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Abstract

The study investigated mathematical proficiency as related to gender and performance in mathematics among 400 Nigerian senior secondary school students from 10 elitist senior secondary schools in Lagos State using the quantitative research method within the blueprint of descriptive survey design. Data collected were analysed using the descriptive statistics of frequency, percentage, mean, and standard deviation and inferential statistics of independent samples t-test, and multiple regression analysis. Findings revealed that senior secondary school students from the elitist schools showed high level of mathematical proficiency. There were significant possible correlations among senior secondary school students' conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, productive disposition and performance in mathematics. While gender differences in mathematical proficiency are no longer important and are dissipating even at the subscale level there are subtle gender differences in performance in mathematics in this study. Gender, conceptual understanding, productive disposition, adaptive reasoning, strategic competence and procedural fluency made statistically significant contributions to the variance in senior secondary school students' performance in mathematics. Based on this base line study, it was thus, recommended that future studies in Nigeria should investigate the mathematical proficiency of non-elitist schools which dominated the length and breadth of this country so as to generalize the results of this study.

Introduction

Right from inception of mathematics into the Nigerian educational system, the mathematics education of Nigerian students has not only been a disturbing affair but of great concern to all and sundry. This is because many perform poorly in both internal and external examinations in mathematics (Awofala, Arigbabu, Awofala, 2013) and this poor mathematical performance may be connected to a lack of mathematical proficiency in which procedures and algorithms are taught in isolation without any recourse to grounding them in conceptual understanding. The National Council of Teachers of Mathematics (NCTM, 2000) has identified five process standards by which children learn mathematics by doing mathematics to include problem solving, reasoning and proof, representation, communication, and connections. These standards are ways to think about how children should engage in learning the mathematical content as they develop both procedural fluency and conceptual understanding. Children involved in the process of *problem solving* create mathematical knowledge and understanding by dealing with and resolving authentic problems as against carrying out mundane mathematical exercises. They adopt *reasoning and proof* to make meaning out of mathematical tasks and concepts and to cultivate, defend, and assess mathematical arguments and solutions. Children construct and deploy *representations* such as diagrams, graphs, symbols, pictures, and manipulatives to think through mathematical problems. They also involve in *communication* as they explicate their ideas and thinking orally, in writing, and through illustrations. Children not only evolve and deploy *connections* between mathematical ideas as they acquire novel mathematical concepts and procedures but also build *connections* between mathematics and other disciplines by relating mathematics to real-world situations.

Many Nigerian students seem not to develop and demonstrate a deep understanding of and capacity to do mathematics. This is against the *Common Core State Standards for Mathematics* (CCSSI, 2010) which outline the following eight Standards for Mathematical Practice which teachers should help children to develop in mathematics: make sense of problems and persevere in solving them; reason abstractly and quantitatively; construct viable arguments and critique the reasoning of others; model with mathematics; use appropriate tools strategically; attend to precision; look for and make use of structure; and look for and express regularity in repeated reasoning.

It is worthy of note that stakeholders in the Nigerian educational sector (parents, teachers, school administrators, government and educational researchers) want students to be mathematically proficient. This is because skill with mathematics opens the door to many career options in the university and its subsequent acquisition may lead to the empowerment of functional citizenry with high economic vitality and social success. Learning mathematics with meaningful understanding is a vital goal of mathematics teaching in schools (Wu, 2008) and studies have shown that sharpening students' mathematical proficiency entails students learning mathematics with understanding (Carpenter & Lehrer, 1999; Hiebert, Carpenter, Fennema, Fuson, Wearne, Murray, Olivier, & Human, 1997; National Research Council [NRC], 2001; Shafer & Romberg, 1999). Mathematical proficiency is used to capture what it means for anyone to learn mathematics successfully. It is an indicator that someone understands (and can do) mathematics. Mathematical proficiency is the quality of being skilled and exhibiting expertise, competence, knowledge, beliefs, and facility in doing mathematics and becoming proficient problem solver with high productive disposition. According to NRC (2001) mathematical proficiency consists of five interwoven and interdependent strands (Figure 1): conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition.

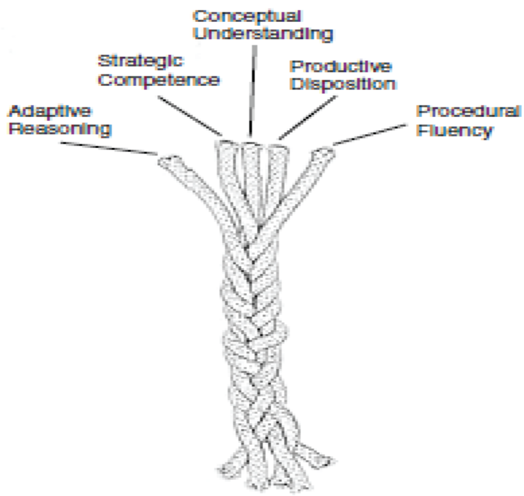

Figure 1. The strands of mathematical proficiency (Source: NRC, 2001, p. 117)

