

# Effect of Training in Math Metacognitive Strategy on Fractional Achievement of Nigerian Schoolchildren

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This study examined the effect of training in math metacognition on fractional mathematics among primary school pupils, with a quasi-experimental design, specifically a post-test only control group design. Two intact classes were randomly selected and assigned to treatment and control conditions. Sixty primary six pupils constituted the sample size. Two research questions and three null hypotheses guided the study. A FAT (Fraction Achievement Test) was developed, validated and used for data collection. The data collected were analyzed using mean, *SD* (standard deviation) and ANOVA (analysis of variance). The result of the study showed that training in math metacognitive strategy improved pupils' achievement in fractional mathematics. The study also showed a significant gender difference in the achievement of pupils in fractional mathematics. Hence, a good understanding of fractions is requisite to excellence in school mathematics; the study recommends that training in math metacognitive strategy should be urgently introduced in teacher preparation in order to remedy the prevalent mathematics fear and failure in Nigeria.

*Keywords:* education, psychology, sociology

## Introduction

Primary education in Nigeria as defined by the National Policy on Education is the education given in institutions for children aged from six to 11 plus. Since later education is built upon primary level education, it is the key to later education (FRN (Federal Republic of Nigeria), 2004). Mathematics being one of the official core subjects in the Nigerian educational system constitutes partly the mainstay on which stand successful primary and subsequent education, and mainly a leeway for the flustering of scientific and technological development in our nation. On the contrary, performances in mathematics, among other science and technological subjects, have been a source of concern to educational and professional researchers (Onah, 2003). In accord with the above assertions, analysis of some public examination results by West African Examination Council reveals dismal performances, which invariably undermines the seriousness of the National Policy on Education attaches to STM (science, technology and mathematic). Onuoha (1999; as cited in Onah, 2003) revealed that mathematics had the lowest rating from May/June 1983 to 1999 WAEC (West African Examination Council) ordinary level examinations. Unfortunately, this negative trend is still prevalent in Nigeria today.

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Results of the senior secondary school examinations recently released negate ideals of the World Summit for good quality education. TELL (2010) reported that in the last 2009 NECO (National Examination Council)/GCE (General Certificate Examination), only 1.8% of the 236,613 candidates that sat for the examinations across 1,708 centers in the country had five credit passes, mathematics and English inclusive. Whilst out of the 1,373,009 candidates that took the senior secondary certificate examination, 25.99% of them had five credit passes in five subjects, mathematics and English inclusive. This dismal performance also observed that in May/June 2009, NECO result would continue, if sustainable reforms were not made to ensure children the best possible start in life and good quality teacher production at all levels of education.

Other cultures have also observed this pattern of dwindling performances in mathematics. The results of the NAEP (National Assessment of Educational Progress) analyzed by Brown, Carpenter, Kouba, Lindquist, Silver, and Swafford (1988) indicated that nine, 13 and 17 years old children had low performance in computation with fractions and little conceptual understanding. In addition, an extensive survey of eight to 13 years pupils old in US shows unexpectedly high incidence of certain wrong answers to fraction questions that suggested the presence of misconceptions, which led to inappropriate strategies (Hart, 1984). This poor understanding of fractional mathematics seems to make the school age population susceptible to an early onset of math difficulties. Hence, these reported difficulties in fractions are due to the misconceptions of its intricate processes, which led to inappropriate strategies, a development of math metacognitive learning strategies specific to fraction would make an effective intervention set.

Fraction is a compulsory topic in all primary mathematics curricula worldwide, generally taught in schools usually from age nine upward (Grade 3 to 6). Generally, it is believed that fraction appear to be an inherently difficult abstraction in mathematics for the following reasons: The first one is its dual characteristics of representing parts of an original whole and wholes within a single whole; and the Second one is that two numbers are used to represent a single quantity (for example, to represent one-half, we needed to use the numbers 1 and 2 in  $\frac{1}{2}$ ). The importance of fractional concepts and skills can be viewed from several perspectives (Ong, 2004).

