International Journal of Social Sciences
Citation: IJSS: **13**(04): 161-165, December 2024
DOI: 10.46852/2249-6637.04.2024.2

RESEARCH PAPER

Influence of Metacognition on Mathematics Test Performance among High School Students in Western Kenya

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Received: 14-09-2024 **Revised:** 20-11-2024 **Accepted:** 02-12-2024

ABSTRACT

The ability for students to perform well in mathematics has been linked to both cognitive and non-cognitive constructs. This study sought to examine how metacognition predict mathematics test performance among high school students in Kenyan public schools. Metacognition has positive effect on students, in mathematics, it helps them continue solving problems by creating new approaches when one approach fails. Using a cross-sectional design, this study employed a sample size of 260 secondary school Kenyan students 140 male (53.85%) and 120 female (46.15%). Data was collected using Mathematics test exercise, Metacognitive Awareness Inventory for students and a Mathematics Test for students. All hypotheses were tested at p < .05 level of significance using regression analysis and ANOVA. The findings showed positive and significant relationship between metacognition and mathematics test performance. Metacognitive strategy use showed a higher predictive value for mathematics test performance than metacognitive awareness. The participation was voluntary and participants' confidentiality and privacy was protected through out the study. These findings will be significant in informing policy on designing of mathematics instruction method in secondary schools and mathematics teacher training as it contributes to existing knowledge and literature on metacognition and mathematics test performance.

HIGHLIGHTS

- Metacognition has an effect on students' test performance.
- There is a positive and significant relationship between metacognition and mathematics test performance.
- Metacognitive strategy has a higher predictive value for mathematics performance than metacognitive awareness.

Keywords: Metacognition, Mathematics test, Knowledge, Strategies

Mathematics presents itself universally, in almost every facet of life; in nature all around us, and in technologies in our hands. Mathematics helps us to describe our understanding of all that we observe and it may be termed as the universal language of our environment (TIMSS, 2013). According to NCES (2012) students who have poor performance in mathematics risk losing many future career opportunities. Kupari and Nissinen (2013), reported a noticeable decline of mathematics performance among students worldwide while Karimi and Vankatesan (2014) report that most students drop out of schools for fear of sitting mathematics tests or performing poorly in them, affecting their overall academic performance.

How to cite this article: Andaya, V.M., Mwaniki, E.W. and Mwaura, P. (2024). Influence of Metacognition on Mathematics Test Performance among High School Students in Western Kenya. *Int. J. Soc. Sci.*, **13**(04): 161-165.

Source of Support: None; **Conflict of Interest:** None

Poor mathematics performance at secondary level has seen very few admissions to mathematics related courses in Kenya (MOEST, 2016; 2017). This may have jeopardized the capability of students to take up career placements to realize the achievement of the government's development agenda.

According to Flavel (1979) metacognition is a level of thinking which involves active control over the process of thinking to learn or solve problems. This may entail thinking about one's thoughts of their study skills, memory capabilities and problem solving. Metacognition is basically characterised into three components, metacognitive awareness, metacognitive strategies and metacognitive experiences (Prather *et al.* 2020). As reported by Veenman (2011) students trained in metacognitive instruction have shown positive effects in their performances in varied fields. In mathematics, metacognition helps students feel encouraged to endure solving mathematics problems without giving up their efforts. They are able to devise new problem-solving tactics and show divergent thinking patterns one approach fails (Surivon *et al.* 2013). According to Du Toit and Kotze (2010), metacognition helps learners like mathematics as they are able to gain simpler ways of solving the problems since they are able to acquire more effective study methods in mathematics.

This study was guided by John Flavell's (1979) metacognition theory. In this theory, Flavell propagates the concept of intentionality supposing thinking as a deliberate action that is goal-oriented and involves planning a sequence of actions. This theory distinguishes three major components of metacognition; (i) metacognition knowledge which denote the knowledge, ideas and beliefs about the varied interface between cognitive tasks and strategies that may be used to accomplish these tasks; (ii) metacognitive strategies imply the skills and processes that one may use to plan, guide, monitor, control, regulate and evaluate cognition and learning; (iii) metacognitive experiences refer to the awareness and feelings elicited in a problem solving exercise. In this study, the researcher incorporated metacognitive knowledge and strategies to find out if metacognition was a predictor of mathematics test performance.