Conceptual understanding is defined as the 'comprehension of mathematical concepts, operations, and procedures' (NRC, 2001, p. 116). 'A significant indicator of conceptual knowledge is being able to represent mathematical situations in different ways and knowing how different representations can be useful for different purposes' (NRC, 2001, p. 119). Thus a person rich conceptual understanding is a function of the many connections to different representations he/she has. For instance, suppose that 60% was given to a student of rich conceptual understanding of percentage and number sense. He may know that 60% is 60/100 which is the same as 30/100 + 30/100 or as 3/10 + 3/10 (or 6/10) (or 3/5). He might be able to connect it to his knowledge of decimal and see 60% as the same as 0.60 which is 6 tenths and 0 hundred or as 60 hundredths (or 600 thousandths). All these connections with different representations make up conceptual understanding. It should be noted that representations allow students to see abstract mathematics concepts in diverse ways, which when intellectually structured and linked, support conceptual understanding. In conceptual understanding, students should be preoccupied with relational understanding-knowing what to do and why as opposed to instrumental understanding-knowing something by rote or without meaning and this relational understanding should be the goal of daily instruction in mathematics. To attain conceptual understanding, students should be made to see the multiple entry points in solving a problem. Conceptual understanding allows students to build new knowledge as they make connections with previously learned knowledge. This method is far more beneficial to students than simple memorization of facts and procedures (Macgregor, 2013). Conceptual understanding promotes retention and fosters the development of fluency (NRC, 2001).

Procedural fluency is defined as 'the knowledge of procedures, knowledge of when and how to use them appropriately, and skill in performing them flexibly, accurately, and efficiently' (NRC, 2001, p. 121). The National Council of Teachers of Mathematics (NCTM) describes procedural fluency as "having efficient, accurate, and generalizable methods (algorithms) for computing that are based on well-understood properties and number relationships." (2000, p. 144). The procedural knowledge referred to is any and all methods one might use to solve a mathematical problem, including (but not limited to) written procedures, mental procedures, computer or calculator use, and modelling with manipulatives (NRC, 2001). It is pertinent to note that procedural fluency does not run contrary to conceptual understanding; in fact, the two work together to help promote mathematical proficiency. Procedural fluency without conceptual understanding will yield non-meaningful and inappropriate strategies for solving applications; conceptual understanding without procedural fluency will yield inefficient strategic applications (Wu & An, 2007, 2008). According to Ostler (2011) procedurally fluent students ostensibly develop the ability to evaluate and simplify various expressions, solve simple equalities, and represent mathematical relationships in graphical form. Students that do not possess an adequate level of procedural fluency will devote much of their attentional resources to the task of basic computation at the expense of developing a deep understanding of more complex mathematical ideas (Gersten, Beckman, Clarke, Foegen, Marsh, Star & Witzel, 2009).

Strategic competence is defined as 'the ability to formulate mathematical problems, represent them, and solve them' (NRC, 2001, p. 124). In the same vein, strategic competence is concerned with a person ability to formulate a problem mathematically and then use his or her previous mathematical experiences to solve it. Having strategic competence enables a person to decipher which strategies might be useful in tackling the problem and in connecting these strategies to previous mathematical experiences. Strategic competence is useful not only in mathematics classroom but in tackling problematic real life situations. Unlike the mathematics classroom environment, students in the real world lack the context with well-defined procedures necessary to help them decide how to approach a problem. In the real world, students are faced with situations that require them to understand the nature of the problem, formulate a model of the problem, think flexibly in choosing appropriate strategy, and solve the problem. Rather than approaching a problem strategically and with understanding, students that lack strategic competence often miss out in their approach to a mathematical problem; they have difficulty formulating a model of the problem and lack the requisite skill to flexibly adopt strategies appropriate to solve the problem. Students that do not possess adequate strategic competence will often approach a mathematical problem with the intention of using a trial and error strategy. Strategic competence can be nurtured through constant exposure to mathematical problems that reflect real life problematic situations. Mathematical problems that require students to comprehend the problem, devising a plan, and carrying out the plan to solve the problem mathematically promote the development of strategic competence.

Adaptive reasoning is defined as 'the capacity to think logically about the relationship among concepts and situations' (NRC, 2001, p. 129). Ability in adaptive reasoning enables one to consider alternative approaches, to follow the mathematical logic of a proposed proof, to note logical inconsistencies or contradictions, and to justify any conclusions (Siegfried, 2012). Students with adaptive reasoning are able to justify the solution steps employed in solving a problem in a logical manner in such a way that they know when the solution steps are wrong or right. Students are said to be capable of adaptive reasoning when they are able to think logically about the existing problems, estimating and reflecting through the problems and giving justifications for solving the problems.