An understanding of fraction provides a rich ground for which children can develop and expand their mental structures necessary for continual intellectual development (Ong, 2004). The researchers further believed that a clear concept of fraction provided a sound foundation prerequisite for the learning of many other important concepts of mathematics, including decimal fraction, percentage, ratio, proportion, multiplication, division, measurement, algebra and graphs. Such understanding can greatly improve a learner's ability to understand and deal with associated real life problem. An early mastery of fractional concepts and skills, therefore, enhances the pupils' feelings of success and provides an intrinsic motivation to handle mathematics successfully in the subsequent stages of pupils' education (Seth & Menon, 1990; Ong, Muhamad, Walaiporn, Wilai, & Wakidi, 1992).

Fraction could be defined as a concept of proportional relation between an object part and the object whole. A fraction is an example of a specific type of ratio, in which the two numbers are related in a part-to-whole relationship, rather than as a comparative relation between two separate quantities. Thus, each fraction consists of a denominator (bottom) and a numerator (top), representing (respectively) the number of equal parts which an object is divided into and the number of those parts indicated for particular fraction. Fractions are rational numbers, which means that the denominator and the numerator are integers (Wikipedia, 2008).

Proficiency in fraction is vital to overall mathematical success. Ong et al. (1992) asserted that fraction has

been identified as the most difficult topic in primary mathematics curriculum to teach and learn, while Ong et al. (1992), on the other hand, ranked it as one of the three most difficult topics. Suydam (1978) reviewed data from a variety of assessments and revealed that fraction had the highest difficulty. Ong (2004) also found that knowledge and skills in common fractions were important bases for subsequent topics in mathematics. They concluded their finding by stating that if initial minor difficulty in each fraction work was neglected as the cumulative fraction syllabus got spirally wider, the difficulty might overspill into other related areas in mathematics and even other subjects.

A student survey on fractional achievement asked: Are deficiencies in fraction skills due to current instructional programmes? Moreover, if yes, should instruction in fraction be postponed until secondary school or should instruction at the elementary levels be revised? A battery of fraction tests consisting of 78 items was developed; tests were classified according to cognitive level as computation, comprehension or applications. Tests were given to average eighth-grade students, and more than 1,500 students took 10-item parts of the battery. Results indicated that students did not have the fractional skills needed to compute or solve problems. Responses to number line and diagrammatic items indicated that they understood fractional concepts; however, performance on other items indicated a poor understanding of the structure of the rational number system.

Hart (1984) observed that children's erroneous strategies were strongly influenced by instruction and represented an effort by the pupils to deal with the fraction task in an adhoc rather than a systematic way. In the same vein, Nik Aziz (1988) revealed areas of misconceptions among children and reported that primary school children failed to make part to whole comparison. A recent study by Fatimah and Zurida (2000) showed that even lower secondary students expressed difficulty in learning fraction and its operations, and demonstrated limited understanding and mastery of basic fraction concepts and skills. To compound the challenges, experienced and prospective mathematics teachers were found to exhibit significant areas of weakness in basic concepts and computational procedures for solving fraction. However, different learning strategies and materials are very effective for teaching various mathematics topics (especially fraction) to a heterogeneous group of learners.

This is in line with Weinstein and Meyer (1986; as cited in Eze, 1999) who identified teaching and learning strategies as several activities that influence the learning process and product. Learning strategies refer to the learner's actively organizing or elaborating, rehearsing or predicting about the presented materials. Learning strategy is a set of steps or sequence of activities, which are deliberately employed by a learner to monitor or coordinate cognition of an academic content. Training in learning strategies, therefore, can affect learners' characteristics by making specific strategies and methods available to the learner. Nwankwo (2005) also identified poor learning strategy as a potential cause of low-level academic achievements when compared with the amount of time put in studies. In the same vein, Nwankwo (2005) observed that many students employed memorization strategy, which did not allow for comprehension. This is because memorization does not permit application of knowledge to new situation, nor permit analysis, synthesis and evaluation of the text read.

