Effect of Metacognitive Awareness on Students' Achievement in Mathematics in Public Secondary Schools in Kitui County, Kenya

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ABSTRACT

Deep conceptual understanding enables learners to transfer new knowledge into new situations and apply it in new contexts. Individuals' understandings of their thought processes as well as monitoring their progress is fundamental for deepening learners' understanding and that may lead to improved performance. The overall students' performance in mathematics at the Kenya Certificate of Secondary Education (KCSE) has been low compared to other subjects. Students' knowledge of facts and skills need to occur in the context of a meaningful and conceptual framework of subject matter that deepens learners' understanding. The purpose of the study was to investigate effect of Metacognitive awareness on secondary school students' achievement in mathematics. The Research employed a Quasi-experimental design and in particular Solomon, Four Design. A stratified random sampling technique was used to draw four boys' and four girls' extra county participating secondary schools. Assignment of the four schools in each category to either experimental or control group was done through simple random sampling. A sample size of 360 Form three students was used. Students in the experimental groups were taught Formulae and Variations using Metacognitive IMPROVE programme while control groups were taught the same topic using Conventional Teaching Approach (CTA). The instrument for data collection used was metacognitive Awareness Inventory Questionnaire (MAIQ). The overall reliability coefficient of MAIQ using Cronbach alpha obtained was 0.754. Data were analyzed using descriptive statistics (mean, percentages and Standard Deviation) and inferential statistics (test, one-way ANOVA and Post hoc Analysis). The hypotheses was tested at 0.05 level of significance. Data analysis was undertaken with the help of Statistical Package for Social Sciences (SPSS) version 25.0 software. The results showed that students' Metacognitive awareness resulted to students' development of the skills of planning, monitoring and evaluating about their own cognitive activities and monitoring the approach they expected to be important for problem solving. The study recommends that teachers should organize the course contents to increase cognitive awareness of the students. Higher cognitive awareness demonstrates high levels of mathematics achievement therefore teacher proficiency need to be adjusted for better teaching and learning.

Keywords: Metacognitive Awareness, Secondary Schools, Mathematics Achievement, Kitui County- Kenya

INTRODUCTION

Academic achievement is the knowledge acquired by an individual after learning which the teacher assesses through tests (Mozafari, 2016). The determinants of academic achievements are class participation, homework assignments, test, examinations, participation in competitions or other events, and metacognitive awareness and ability. Academic achievement is related to factors such as students' awareness of the various types of metacognitive knowledge and learning approaches (Efklides, 2009). As the learners develop awareness of how they learn, they can adjust processes of learning and when one approach fails to give them the required results, they quickly realize their mistakes and try another approach. Metacognitive awareness enables students to use their higher order cognitive skills to acquire new information to become independent thinkers (Whitebread et al., 2009). Effective use of higher order cognitive skills enable students to become aware of their strengths and weakness in mathematics. Such students are independent of autonomous in learning enabling them to monitor and control their learning behavior to reach a higher level of academic

achievement.

Many students have challenges in awareness and understanding of their thinking and the approach to use to learn effectively (Whitebreed et al., 2009). Without the awareness, students are not able to use cognitive processes such as re-organization, representation, re-construction, and social negotiations in making connections between direct instruction and new tasks. Metacognitive awareness empowers students to think about their own thinking. Awareness enhances students' ability to control their process of solving mathematical tasks. Metacognitive awareness is part of cognitive processes that allow the mental normal functioning of individuals. Its important for students to know and apply various learning strategies in the classroom. Development of students metacognitive awareness involves beliefs about awareness of ones strengthens and weakness and monitoring of cognition, and ability to implement strategies to increase conceptual understanding.