Productive disposition is defined as 'the tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics' (NRC, 2001, p. 131). Rather than see mathematics as a set of arbitrary rules that one must memorise, students with productive disposition view mathematics as a system of connected conceptions that can be understood with perseverance and diligent effort. A line of distinction can be drawn between this strand and the other four strands although productive disposition is needed to build the other four strands (NRC, 2001). While the other four strands deal with a person's cognitive processes and relate to mathematical content knowledge, productive disposition is enshrined in a person's affect, beliefs, and identity and strengthening of the other four strands helps build a person's productive disposition. Thus, a symbiotic relationship exists between productive disposition and the other four strands. Students who do not possess productive dispositions might not see themselves as learners or doers of mathematics and might not see value in steady effort and perseverance in mathematics. In addition these students might not even think that mathematics is supposed to make sense. It can be said that developing mathematical proficiency involves acquiring capability to engage in mathematical habits of mind that promote not only procedural fluency but also conceptual understanding, adaptive reasoning, and strategic competence within the confine of mathematisation. While mathematisation plays a significant role in developing proficiency, the processes of mathematisation which include connecting, communicating, reasoning, argumentation, justifying, representing, problem-solving and generalising should infiltrate all learning and teaching activities in mathematics (NCCA, 2014).

In Nigeria, mathematics is viewed as a problem solving activity and this view is entrenched in the new senior secondary school mathematics curriculum. But evidence suggests that there is a mismatch between this view and mathematics that the majority of students are exposed to in the classroom. It is clear that most teachers adopt the traditional lecture method in teaching mathematics (Ifamuyiwa & Akinsola, 2008; Awofala, Fatade & Ola-Oluwa, 2012) and more often than not teachers are glued to the traditional mathematics textbooks when giving instruction in mathematics with emphasis on lower-order thinking skills (Awofala, 2012) and mathematical procedures. These teachers' activities negate not only the principle of constructivism but deny students the opportunity to experience mathematics as a creative and engaging process. Creativity is further compromised by these activities that reward convergent thinking and approve correct answers. While examples in these traditional textbooks may enhance students' skill in procedural fluency, they are generally inadequate for students in fostering the other strands of mathematical proficiency and to appreciate the beauty, orderliness and usefulness of mathematics.

In general, researches into mathematical proficiency are in its infancy stage despite its importance as a goal that must be nurtured in the mathematics classroom. Wu (2008) assessed 491 Chinese sixth graders' mathematics proficiency as reflected in conceptual understanding, procedural fluency, and competence in word problem applications using the model – strategy - application (MSA) approach. The results showed that Chinese students' procedural fluency was at a higher level compared to their conceptual understanding and word problem in real-world applications. The results further revealed that a higher level of computation did not lead Chinese students to a deep understanding of fractions and decimals. Kinnari (2010) investigated the mathematical proficiency of first year engineering students at Tampere University of Applied Sciences (TAMK) in which TAMK had designed a diagnostic procedure based on the NRC's five strands of mathematical proficiency framework. The students took a 20 multiple question online survey based on three of the strands: conceptual understanding; procedural fluency; and strategic competence. The results showed that the students scored from 8.1 to 18.3 points (out of 40), with a mean score of 13.8, representing a significant lack of mathematical proficiency. Samuelsson (2010) investigated the effect of two differently structured methods, traditional and problem-solving on students' mathematical proficiency in Sweden. The results showed that there were no significant differences between teaching methods when assessing procedural fluency but students' progress in conceptual understanding, strategic competence, and adaptive reasoning was significantly better when teachers taught with a problem-based curriculum. In addition, students' productive disposition, beliefs in diligence and one's own efficacy, was affected significantly more if students worked traditionally.

Taking mathematical proficiency as the aim of mathematics education has the likelihood to transform the kind of mathematics and mathematical learning that young children are exposed to (NCCA, 2014) irrespective of their gender. Worldwide the gender dimension is a frequent element of research in the field of mathematics education. In Nigeria, both male and female students not only struggle with mathematics learning but consider mathematics as a difficult school subject. While the stereotypical view is that females are deficient in mathematical ability, an avalanche of research suggests that males and females show little difference in their achievement in mathematics (Hyde, Fennema & Lamon, 1990; Hyde, Lindberg, Linn, Ellis & Williams, 2008; Else-Quest, Hyde & Linn, 2010). Evidence suggests that females have the proclivities to report less positive attitudes and confidence in their mathematics ability, and that the gap broadens throughout schooling when males report greater self-confidence (Hyde et al., 1990; Pajares & Graham, 1999). In addition, females are seen to have higher levels of mathematics anxiety and lower self-beliefs (Casey, Nuttall & Pezaris, 1997; McGraw, Lubeinski & Strutchens, 2006). In short there were marked differences between males and females in their interest in and enjoyment of mathematics, their self-related beliefs, as well as their emotions related to mathematics. The implication of this is that teachers tend to associate students' confidence with mathematical ability. Thus, teachers may underrate females' mathematical abilities as they are likely to show more mathematics anxiety than males even if they have high ability (Kyriacou & Goulding, 2006). The PISA 2003 confirmed that in EU countries, females experience significantly more feelings of helplessness, anxiety and stress in mathematics classes than males with statistically significantly higher levels of anxiety among females in Denmark, Germany, Spain, France, Luxembourg, the Netherlands, