metacognition is undoubtedly an indispensable aspect of students’ learning about problem solving. Yet, perhaps owing to lack of awareness of the importance of metacognition, or alternatively, the belief that it is not the responsibility of teachers to foster metacognitive abilities, little research to this point has addressed issues related to the role of metacognition in everyday problem solving.

Naturally, conducting a study with samples of convenience in natural educational settings provides multiple threats to external validity that may hinder generalizability of the results. The major limitation in this study was the size and nature of the sample used. The small sample size (n=150) may hinder precision of the sample statistics, and more importantly, may not be a representative of the population of interest, given that the sample was drawn from a low-achieving school. While it is clear that, in general, metacognition contributes favorably to everyday problem solving, many open questions abound. Some issues for future research in problem solving are (i) how can metacognition best be promoted in learning (ii) how can metacognitive aspects of problem solving best be assessed? (iii) How are the various aspects of metacognition related to problem solving outcomes?

Conclusions

The results of this study provide supportive evidence for models that assert students with high metacognitive ability are good at problem solving. The analysis and the comparison of students’ metacognitive awareness self-report questionnaire with answers of their problem solving question showed that the metacognitive ability is important in decision making. When one has high metacognitive ability and knows how to apply it, there is a higher chance that problem solving will be successful. In general, we consider that the findings of this study will contribute important information towards the study of meta-cognition and specifically towards the integration of metacognitive instruction in teaching and learning so as to promote problem solving and hence academic achievement.

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Appendix 1:

Metacognitive Awareness Inventory (MAI)

- 1 I think I know whether I have understood the problem well
- 2 I set a goal before solving the problem
- 3 I know what kind of information is most important when solving the problem
- 4 I ask myself how well I have solved the problem once I have finished
- 5 I know when each plan I use will be most effective
- 6 I find myself pausing regularly to check my understanding
- 7 I can solve the problem best when I know something about the problem

- 8 I ask myself if I have considered all options when solving the problem
- 9 I ask myself now and then if I am meeting my goal
- 10 I ask myself about the case before starting to solve the problem
- 11 I think I am good at sorting out the information presented in the problem
- 12 I consider several ways to solve the problem before I answer
- 13 I organize my time to best solve this problem
- 14 I know how well I did after solving the problem
- 15 I summarize what I have learned after solving the problem
- 16 I solve the problem better when I am interested in it
- 17 I ask myself if I have considered all options after I solve the problem
- 18 I am aware of the plans I use when solving the problem
- 19 I try to think in the ways that have worked in the past
- 20 I have a specific purpose for each plan I use
- 21 I ask myself whether I have considered carefully before I make a choice
- 22 I can make myself to solve the problem when I need to
- 23 I use different plans to solve the problem depending on situation
- 24 I find myself using helpful methods naturally when I solve the problem
- 25 After I had solved a problem, I ask myself whether there is an easier way to solve the problem

Problem-Solving Questionnaire (PSQ)

Choose the option that best describes your decision in buying the bicycle. Encircle the correct option. “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 choose 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.

Appendix 2

Factor Structures of the Metacognitive Awareness Inventory for Kenyan Students (N = 150)

Items	F1	F2	F3	F4	F5	F6
1						.796
2					.458	
3	.365					
4		.546				

5						.796
6					.599	
7			.615			
8				.417		
9	.440					
10					.675	
11						.708
12				.826		
13		.531				
14			.537			
15				.439		
16			.646			
17	.536					
18				.688		
19		.710				
20						.483
21	.657					
22			.422			
23		.527				
24					.390	
25	.587					

Note: F1=Factor 1 (Planning), F2= Factor 2 (Conditional Knowledge); F3=factor 3 (declarative Knowledge); F4= Factor 4 (Evaluation); F5=Factor 5 (Procedural Knowledge), and F6=Factor 6 (Monitoring).

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