One of such strategy is the IMPROVE programme. Improve programme is adopted from Kramarski and Mavarech (2003) IMPROVE is an acronym (I- introduction of mathematical concepts, M- metacognitive questioning, P-practicing , R- reviewing, O- obtaining masterly, V- verification and E- enrichment). IMPROVE programme allows the learners to evaluate their mathematical problems strengths and weakness. IMPROVE programme has been shown to enable students to become more active participants and helps them achieve higher order skills which enables students to solve problems effectively yielding better scores in mathematics (Cetin et al., 2014, & Gritzzle- Martin, 2014). It has been shown in research when students memorizes concepts and skills rather than approaching learning through thinking deeply about mathematics ideas, concepts, and creativity they are not able to score well in mathematics test (Boaler & Zoido, 2016). The students follow the IMPROVE programme strategy towards the achieving some specific learning goals. For effective use of metacognitive IMPROVE programme a learner need to access a set of strategies in each of the seven steps. Such strategies are planning (thinking ahead, setting goals and selecting right strategy to approach the problem), monitoring (tracking the performance of a task and Reflection (thinking ahead and back). A conducive learning environment created by IMPROVE program that allows learners to explore and develop the metacognitive self regulation has been shown to improve achievement in mathematics (Gidalevich & Kramarski, 2019). IMPROVE self-questions prompts focused on continuous practice helps learners to develop autonomous learning. Therefore, the teacher needs to set clear learning goals that prompt and encourage their learners as the learners go through the seven steps of IMPROVE programme.

Mathematics teachers needs to support students' metacognitive learning by allowing students practice how to think as they solve problems about how they think and how they approach learning that makes learning visible to them. Metacognitive awareness proposed enable the learners to acquire the ability to understand what they know about topic Formulae and Variation. Students then think about what they want to know about variation, reflect on their knowledge of the mathematical problem and what they do not know about this new problem. Finally, engage in input specific for their needs based on their diagnostic. Metacognitive students know themselves as learners and know each learning task and what each task might require. Such students can create connections among ideas that may result in higher academic achievement. The use of different learning strategies depend on awareness of what one is doing. According to Rahimia and Katal (2012), when one is aware of what he or she is doing can use various strategies that leads to successful learning. Students who are not able to monitor their cognitive progress result in solving mathematics problems without proper analysis of the question and strategy and therefore end up jumping to the mathematical problem to be applied (Bessoondyal, 2017). The metacognitive achievement was assessed on the metacognitive processes the learner goes through before, during, and after solving a mathematical problem. The metacognitive achievement was measured through MAIQ under the subscale of planning, monitoring and evaluation.

Jaleel and Premachandran (2016) in India designed a study involving 180 students from secondary schools in Kottayam district on students' metacognitive awareness. The results of the study showed that

metacognitive-aware students are mindful of their cognitive process. When students are aware of different types of knowledge, they purposively regulate cognitive process. Such students can learn from experiences, generate ideas that enable them to apply appropriate learning approach for solving new problems; evaluate how they use such an approach next time moreover and determine how they might do things differently. The results suggest teachers should be aware of learners' individual differences in the level of metacognitive awareness in order to use appropriate teaching and learning approach such as metacognition. Studies in India by Rahman et al. (2010) on the impact of some student's related factors on their metacognitive awareness revealed students exposed to internet and library use were more metacognitive aware than those not exposed to it.

A study on the relationship between metacognitive awareness and academic achievement and relation to teaching performance was conducted in the Arabs Emirates by Heliyon (2020) The study respondents were pre-service teachers at Ajman University Arab Emirates. A Sample of 75 pre-service female teachers participated in the study. The metacognitive inventory questionnaire was used to collect data. The findings revealed that the metacognitive awareness supports students' achievement more than their counterparts who use other teaching and learning approaches.

Objectives of the Study

To establish the effect of the Metacognitive awareness on students' mathematics achievement in Public secondary schools in Kitui County, Kenya.

Hypotheses

There is no statistically significant relationship among students' Metacognitive awareness and their mathematics achievements in Public secondary schools in Kitui County, Kenya.

Statement of the Problem

The capacity to solve mathematical problems is a skill for many learners that has been difficulty. Learners need to develop a variety of metacognitive strategies that ranges from analyzing the problem, interpreting to establish what is required and provided, using reasoning to select the right strategy, predicting by examining the association of the variables provided, evaluating and reflecting. Gaining such skills is closely related to the metacognitive awareness among the students. Metacognitive awareness aimed to control and monitor our thought in a way that checks the accuracy of memorization, technique, and guide in the choosing of the correct strategy to use for a specific learning task. When students are metacognitive aware of their thinking processes can control learning and are likely to master the prerequisite skills, which causes difficulty in understanding the new topics if not well mastered. IMPROVE Programme suggested has been shown to improve students achievement in subjects such as geography, English reading skills and physics. It has been shown that awareness created through IMPROVE programme enables students to be active in their world and leads to development of higher- order thinking skills. However, many students' are not aware of this type of thinking which was sought to be established in the present study.

RESEARCH METHODOLOGY

The study adopted a quasi- experimental research design and in particular, Solomon's four non – equivalent control group designs suitable for pre-test and post-test studies (Shuttleworth, 2009). The design is appropriate because once the students have been assigned classes in form one they remain intact groups and the school administration do not normally allow such classes to be split and regrouped for research purposes. The study sample was drawn from a population of all public secondary schools. The units of sampling were schools and not subjects. Stratified sampling was used to draw counties with desired

characteristics. The desired characteristic was a low performance at KCSE in comparison to the National performance index. Through purposive sampling, one county was selected to participate in the study. Simple random sampling was then used to draw four boys-only and four girls-only schools. The desired characteristic was a school with more than forty-five students per stream, an approximate number of boys or girls per stream, and qualified mathematics teachers with experience of at least two years. Three hundred and sixty form three students in the sample schools participated in the study. The Metacognitive Inventory Assessment Questionnaire(MIAQ) test was used to measure students' metacognitive awareness in mathematics. MIAQ comprised of twenty four test items. The items in the test were adopted from Schraw and Dennison(1994). The items were reframed to make them suitable for the study. The test items in (Test 1) assessed general students' achievement before treatment, and Post- test (Test 2) tested students on conceptual understanding of the topic Formulae and variations. There was four week treatment period carried out on the experimental group while the control group received no treatment. After four weeks of treatment, MIAQ was reorganized and administered as a Post- test. The results were converted into percentages and the student means and standard deviation were calculated. The items in MIAQ were screened, coded and moderated by mathematics teachers.

RESULTS AND DISCUSSION

Table 1: Metacognitive Inventory Assessment Means and t-test of Pre-test for Group E1 and C1

Group	N	Mean	Std. Deviation	T	df	P-Value
E1	88	3.63	0.485	1.564	174	0.120
C1	88	3.76	0.575			

The data obtained in Table 1 indicates that the total number of students Experimental group E1 and control group C1 were equal hence suitable for comparisons purposes. The mean score for experimental group E1 was 3.63 with a Standard deviation of 0.485 while for Control group C1 has a mean of 3.76, Standard deviation 0.575. The obtained values of standard deviation shows that the data points are clustered close to the mean. The low value of standard deviation reveals that there is a low variability in the scores obtained by students in the experimental group E1. The students in the control group C1 obtained higher mean scores than those in the Experimental group E1. To test whether the means are statistically different a t- test was performed. Information on Table 1 indicates that there was no significant difference in the means at (α=0.05,t (174) =1.564, P >0.05) between students in experimental group E1 and control group C1. Thus, theobtained value that is more than 0.05 implies the two groups are equivalent. From the results, the level of metacognitive awareness before treatment was similar and therefore the two groups were suitable for the study. The results are presented in Table 2.

Table 2: Metacognitive Inventory Assessment Means and t-Test of Post-test for E1 and C1

Group	N	Mean	Std. Deviation	T	df	P-Value
E1	88	3.82	0.452	6.887	174	.000
C1	88	3.00	1.029			

The mean for experimental group 1 was 3.82 while for control group 1 was 3.00. A t-test was conducted to check for the differences between the means. The results indicated that there was a significant difference in the means at α =0.05, t(174)= 6.887, p=0.000 between students exposed to IMPROVE programme and those exposed to Conventional teaching approach. To investigate the effect of metacognitive awareness on mathematics achievement a comparison was done between group E2 and C2 and the results are tabulated in Table 3.

Table 3: Metacognitive Inventory Assessment Means and t-Test of Post-test for E 2 And C 2

Group	N	Mean	Std. Deviation	T	Df	P-Value
E2	88	3.65	0.420	5.617	174	.000
C 2	88	3.12	0.787			

The results in Table 3 indicates that the mean score and standard deviation for group E2 was (3.65, 0.420) respectively while for group C2 was (3.12, 0.787) respectively. The results reveals that the scores of students in the Control group C2 were more spread far from the mean, the standard deviation (.787) is greater than that of group E2 (0.420). Information on Table 3 also reveal that students mean score of group E2 was higher than the mean score obtained by the students in the control group C2. A t-test was conducted to check for the differences between the means of group E2 and C2. The results shows that there is a statistical significant difference in the means at $\alpha=0.05$, $t(174) = 5.617$, $p=0.000$ between students exposed to IMPROVE programme and those exposed to the Conventional teaching approach. This shows the position of metacognitive awareness in influencing mathematics achievement. The results show that the groups are not similar in characteristic probably due to treatment. The results suggest that metacognitive awareness had positive effect on students' mathematics achievement.

The findings of the study are in line with results of a study by Veenman (2016) that examined self-regulation among secondary students in the United State of America (USA). Veenman revealed that metacognitive awareness enable the learners to understand and monitor their cognitive processes during problem solving. The results of the present study suggest that learner knowledge about oneself, knowledge about learning strategies, and knowledge of thinking during the learning process need to be integrated into regular learning methods. In an interactive classroom, the achievement is likely to be high since learners monitor their learning. Students'' metacognitive awareness enables them to select the appropriate strategy for solving mathematics after assessing their strengths and weakness.

The findings of the study are in harmony with other findings by Huang and Witz (2012). Huang and Witz designed a study on children concepts of area measurement and the choice of appropriate strategy for solving these problems. The study involved twenty-two fourth graders from public elementary schools in Taiwan. The findings of the study revealed that pupils who understood clearly the concept of area and the suitable corresponding formula were able to identify geometric shapes, using formulas for finding area of these shapes and were able to check their mistakes. In responding to the needs of teaching and learning, manipulation help students' in developing conceptual understanding of mathematics. The results of the study shows that Metacognitive awareness created through IMPROVE program provides an appropriate pedagogical approach for enhancing this conceptual understanding.

Comparisons of Students Posttest MAIQ Scores between Experimental and Control Groups There is no statistically significant relationship among students' Metacognitive awareness and their mathematics achievements in Public secondary schools in Kitui County, Kenya. The results of the MAIQ Post- test mean scores obtained by the students are presented in Table 4.

Table 4: Mean Gain for Experimental Group E1 and Control Group C1

Group	N	Mean for Pre-test	Standard Deviation	Mean for posttest	Standard Deviation	Mean Gain
E1	88	3.63	0.485	2.82	0.452	1.19
C1	88	3.76	0.575	3.00	1.029	0.76

Information on Table 4 indicates that there was a mean gain in mathematics achievement between students in experimental group E1 (1.19) which was higher than the mean gain obtained by students in control group

C1 (0.76). This implies that the students who were exposed to metacognitive awareness performed better than those taught through conventional teaching approach. The results of the study also reveal that control group recorded higher variability of the scores than the experimental group.

The results of the present study are in agreement with the findings of Mokos and Kafoussi (2013). They established metacognitive awareness enables learners select and apply appropriate metacognitive strategies that do enhance students' attempt to solve mathematical problems. This attempt requires cognitive intervention (ability to implement strategies to increase performance and understanding). One way of improving students' cognitive ability is through instruction using Maverech and Kramerski approach to metacognitive learning IMPROVE programme. The study established that students who used IMPROVE programme were able to construct their knowledge more meaningfully resulting to cognitive development. The result of the present study shows that cognitive interventions are necessary while solving mathematical problems. The results suggest that the mean differences between the experimental group and control group could be attributed due to treatment.

The results obtained from the study indicate that students exposed to metacognitive awareness achieved better mean scores in MIAQ than their counterparts who were exposed to the conventional teaching approach. The results of this study concurs with other results of studies by Deelen et al. (2010) who found that metacognitive ability predicted mathematical achievement. Metacognitive ability enable students to develop appropriate thinking strategy for different learning tasks. It lays a foundation for the development of self-regulation and managing one's own motivation for learning. Students who are metacognitive aware are likely to have deep understanding of concepts and thus are able to analyze the questions step and choose the appropriate strategy to use.