LITERATURE REVIEW

Most theories agree that there are at least two or three components of metacognition, knowledge about and control over one's own cognitive system (Flavell, 1979), thus, metacognitive knowledge; and metacognitive strategies which are skills of carrying out the task (Meroyi, Amosun & Sotoyinbo, 2022). Gimbert *et al.* (2019) reported that spontaneous control of one's own learning process may occur without the person being aware of it. The conscious executions of strategies are thus manifested by planning, monitoring and meta-strategic activities through the implementation of metacognitive knowledge.

In a study done among Belgian children from Grade 1 to 6, it was reported that the metacognitive knowledge and skills of children were directly related to their accuracy in responding to mathematics problems. Children who scored low in metacognition also evaluated their own performance in mathematics as worse, (Desoete *et al.* 2019). Dagoc and Tan (2018) concluded that the use of metacognitive scaffolding was of great help to the pupils as it helped them benefit from cooperative learning. They further reported that pupils whose metacognition were high found less difficulties in understanding the mathematics concept, could easily analyze the problems and suffered little memory challenges, possessed better basic mathematics skills and showed positive attitudes towards mathematics and less anxiety when faced with a mathematics problem. Similarly, Ohtani and Hisasaka (2018) in their meta-analysis using 179 samples from 118 articles revealed that metacognition greatly predicted academic performance when intelligence was controlled for.

Ortlieb and Norris (2012) in a quasi-experiment using kindergarten children in Texas America found out thinking aloud as they read increased the learners' comprehension of science concepts. The sample size for this study was kindergarten children who may have not fully developed their metacognitive abilities as compared to secondary school students who were used in the current study.

In Kenya, using a sample of 310 class 6 pupils and a correlational research design, Mwaniki (2015) found a positive and significant relationship between metacognition and reading comprehension performance. This study tested primary school pupils who were below 13 years old. Young children may be low on metacognition because it is still developing as compared to students in secondary school who may have advanced in metacognition development which the current study has sampled. Metacognitive strategies used in reading may be different from strategies used in mathematics, thus the current study examined how metacognition relates to students' mathematics test performance in Kenya.

METHODS

Sample

A sample of 120 participants (60 boys and 60 girls) from the boys and girls boarding schools and 140 participants (80 boys and 60 girls) from the co-educational schools was used. This made up the total sample to be 260 participants (140 boys and 120 girls) from public secondary schools in Kakamega County, Kenya.

Instruments

The following instruments were used in data collection:

- ***Mathematics Test exercises*** collected the demographic data and the mathematics exercise performance.
- ***Metacognitive Awareness Inventory (MAI) for students*** adapted from Schoenfeld (1985) metacognitive awareness inventory guide, was used to measure metacognition as low, medium or high. Some items were modified for ease of understanding, for example one item was modified to read; 'I rarely draw pictures or diagrams to help me understand while learning' from 'I hardly ever use illustrations to help me understand while learning'.

Procedure

Clearance was sought from the graduate school at Kenyatta University, the researcher sought approvals from the National Council for Science, Technology and Innovation (NACOSTI), the County Education officer and the County Commissioner to conduct the study. Through preliminary visits to sampled schools, permission was sought from the school principals and teachers before data collection. Students participated voluntarily. Students started by doing the metacognitive awareness inventory, thereafter, the mathematics anxiety rating scale then the short mathematics test were administered respectively. Participants completed the data collection tools across a period of 80 minutes without a break. Mathematics test was marked separately by two mathematics teachers and a mean score attained per respondent. The data was cleaned, coded and entered SPSS 22 for analysis.

Ethical considerations

The researcher obtained consent through a letter to the parents/guardians requesting then to allow their children to participate in the study. During the study, the researcher explained the purpose of the study to participants, assured confidentiality, informed them of their voluntary participation and the freedom to withdraw from the study at any time if they felt uncomfortable, reassuring them that their decision will be respected and not used in any way against them. All data collected was treated confidentially and used solely for the purpose of the study. All responses to the questionnaires and the test were purely voluntary.