Learning strategies are intended to make learners highly aware of what they are doing, thus, making their approaches to completing specific task more purposeful, systematic and more effective (Onuigbo, 2007). Learning strategies are ideas for accomplishing learning goals, a kind of overall plan of attack. Learning tactics are the specific techniques that make up the plan, such as using mnemonics or outlining a passage. Thus, the use of strategies and tactics reflects metacognitive knowledge (Woolfolk, 1995). A math metacognitive strategy

is one of the instructional interventions that could be explained as memorable plans or approaches students use to solve mathematical problems. It includes student's thinking as well as their physical actions (Lenz, Ellis, & Scanlon, 1996). Mason and Au (1990), in contrast, believed that young children often did not monitor their own comprehension processes while reading and seemed blissfully unaware that information was not being put together in a sensible way. Mason and Au (1990) further explained that effective readers were aware of what they were doing as they read and what they needed to do to meet their purposes. This is equally the case in mathematics. Self-coordinated and purposive learning approaches are required to improve the understanding of fraction tasks.

Metacognition is awareness of one's own thinking or cognition. It is a higher order thinking, which involves active control over the cognitive processes engaged in learning. Activities, such as planning how to approach a given learning task, monitoring comprehension and evaluating progress towards the completion of a task, are metacognitive in nature (Livingston, 1997). Some of the common math metacognitive strategies come in the form of mnemonics, which are meaningful words with letters in the word, each standing for a step in a problem-solving process or for important pieces of information about a particular interest, such as SOHCAHTOA (sine, cosign, tan) and BODMAS (bracket of division, multiplication, addition and subtraction). Metacognitive strategies can also come in the form of easy to remember phrases or through pictures that are easy to recall. Mnemonics are systematic procedures for improving one's memory. These techniques have been demonstrated to be effective for students of all ages, from preschool to college (McCormick & Levin; as cited in Woolfolk, 1995). To remember information for a long period, an acronym may be the answer. An acronym is a form of abbreviation, a word formed from the first letter of each word in a phrase. Another method forms phrases or sentences out of the first letter of each word or items in a list.

Metacognitive strategies positively impact students who have learning problems, because they provide these students an efficient way to acquire, store and retrieve information and skills, the inability to inefficiently retrieve information previously stored in memory negatively impacts ability to accurately express knowledge (C. D. Mercer & A. R. Mercer, 1993). Well-developed metacognitive strategies aid such information retrieved by these students. Strategies should be directly taught to students with learning problems. The use of explicit teacher modeling is the most effective strategy to ensure that the students will understand the purpose of a metacognitive strategy and how to bring them under what circumstances it should be used (Lenz et al., 1996).

However, math metacognitive strategies are taught after the student has acquired an adequate understanding of the math concept/skill. Strategies are not intended to be for conceptual understanding. Oftentimes, simplifying a complex fraction requires many guiding principles, such as comparing, converting and reducing fraction, in converting mixed numbers to improper fraction or improper fraction to mixed numbers. The intricacies involved in converting so many mathematical signs could be coordinated through a math metacognitive strategy, thereby making fraction solving less confusing. This study seeks to examine the effect of math metacognitive strategy developed to streamline the sequence of comparing, converting and reducing fraction on fractional mathematics.

The TIMSS (Third International Mathematics and Science Study) addressed middle-school mathematics achievement (grades seven and eight) in six content areas, fraction and number sense, measurement, proportionally, data representation, analysis and probability, geometry and algebra. Results showed large differences in average achievement between top performers and bottom performing nations. Gender differences in mathematics achievement were small or nearly non-existent in most countries, but when they did appear,

they favored boys. Pallas and Alexander (1983) observed that there appeared to be few or no difference between boys and girls in math achievement at the beginning of high school; but during high school, girls took fewer math courses. As soon as mathematics courses become optional, many girls avoid them. Nevertheless, other researchers have reported that high ability boys are superior to high ability girls in mathematical reasoning even when participation in previous math courses is taken into account (Benbow & Minor, 1986). On the other hand, government survey revealed the following data on the percentage of males and females who enrolled in and then completed high school courses in several areas. There was an 81.6% male completing course in algebra, as against 50.3% female completion (National Center for Education Statistics, 1991). Oakes (1990) analyzed the reasons why only 15% of the scientists, engineers, and mathematicians in the US were women; she concluded that academically qualified girls choose not to take advanced science and math courses in high school. Thus, they did not develop their abilities in these areas.