The findings of the study are in harmony with results of another study by Ozsoy (2011) in Turkey. The study involved 242 primary school students from six different schools. The study examined relationship between metacognition and mathematics achievement of fifth grade students. The results of the study revealed that 42% of the total variance of mathematics achievement was influenced by students' metacognitive knowledge and skills. The results suggest that metacognitive awareness significantly influences students' metacognitive knowledge and skill. However, the results of the study contradicts findings of Presssley and Ghatalas (1990) that students exposed to metacognitive learning do have higher metacognitive levels but this do not necessary lead to higher academic achievement.

The results of the study are in line with another study by Mutua (2014) on metacognitive practices of secondary school students in Kenya. Mutua established that metacognitive awareness incorporates various aspects of metacognition and these aspects do enhance the academic achievement of students. Learners who use metacognitive awareness tend to be conscious in undertaking the right steps to understand what they are doing while learning and therefore are successful learners. Temur et al. (2010) agrees with the findings of this study that a metacognitive awareness enable the learners to focus their attention and to derive meaning and make adjustments in learning. Temur established that in the process of learning, a learner thinks about the appropriate strategy to use. The use of the right strategy assist students to avoid mistakes while solving problems and to use knowledge of procedures to generate examples of mathematical concepts. However to show whether the difference in the mean score was statistically significant One – Way Analysis of Variance (ANOVA) was done. The results for the four groups are summarized in Table 5.

Table 5: ANOVA for the Post test E1 and Control MIAQ of the Four Groups

Squares	df	Sum of Mean Square	F	Sig.
Between Groups	3	42.562	27.558	0.000
		14.187		

Within Groups	348	179.159		
		0.515		
Total	**221.721**	**351**		

ANOVA test was conducted to compare metacognitive awareness levels of the four groups for Four components and metacognitive awareness. There was a statistical significant relationship between the four groups as determined by One-Way ANOV(3,348)= 27.558, P=0.000) The p value is less than 0.05 indicating that there is a statistical significant difference between the four groups as determined by the one way- ANOVA. The results confirms that the results of the four groups were statistically different from each other. The null hypothesis was therefore rejected. This implies that metacognitive awareness had significant difference in mathematics achievement. One- way ANOVA analysis is not able to check which of the groups mean difference is statistically significant. To establish where the significant differences existed among the means scores of students in Post -test MAT. Information on Table 6 presents the summary of Turkey post- hoc analysis.

Table 6: Post Hoc comparisons of Metacognitive Inventory Asessment of the Four Groups

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
E 1	C 1	0.82528*	0.10817	0.000
	E 2	0.16761	0.10817	0.409
	C 2	0.70170*	0.10817	0.000
C 1	E 1	-0.82528*	0.10817	0.000
	E 2	-0.65767*	0.10817	0.000
	C 2	-0.12358	0.10817	0.663
E 2	E1	-0.16761	0.108h17	0.409
	C 1	0.65767*	0.10817	0.000
	C 2	0.53409*	0.10817	0.000
C 2	E 1	-0.70170*	0.10817	0.000
	C 1	0.12358	0.10817	0.663
	E 2	-0.53409*	0.10817	0.000

***. The mean difference is significant at the 0.05 level.**

The post-hoc Tukey test in Table 6 shows that there was a statistical significant difference between the posttest mean scores of the experimental and control groups. The results show a statistical significant difference between E1 and C1, E1 and C2, and E2 and C1 and E2 and C2 with the obtained value of P<0.05. The means between experimental group E1 and E2 or C1 and C2 were not significantly different at level of significance with P value less than 0.05. The difference in mean scores could be attributed to the treatment which suggests that metacognitive awareness has a statistical relationship with students' mathematics achievement.

