Teaching, Academic Achievement, and Attitudes Toward Mathematics in the United States and Nigeria

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Abstract

This paper explores the relationships among attitudes toward mathematics, teaching, and academic achievement in mathematics. Based on the contextual and social nature of academic self-concept, two complementary studies are discussed. The first study from the northeastern United States examined the relationships among these variables in 84 high school students. A second study from southwestern Nigeria examined how teaching approach can engender changes in student achievement and attitudes toward mathematics through the analysis of 36 preservice teachers associated with 830 students. Instruments used included the Program for International Student Assessment, the June 2012 New York State Integrated Algebra Regents Examination, the Student Mathematics Attitudes Questionnaire, and the Student Mathematics Achievement Test. Analytic methods included descriptive statistics, correlations, linear regression, and analysis of covariance. Together, the research supports the link between attitudes toward mathematics and academic achievement and suggests that teachers can improve student attitudes toward mathematics based on their teaching approach.

Background

Mathematics is a necessary tool needed to be able to function effectively in the present technological age (Aremu, 1998). The present age of information and computer technology (ICT) owes a lot to mathematics (Akinsola and Tela, 2001). Fayemidagba (1991) stated that the teaching of mathematics is very important to all human existence because mathematics is all about finding solutions to problems. Several studies, including Olowojaiye (1998), Alli and Anakwe (1997), and Oyeniran (2007) have indicated the role mathematics can play in the study of other school subjects.

Mathematics educators in Nigeria (Abimbade, 1990; Oladeji, 1995; Esan, 1999; Akinsola, 2001) have carried out research on methods and ways of improving the teaching and learning of mathematics at both the primary, junior and senior secondary school levels for several years. Research centered on effective teaching and learning of mathematics. Despite these efforts, the results of students' performance at both the West African senior secondary school certificate examination (WASSCE) and National examination council (NECO) have not improved significantly (Adetula, 1995; Olowojaiye, 2001). In 2002, the failure rate which was 36.1%; by 2008, it was still high at 25.1%.

The United States is also faced with challenges that can hinder the nation's ability to lead in the field of mathematics. The 2011 National Assessment of Educational Progress, The Nation's Report Card, reported that 27 percent of the eighth-grade students tested from the United States performed below the basic achievement level, while 35 percent were at or above the proficient achievement level. This level of proficiency does not meet the expectations of an international leader (NAEP, 2011).

The rationale to improve mathematics academic achievement in both Nigeria and the United States prompted the examination of two studies discussed in this article. Rather than emphasize instruction or educational policies, which can vary markedly by context, both studies consider the role of ATM. The Nigeria study considers how teacher approaches relate to attitudes toward mathematics (ATM) and the United States study emphasizes the relationship between ATM and academic achievement. The study frames ATM as one part of academic self-concept. Through a critical review of international empirical studies, Marsh and Yeung (1997) found support for causal effects of both academic self-concept and achievement upon the other. They therefore hypothesized "a 'reciprocal effects' model in which prior academic self-concept affects subsequent achievement and prior achievement affects subsequent academic self-concept" (p. 43). Because academic self-concept is maintained in a social context in which teachers can be significant others (e.g. Hoelter, 1984) it is important to consider not just student academic self-concept, but also the role of teachers or teacher approach. Summarizing prior research, Irvine (1990) cautioned that students who do not believe that their teachers like them may feel isolated and discouraged to the extent that they eventually fail.

Together, the two present studies explore the complex relationship between teaching, attitudes toward mathematics, and academic achievement. Prior research within each variable supports this examination, rather than examining the variables in isolation.

Theoretical Framework

This paper concerns the relationships among teaching, academic achievement, and ATM. The literature surrounding the link between ATM and academic achievement does not paint a coherent picture. For example, in a meta-analysis of 113 studies, Ma and Kishor (1997) assessed the relationship between ATM and achievement in mathematics. The causal relationship between ATM and achievement in mathematics was not statistically significant, so researchers concluded that ATM has virtually no effect on achievement in mathematics (Ma & Kishor, 1997). Subsequent research has demonstrated that ATM can impact achievement in mathematics, however. Higbee and Thomas (1999) concluded that student attitudes toward themselves as learners and ATM are related to achievement. They found positive correlations between non-cognitive variables such as ATM and cognitive variables including a final grade in a developmental mathematics course. Lipnevich, MacCann, Krumm, Burrus, and Roberts (2011) studied middle-school students from the United States and Belarus. They found that ATM explained 25 percent of the variance in mathematics achievement in students from the United States and 28 percent of the variance in mathematics achievement in students from Belarus. Their results support Higbee and Thomas (1999) and highlighted the importance of non-cognitive variables in prediciting academic achievement.

This paper frames ATM as one part of a broader academic self-concept, which includes self-efficacy, self-esteem, attitudes, and other aspects (Perry, 2007). Self-concept is one's reflexive consciousness, which includes perceptions, beliefs, and attitudes about one's self (Baumeister, 1999). To assert the complexity and scope of the self-concept, social psychologists have also defined it as "the totality of the individual's thoughts and feelings with reference to himself or herself as an object" (Gordon, 1982, p. 2). Academic self-concept could be considered "a person's evolving mental picture of herself - actual, desired and feared; past, present and future" within the academic domain (Perry, 2007, p. 9).

Prior research supports that academic self-concept and academic achievement are closely related. For example, Hamacheck (1995) found a strong simultaneous relationship between students' academic achievement and self-concept. The interactive and reciprocal academic self-concept seems to increase with accomplished higher achievement levels (Hamachek, 1995). Similarly, students with positive academic self-concepts have achievable goals, are task-persistent, take school work more seriously, are capable of working more independently, have higher degrees of curiosity, prefer to undertake more challenging work, and experience fewer school failures than those students who have low self-concepts (Hamacheck, 1995). Valentine, DuBois and Cooper (2004) identified self-concept as a multidimensional structure and measure. Their research demonstrated the prevalence of a strong connection between students' academic self-concept and their achievement (Valentine, DuBois & Cooper, 2004). Other researchers have similarly noted that students with a high self-perception are able to achieve more than those with a lower view of themselves (Marsh, Trautwein, Ludtke, Koller, & Baumert, 2005).

Although informed by prior achievement, academic self-concept is subjective and maintained within a social context. Mead (1934) asserted, "The individual experiences himself. . .not directly, but only indirectly, from the particular standpoints of other individual members of the same social group, or from the generalized standpoint of the social group as a whole to which he belongs" (1934, pp. 138-139). Moscovici (1998) connected the social origin of perceptions and beliefs in conjunction with the human tendency to perceive and explain things with the use of representations and concepts. When someone reasons, ideas and beliefs are induced within the interconnected framework of his or her social world, as this world has provided cultural tools and cues. In other words, no knowledge or way of thinking is discrete; instead, it is connected with other ideas or beliefs within a person's self-concept. For example, Markus, Mullally, and Kitayama (1997) considered thinking in light of selfways-a community's normative ideas about being a person and the social practices, situations, and restrictions of everyday life that represent and foster these ideas. This social nature of the academic self-concept supports its examination in different contexts; this paper considers aspects of academic self-concept in the United States and Nigeria.

Research has demonstrated a correlation between people's self-concepts and how they believe significant others view them. For students, "significant others" may include teachers, parents, and friends (e.g., Hoelter, 1984). Therefore, researchers have noted that both school climate and individual teachers can have an effect upon aspects of academic self-concept. Researchers have framed and supported the effect of teachers and school climate as based upon students' subjective interpretations, rather than objective characteristics (Hoge, Smit, & Hanson, 1990). Because of the relationship teachers can have with student academic self-concept, the Nigeria study emphasizes the role of teachers and student achievement, while the United States study explores the relationship between academic achievement and student self-efficacy, anxiety, and ATM. These other aspects of the academic self-concept are discussed below.

Developed in the discipline of social psychology, self-efficacy strongly influences an individual's behavioral choices, performance, perseverance, and feelings in the attainment of goals (Bandura, 1994). Researchers have used the concept of mathematics self-efficacy to investigate and judge the competence of their subjects' ability to solve specific mathematical problems as well as their success in mathematics courses. Path analysis has demonstrated

mathematics self-efficacy to be more predictive of problem solving abilities than the perceived usefulness of mathematics, prior experience with mathematics, self-concept, and gender (Pajares & Miller, 1994). In their study using commonality analysis on matrix summaries available from prior studies on mathematics self-efficacy, Zeintek and Thompson (2010) found that mathematics self-efficacy consistently accounted for substantial unique variance in mathematics performance when other variables that contributed to mathematics performance were present.