The existing gaps filled by this study are as follows: There are varying findings in respect of math metacognitive strategies. However, literature showed that math metacognitive strategies are effective tools in facilitating children's education anywhere in the world (C. D. Mercer & A. R. Mercer, 1993; McCormick & Levin, as cited in Woolfolk, 1995; Lenz et al., 1996). Although, metacognitive strategies have been employed extensively in helping pupils with various learning problems in subject area; nevertheless, researches in its effectiveness in alleviating math problem are few and emerging in Nigeria. Some math metacognitive strategies have been in application solving fraction and geometry for many years now.

The use of BODMAS in fraction solving only coordinates order of operation in simplifying complex fraction. The misconceptions and confusion encountered in converting, comparing and reducing fraction and mixed numbers result to fraction difficulties, as pupils resort to use of inappropriate strategies. Thus, the researchers wished to explore further the effect of math metacognitive strategy on fraction achievement among Nigerian primary school pupils, in discovering better ways of facilitating the teaching and learning of fraction, in order to cultivate a better mathematical culture and promote a child-friendly math teaching practices in the Nigerian schools.

Gender differences in mathematics achievement initially favored boys. Later studies show that this assertion is small or nearly non-existent in most countries, but when they did appear, favored boys (TIMSS). These findings were not specific in fraction achievement. Thus, as culture, teaching styles, teachers' attitudes and other societal influences have been found to contribute immensely to gender difference in math achievement and Nigeria is a peculiar culture; the researchers hoped to ascertain the influence of gender on fraction achievement of Nigeria schoolchildren vice-a-vice training on math metacognitive strategy.

The general purpose of this study is to determine the effect of math metacognitive strategy on fraction achievement among primary school pupils in Nigeria. Specifically, this study intends to study the extent to which math metacognitive strategy training and gender would improve fractional achievement of primary school pupils in Nigeria.

### **Research Questions**

The following research questions were posed:

- (1) To what extent does math metacognitive strategy training improve academic achievement in fraction?
- (2) What is the influence of pupils' gender on fractional achievement?

## Hypotheses

The following hypotheses were formulated to guide the study:

Ho<sub>1</sub>: There is no significant difference in the mean achievement scores of pupils instructed on math metacognitive strategy and those who were not;

Ho<sub>2</sub>: There is no gender difference in the mean achievement scores of male and female pupils as measured by FAT (Fraction Achievement Test);

Ho<sub>3</sub>: There is no interaction effect of gender and math metacognitive strategy training on the pupils' mean achievement scores as measured by FAT.

## Methods

This study is a quasi-experimental research, particularly the post-test only control group design with one treatment and one control group. In executing the experiment, two equivalent intact classes were randomly composed and assigned to experimental conditions. Thus, one group was subjected to experimental treatment and the other to control conditioning. While the experimental group received math metacognitive strategy training, the control group received conventional teaching.

### Participants

The sample for the study comprises 67 primary six pupils selected from two urban schools in Nsukka. The sample size was composed of two schools randomly selected for the study. Through simple toss of the coin, pupils were assigned to classes and each intact class was randomly assigned to treatment and control group conditions. The class that obtained the "head" and the "tail" received experimental treatment and conventional instruction. Thus, there were 32 pupils in the treatment group and 28 in the control group. In all, the gender of the sample for the study consists of 29 males and 31 female pupils.

### Instrument

The dependent measure for the study was FAT, adapted from MAN (Mathematical Association of Nigeria) mathematics for primary six. The adaptation took place after other math textbooks were reviewed to ensure content coverage and process details. A scoring guide was developed and used in assessing pupils' performances on the test. The test obtained both face and content validation. Since the test items were not dichotomously scored, Cronbach Alpha was used to determine its reliability. The FAT obtained an internal consistency reliability estimate of 0.71, which indicates a high reliability index for the test instrument.

### Procedure

A MMTP (Math Metacognitive Training Programme) was developed and subjected to validation of experts. MMTP contained lessons covering and following many sessions of learning strategy model (University of Kansas Group; as cited in Lerner, 1995). The training sessions lasted for four consecutive weeks. While the training programme was employed in instructing the treatment group, the control group received conventional math lessons. Immediately after the training sessions, FAT was administered to participants in both group conditions.

### Statistics

The test data (responses) were collected, scored and subjected to statistical analyses. Mean and *SD* (standard deviation) scores were used in answering the research questions, while the univariate ANOVA was used in testing the hypotheses.

## Results

The results of the study are presented as follows:

### Research Question 1: To What Extent Does Math Metacognitive Strategy Training Improve Academic Achievement in Fraction?

Table 1 shows that pupils who received math metacognitive training (the treatment group) has a total mean achievement score of 6.75 and *SD* of 2.58, while pupils that received conventional teaching (the control group) had total mean achievement score of 4.25 and *SD* of 2.52, respectively. These results seem to suggest that the treatment group had better fractional achievement than the control group. However, the probability that the observed difference resulted from sampling error is high. Thus, differences observed are such that could have arisen from sampling error.

Table 1

#### Posttest Mean and SD Scores

Group	Gender of participants	Mean	Standard deviation	<i>N</i>
Experimental group	Male	7.64	2.27	14
	Female	6.06	2.65	18
	Total	6.75	2.58	32
Math metacognitive group	Male	4.07	2.60	15
	Female	4.46	2.50	13
	Total	4.25	2.52	28
Conventional teaching group	Male	5.79	3.02	29
	Female	5.39	2.67	31
	Total	5.58	2.52	60

### Research Question 2: What Is the Influence of Pupils' Gender on Fractional Achievement?

In respect of gender, results displayed in Table 1 reveal that males in the treatment group had a mean achievement score of 7.64 and *SD* of 2.27, while the females in the same group obtained a mean achievement score of 6.06 and *SD* of 2.65. This seems to suggest that the male pupils perform better in fractional mathematics when trained on the use of metacognitive learning strategy. However, when the performance of all the males and all the females in both treatment and control groups were compared based on FAT, the males obtained mean achievement score of 5.79 and *SD* of 3.02, while the females had mean achievement score of 5.39 and *SD* of 2.67. These results seem to suggest still that the males performed better than their female counterpart on FAT across both experimental conditions. Nonetheless, the females in the control group were superior to the males. While the males obtained 4.07 and *SD* of 2.60, the females were very much ahead with the mean score of 4.46 and *SD* of 2.50. However, the probability that the observed difference resulted from sampling error is high. Thus, the differences observed are such that could have arisen from sampling error.

### Hypothesis 1: There Is No Significant Difference in the Mean Achievement Scores of Pupils Instructed on Math Metacognitive Strategy and Those Who Were Not.

Data in Table 2 shows that there is a significant difference in the mean fractional achievement of pupils that received math metacognitive training when compared with those that did not. This inference is informed by the fact that computed *f*-value of 15.527 in respect of math metacognitive training is greater than 0.000 critical *f*-value obtained at the significance level of 0.05 for two-tailed test. This implies that training in math metacognitive strategy given to primary school pupils does improve their fractional achievement sufficiently.

Therefore, the null hypothesis of no significant effect of math metacognitive strategy training on fraction mean achievement of pupils is, therefore, rejected.

Table 2

*ANOVA on the Effect of Treatment and Conventional Teaching*

Source	Type III sum of squares	Difference	Mean square	Frequency	Significance
Corrected model	114.261 <sup>a</sup>	3	38.087	5.986	0.001
Intercept	1,825.832	1	1,825.832	286.949	0.000
Exp	98.794	1	98.794	15.527	0.000
Gender	5.255	1	5.255	0.826	0.367
Exp*gender	14.521	1	14.521	2.282	0.136
Error	356.323	56	6.363		
Total	2,341.000	60			
Corrected total	470.583	59			

Note. R-squared = 0.243 (adjusted R-squared = 0.202).