The results of the study are in harmony with results of another study by Bakar (2020) on metacognitive learning in enhancing students' mathematical achievement. The results of the study revealed that metacognitive learning instills metacognitive awareness among learners. Such activities like questioning,

prepare the learners to be more conscious about the errors they might make during solving the problem. Metacognitive awareness provide an opportunity for learners to self-regulate through self-questioning. Avoiding errors while solving mathematics problems can result to better achievement in mathematics.

The findings of the study concurs with results of another study done by Ozturk (2021). Ozturk examined the effect of IMPROVE method a metacognitive training on academic achievement of middle school students on the topic algebraic expression. A total of 49 sixth grade students were respondents in the study. The results revealed that students exposed to metacognitive awareness IMPROVE programme, their motivation to learn and affective characteristics changed positively. Metacognitive awareness do assit students in understanding the mathematical problems, organizing one's self and regulating their own learning. The results of the study suggest that Metacognitive awareness help students to make use of higher order thinking skills resulting to better scores in mathematics.

In related line of research, Smith and Mancy (2018) explored the relationship between metacognitive and collaborative talk during group mathematical problem solving. The study was conducted in USA in primary schools pupils aged nine to ten years. The findings of the study indicated that students involved in group think aloud tasks in solving problems led to increased mathematics achievement The findings of the study concurs with findings of another study by Stillman and Mavarech (2010) who revealed that the use of metacognitive awareness is related with successful learning outcome. Ozsoy (2011) found out that metacognitive processes in group learning environment is complete, mathematics achievement is well established. Although there is positive evidence suggesting metacognitive awareness has influence on mathematics achievement, the study was carried out on primary school pupils who might not have developed metacognition. The present study involved students in secondary school of Kitui County, Kenya.

The findings of the study do agree with the findings of Cetin, et al. (2015) in USA. Cetin et al. (2015) examined metacognitive training effects on students programming knowledge and metacognitive awareness. A total of 51 respondents (28 males, 23 females) students from Public University participated in the study. The findings showed no significant difference between students problem solving and metacognitive strategies use. It was also showed that students in the experimental group revealed positive feelings towards the metacognitive teaching approach. Posttest results revealed metacognitive awareness improved students understanding in programming topics.

The findings of Grizzle-Martin (2014) are consistent with the findings of the present study. Grizzle- Martin had designed a study on cognitively driven Programme IMPROVE effectiveness on student's mathematics achievement in USA. A total of 24 participants' grade five students below 50th percentile rank on the lower tests on the basic skills were involved in the study. Results revealed students who were inducted through the IMPROVE program performed better in posttest in comparison to those who were taught by the regular teaching approaches. In the present study, meaningful learning is founded on the basis of interpretation rather than rote memorization of facts. Metacognitive awareness enable students to build meaningful relationship between new and previous knowledge by giving students enough time to think and reflect on the learning process.

CONCLUSIONS

The results of posttest MIAQ analysis revealed that there was a statistically significant relationship among students exposed to metacognitive awareness and those taught through conventional teaching approach. The hypothesis was rejected at alpha less than 0.05. The results of the study indicate metacognitive awareness is effective since it improved students' academic achievement as compared to the conventional learning approach. The results of the study revealed a significant difference in achievement in mathematics between the student exposed to metacognitive awareness and those exposed to the conventional teaching approaches.

When students plan, monitor their cognitive progress, and reflect on their learning through questions every step in while solving a problem and accuracy of their solution, results in improved mathematics achievement. Therefore, IMPROVE programme can be to enhance metacognitive awareness to supplement the conventional teaching approach since it produces higher mathematics achievement.

RECOMMENDATIONS

The study established that metacognitive awareness improves students' achievement in mathematics in the topic formulae and variation. Metacognitive awareness among learners in a classroom situation it makes the learners improve their understanding of the concepts in mathematics, and hence promote meaningful learning. Mathematics teachers should be encouraged to develop metacognitive awareness among learners to enhance understanding of mathematical concepts and masterly that results to improved academic achievement. If mathematics teacher adopts metacognition in their teaching it become a common practice in mathematics learning that may improve performance in mathematics in KCSE. Teachers should acquire the understanding of enhancing students understanding of metacognitive knowledge by creating an enabling flexible environment for metacognitive learning.

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