Data analysis

Multiple regression analysis was used to explore if the was any relationship and the form of relationship between the variables. Pearson correlation coefficients were used to test for significance relationship between mathematics anxiety and test performance while the *t*-test for independent samples was used to test for any differences due to gender.

RESULTS AND DISCUSSION

Relationship between metacognition and mathematics test performance

As shown in Table 1, majority of the respondents scored Low in the MAI inventory they also exhibited low grades in the MTS scores, most of whom scored 34 marks and below. Respondents who scored High in the MAI inventory showed high scores in the MTS scores. This implies that there is a positive correlation between a student's metacognition score and their performance in a mathematics test. It therefore means that when students' metacognitive awareness and strategies are improved, then their performance in mathematics is more likely to improve. Based on these observations, the researcher can report that with all other factors held constant, students who score low in metacognition may not perform well in mathematics hence the need to improve their metacognitive capabilities for them to realize better performance in mathematics. Students in Co-Educational schools scored the least in metacognitive awareness similar to most girls in Girls Boarding schools. On the contrary, more boys in Boys Boarding schools scored higher. This may imply that boys have better metacognitive capabilities as compared to girls, and these capabilities improve further when they are in boarding secondary schools.

Table 1: Hypothesis testing: correlations between metacognition and mathematics test performance

		MTS	MAI	MA	MS
Pearson Correlation	MTS	1.00	.47	.55	.42
	MAI	.47	1.00	.51	.39
	MA	.55	.51	1.00	.38
	MS	.42	.39	.38	1.00
Sig. (2-tailed)	MTS	.	.000	.000	.000
	MAI	.000	.	.000	.000
	MA	.000	.000	.	.000
	MS	.000	.000	.000	.

Note: *MTS = Mathematics Test Score; MAI = Overall score in metacognition; MA = Metacognitive Awareness; MS = Metacognitive Strategies*

N= 2,254; n = 260

The results revealed that there was a significant relationship between metacognition and mathematics test performance as was expected in the alternative hypothesis. This relationship was also a positive one. The highest correlation was between metacognitive awareness and mathematics test performance $(r\ (258) = .55,\ p < .05)$; followed by overall score in metacognition and mathematics test performance $(r\ (258) = .47,\ p < .05)$; then finally metacognitive strategies and mathematics test performance $(r\ (258) = .42,\ p < .05)$. The null hypothesis was thus rejected. These findings may indicate that many students are aware of the various metacognitive strategies that can be used to solve mathematics problems but they do not use them when solving the problems. This could be due to other prevailing variables that were not included in the study. Examples of such variables maybe but not limited to; student's achievement motivation, teacher's competency, and student's level of interest in mathematics.

Table 2: Adjusted R2 from the correlations between metacognition and mathematics test performance

Model	R	R Square	Adjusted R Square	SEE
1	.55[a]	.30	.30	2.64
2	.59[b]	.35	.35	2.54
3	.62[c]	.38	.37	2.49

Note: SEE = Standard Error of Estimate; a. = Predictors: (Constant), Metacognitive Awareness; b. = Predictors: (Constant), Metacognitive Awareness, Metacognitive Strategies; c. = Predictors: (Constant), Metacognitive Awareness, Metacognitive Strategies, Mean Score in Metacognitive Awareness Inventory.

N = 2,254; n = 260

Metacognitive awareness alone accounts for R^2.30 or 30% of variance in mathematics test performance. However, metacognitive awareness and metacognitive strategies jointly account for 35% of variance in mathematics test performance, and a mean of metacognition accounts for 37% of variance in mathematics test performance.

CONCLUSION

The study hypothesizes how mathematics test performance is predicted by metacognition and mathematics anxiety. These findings point towards an existence of a significant positive relationship between metacognition and mathematics test performance. It can be concluded that students who use metacognitive strategies while solving mathematical problems are more likely to score highly. Learners need to have an awareness of the various strategies available for use in order for them to apply them effectively. These approaches may as well help the teacher identify weak and struggling students who can be given further assistance.

Limitations and Future Studies

There is need to find out the level of metacognition awareness among teachers of mathematics and how they use this awareness to help their students improve in mathematics. Future studies could explore use of other study designs such as experimental design to test the hypothesis. Longitudinal studies may help ascertain whether metacognition improves with age.

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