**Hypothesis 2: There Is No Gender Difference in the Mean Achievement Scores of Male and Female Pupils as Measured by FAT.**

When the results reported on gender (see Table 1) were further subjected to *f*-statistical analysis (see Table 2), it could be inferred that there is significant gender differences in the mean achievement scores of boys and girls in respect of FAT. This is because the computed *f*-value for gender is 0.826, which is obviously significant at 0.367 critical *f*-values. This means that at significance level of 0.05 for two-tailed test, the computed *f*-value is significant, which implies that the observed gender superiority of males in fractional achievement evident in the treatment group is significant when subjected to *f*-statistics. Thus, the null hypothesis of no significant gender influence on FAT is rejected. In sum, gender has significant influence on the mean achievement of pupils in fractional mathematics.

**Hypothesis 3: There Is No Interaction Effect of Gender and Math Metacognitive Strategy Training in the Pupils' Mean Achievement Scores as Measured by FAT.**

Inferring also from the Table 2, gender and math metacognitive strategy training (the experimental condition) have a significant interaction effect on pupils' mean achievement on FAT. This is because the computed *f*-value of 2.282 is more than the 0.136 *f*-critical values at the significance level of 0.05 for two-tailed test. Thus, the null hypothesis of no significant interaction effect is, therefore, rejected. However, the probability that the observed difference resulted from sampling error is high.

**Discussion**

The findings of the study show that training in math metacognitive strategy improves tremendously pupils' achievement in fractional mathematics. This indicates that equipping Nigerian school pupils with relevant skills in math metacognitive strategy enhances the abilities of the pupils to solve fraction and achieve better in mathematics as whole. This is because proficiency in solving fraction is associated directly with mathematics achievement. The results of this study is consistent with the findings of Seth and Menon (1990), Ong et al. (1992), Ong (2004), Hart (1984) and Nwankwo (2005) whose research reveals that students with learning problem especially in math improves with the use of appropriate metacognitive strategies. These learning strategies have been found among high achieving performers. For many students with math learning problems, the inability to retrieve information previously stored in memory affect negatively the achievement



in fraction. The finding of this study is further supported by C. D. Mercer and A. R. Mercer (1993) whose studies show that math metacognitive strategies positively impact students who have learning problems because they provide an effective way to acquire, store and retrieve information and skills.

The result of the study also shows that gender has significant influence on fraction achievement scores of pupils based on math metacognition. The results revealed that boys obtained better fraction achievement scores than girls. This finding is consistent with the TIMSS, Pallas and Alexander (1983), Benbow and Minor (1986) and Oakes (1990) who reported that gender differences in mathematics achievement were small or nearly non-existent in most countries, but when they did appear, favored boys.

The study further revealed that there is significant interaction effect of treatment and gender on fractional mathematics achievement scores of primary school pupils. This indicates that the effect of training in math metacognitive strategy had a greater impact on boys. The male participants benefited more from the training than the females. Thus, gender is a potent source of variance in fractional achievement of pupils trained in the use of math metacognitive strategy.

### Conclusions and Recommendations

The result of the study has proffered some empirical evidence that training in math metacognitive strategy improves pupils' achievement in fractional mathematics. Given that most children with learning problem in math do not have active control over their cognitive processes, they do not coordinate their understanding of learning tasks. Math metacognitive strategy provide children with sequence of steps which coordinate the complex processes involved in reducing, comparing and converting improper to proper fraction, vice-versa. Therefore, the teaching and use of math metacognitive strategy (as stated above) should be introduced in schools, in addition to other mnemonics used in math instruction. Teachers, publishers of math textbooks and curriculum experts should integrate metacognitive strategies in fraction instruction and learning.

On the other hand, the economy of any nation, which determines the per capita income, individual's standards of living and poverty levels, depends largely on his/her scientific and technological advancements. Thus, the findings of this study which proffered strategy for improving fractional achievement would predictably improve overall mathematical achievements in schools; thereby culminating in techno-scientific advances and socio-economic well-being of the Nigerian citizenry.

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