The concept of mathematics anxiety has been the subject of various studies and has received much attention in the research literature. Mathematics anxiety usually arises from a lack of confidence when working in mathematical situations or solving mathematical problems (Stuart, 2000). This lack of confidence creates a state of discomfort that includes emotional and physiological responses such as fear, distress, sweaty palms, nervous stomach, difficulty breathing, and loss of ability to concentrate (Bursal & Paznokas, 2006; Hembree, 1990). These responses lead to avoidance of mathematics, which can lead to an increase in mathematics anxiety when required to complete mathematical problems. Mathematics anxiety has been found to be a significant impediment to mathematics achievement that affects a large portion of the population (Ashcraft & Moore, 2009).

Because teachers can be considered significant others in developing students' ATM, two different teaching approaches are contrasted. The notion that people build their own knowledge and their own representation of knowledge from their own experience and thought is called constructivism. This is different from a traditional direct instruction format, in which a teacher provides information to students. There are various strategies associated with constructivists' model learning which include problem-based learning, cooperative learning, concept mapping, advance organize, and interactive approach. The works of Stevenson (1988) and Ampiah (2002) supported that students taught with constructivist methods perform better than students taught with the traditional method, but research connecting constructivism to attitudes toward mathematics is less consistent.

Methodology and Sample

The survey used in the United States study was designed to measure students' mathematics self-efficacy, mathematics anxiety and ATM. It consisted of 21 questions that were utilized in the 2003 administration of the Program for International Student Assessment (PISA) (OECD, 2005). The survey instrument utilized a four-point Likert type scale where eight items measured mathematics self-efficacy, five items measured mathematics anxiety and eight items measured ATM. The Cronbach alpha coefficients were .77 for mathematics self-efficacy, .87 for mathematics anxiety, and .86 for ATM. Correlation analysis was used to determine relationships among the variables, and linear regressions were calculated to determine if the variables predict performance.

The participants in the United States study were limited to tenth-grade students that had completed the June 2012 New York State Integrated Algebra Regents Examination (ARE) as ninth-grade students and were enrolled in two large suburban high schools within the same school district. There were 305 students that met the criteria for inclusion and invited to participate in this study. On the day of data collection, 84 of these students, 27.5 percent of the students invited to participate, were present and participated in this study. The demographics of the participants in this study were 49 percent male, 51 percent female, 75 percent Caucasian, 15.5 percent African American, 7.1 percent Hispanic, and 2.4 percent Asian. The participants in this study had a mean score of 82.9 on the ARE and scores on this examination ranged from 70-97.

For the Nigeria study, researchers employed pretest/posttest control group quasi-experimental design with 2x2x2 factorial matrix to examine the relationship between teaching approach and student achievement and ATM. Thirty-six pre-service teachers of two colleges of education in the southwestern Nigeria and their 830 students were sampled for the study. The findings discussed in this paper represent a portion of a larger study on training in constructivist strategies for pre-service teachers.

Relevant measures included the Student Mathematics Attitude Questionnaire (SMAQ), a four point Likert type attitudinal scale with options of Strongly Agree, Agree, Disagree, and Strongly Disagree. Twenty times were constructed and validated by experts in field of education. Based on their comments, some items were modified. The instrument was also piloted. Study data collected obtained a Cronbach alpha coefficient for the internal consistency and reliability of 0.81. Another measure was the Student Mathematics Achievement Test (SMAT). This instrument contained thirty multiple choice items which covers mathematical concepts in the Junior secondary school II curriculum. To establish the content and face validity of the instrument, copies of the draft were given to experts in the field of education for necessary comments in regards to suitability, item difficulty and coverage. Based on their comments, certain modifications were made. The reliability index (KR_{20}) value obtained was 0.83 and average item difficulty level obtained was 0.58 which showed that the test was neither too low nor difficult. So that researchers could determine if the training had differential effects by teacher gender, study respondents also reported their gender.

Findings

The United States part of the study included correlational analysis to examine the relationships among variables and a linear regression analysis to determine the extent to which different variables predicted academic achievement as indicate by performance on the ARE. The correlations are summarized in **Table 1** as follows:

Table 1: Correlations Among Student Performance on the June 2012 New York State Integrated Algebra Regents Examination, Mathematics Self-Efficacy, Mathematics Anxiety, Attitudes Toward Mathematics, Gender, Race, and Overall Grade Point Average

		Score	MSE	MA	ATM	Gender	Race
Mathematics Self-Efficacy	r r^2 N	.428 18.3% 84					
Mathematics Anxiety	R r^2 N	-.204 4.2% 84	-.324 10.5% 84				
Attitudes Toward Mathematics	r r^2 N	.324 10.5% 84	.269 7.2% 84	-.492 24.2% 84			
Gender	r r^2 N	-.044 .19% 84	-.205 4.2% 84	.255 6.5% 84	-.086 .74% 84		
Race	r r^2 N	-.320 10.2% 84	-.112 1.3% 84	-.043 .18% 84	-.027 .07% 84	.014 .02% 84	
Overall Grade Point Average	r r^2 N	.579 33.5% 84	.463 21.4% 84	-.086 .74% 84	.215 4.6% 84	.050 .25% 84	-.331 11.0% 84

Note. Score = June 2012 New York State Integrated Algebra Regents Examination Score;
MSE = Mathematics Self-Efficacy; MA = Mathematics Anxiety; ATM = Attitudes Toward Mathematics.

Researchers found that there was a moderate positive relationship among student performance on the ARE, and mathematics self-efficacy, ATM and overall grade point average. The results indicated that mathematics self-efficacy, ATM, and overall grade point average had the most impact on student scores on the ARE accounting for 18 percent, 11 percent and 34 percent of the variance respectively.

There was a weak inverse relationship between mathematics anxiety and student performance on the ARE. This indicated that students with higher levels of mathematics anxiety had lower scores on this examination than their classmates with lower levels of mathematics anxiety. This inverse relationship accounted for 4.2 percent of the variance in student performance on the ARE.

Overall grade point average and ATM showed a positive correlation with student performance on the ARE. Overall grade point average alone accounted for 33.5 percent of the variance in student scores on the ARE. The variance increased by 4.2 percentage points when ATM was included.

Overall grade point average and ATM accounted for 37.7 percent of the variance in student scores on the ARE. The effect that overall grade point average and ATM had was found to be statistically significant, p = .000 and p = .022 respectively. This indicated that overall grade point average and ATM are very strong predictors of student performance on the ARE.

To determine the extent to which multiple variables predicted student performance on the ARE, researchers performed a stepwise linear regression. Variables tested included ATM, mathematics self-efficacy, mathematics anxiety, gender, race, and overall grade point average.

Table 2: Regression models to predict performance on Algebra Regents Examination

Model	R	R Square	R Square Change	Adjusted R Square	Std. Error of the Estimate
1	.579[a]	.335		.327	4.59
2	.614[b]	.377	.042	.362	4.47

a. Predictors: (Constant), Overall Grade Point Average
b. Predictors: (Constant), Overall Grade Point Average, Attitudes Toward Mathematics

Of all the variables considered, only grade point average and ATM emerged as significant predictors of academic achievement as indicated by performance on the ARE (**Table 2**). Together, these variables describe nearly 38% of the variation in ARE scores. Grade point average is not surprising, given that it is another indicator of achievement. More notable is the inclusion of ATM in the model, as a better predictor than any other non-academic achievement variables. The coefficients of the second model are shown in **Table 3** below.

Table 3 indicates that student scores on the ARE were expected to increase by 0.49 of a point when overall grade point average increased by one point and attitudes toward mathematics remained consistent. When ATM increased by one point and overall grade point average remained consistent, student scores were expected to increase by 0.24 of a point. The effect that overall grade point average and ATM had on regression model 2 was found to be statistically significant, p = .000 and p = .022 respectively. This indicated that overall grade point average and ATM are significant predictors of student performance on the ARE.

The United States part of the study therefore supported the relationship between ATM and academic achievement. The Nigeria part of the study suggests that teaching approach can support the development of students' positive ATM. While the United States-based study emphasized the relationships among variable, the Nigeria study tested significant differences by teaching approach. The treatment group of pre-service teachers received interactive training in constructivism and the comparison group received more traditional training. Instead of employing independent samples t-tests, researchers employed Analyses of Covariance (ANCOVAs) to determine the effects of teacher training. This decision is due to students in the two teaching conditions differing significantly on the pretest. The table below summarizes the ANCOVA of post-test achievement on the SMAT, where treatment refers to the teaching approach (constructivist versus traditional).

Table 3: Coefficient values for overall grade point average and attitudes toward mathematics for regression model 2

	Unstandardized Coefficients		T	Sig.
	B	Std. Error		
(Constant)	35.6	7.01	5.08	.000
Overall Grade Point Average	.494	.083	5.94	.000
Attitudes Toward Mathematics	.242	.104	2.34	.022

Table 4: ANCOVA of student post-test achievement by treatment and gender

Source of variance	Hierarchical Sum of squares	Df	Means square	F	Sig.
Covariance pre-test	5.739	1	5.739	.225	.636
Main effects (combined)	39.599	5	1376.679	53.870	.000
Treatment	728.219	1	364.109	14.248	.000
Gender	499.219	1	499.219	19.535	.000
2 ways combined	1490.442	8	186.305	7.290	.000
Interaction treatment	93.273	2	46.637	1.825	.162
Model	8685.332	18	482.518	18.881	.000
Residual	20725.595	811	25.556		
Total	29410.927	829	35.478		

Table 4 illustrates that there was a significant effect of treatment of student achievement in mathematics f(2,811) = 14.248, p = .000). On average, students of teachers who received the interactive training scored significantly higher on the post-test even when accounting for pre-test differences, with a mean achievement score of 26.62 versus the traditional group score mean of 11.45. Males scored significantly higher than females as well, with a mean of 13.19 versus the female mean of 12.03. This suggests that the constructivist approach in mathematics may help males more than females. While these findings are notable, the most central aspect of the study is the relationship between teaching approach and ATM. This is shown in the ANCOVA summary below (**Table 5**).

This table illustrates that the effect of treatment on students attitude towards mathematics is significant (F(2,4127) = 45.13, p = .000). After controlling for prior achievement, the students of teachers trained in constructivist teaching had significantly more positive ATM, with scores of 60.98 versus 57.66. While a difference of three points might not seem meaningful, it was statistically significant. It supports the immediate role that teachers can play in supporting a positive ATM, which the other study demonstrated was linked with academic achievement in mathematics.

Discussion

The impact that ATM had on student performance in this study was found to be substantial in both the United States and Nigeria contexts. For the tenth-grade high school students in the United States study, ATM accounted for 11 percent of the variance in their scores on the ARE. This indicates the important influence positive ATM had on increasing mathematics performance. Furthermore, this impact on the variance demonstrates that ATM should be considered and included when examining methods to improve student performance in mathematics.

ATM and overall grade point average were found to be the best predictors of performance for all the participants on the ARE. ATM has been demonstrated to be a valid predictor of mathematics performance (Higbee & Thomas, 1999). In the present study ATM was found to be a better predictor of mathematics performance than mathematics self-efficacy. Similar conclusions are rare when

Table 5: ANCOVA of student attitude toward mathematics by treatment and teacher gender

Source of variance	Hierarchical Sum of squares	Df	Means square	F	Sig.
Covariance	914.425	1	914.425	9.998	.002
Main effects (combined)	11060.781	5	2212.156	24.186	.000
Treatment	8255.279	2	4127.640	45.128	.000
Gender	2183.940	1	2183.940	23.877	.000
2 ways interactive	926.196	2	463.098	5.063	.007
Model	21111.950	18	1172.886	12.823	.000
Residual	74178.316	811	91.465		
Total	95290.266	829			

mathematics self-efficacy and ATM have been included in the same study (Akay & Boz, 2010; Lee, 2009; Randhwaw, Beamer, & Lundberg, 1993). This demonstrates, and confirms, that the variable ATM is a valid, useful predictor when using affective mathematics variables to predict student performance in mathematics.

The Nigeria-based research finds that that a teacher's attitude can be a factor in shaping a student's attitude toward mathematics. This is supported by prior research that concluded when students believe that their instructor is not happy teaching mathematics, and does not enjoy being with them in the classroom, the students will become less motivated to learn which fosters a negative attitude toward mathematics (Jackson & Leffingwell, 1999). ATM is not only formed by an instructor's attitudes, but by his or her teaching style as well. A learner will develop negative attitudes toward a discipline when a teacher's teaching style is inconsistent with the learner's learning style (Ertekin, Dilmac, & Yazici, 2009). A teacher's own attitude toward mathematics has an impact on the teaching styles he or she utilizes. This research suggests that constructivism, or supporting students in building their own representation of knowledge from their own experiences, might engender more positive student ATM.

From a larger perspective, teaching approach may have an effect on ATM, just as it can upon achievement. This research tentatively suggests that teachers may have both a direct effect upon student achievement and an indirect effect through attitudes toward a subject. Comparative international studies with identical measures would strengthen our understanding. Because both ATM and teaching approach share a relationship with achievement and each other, future research should continue explicating the relationship between teaching method, attitudes toward mathematics, and student achievement.

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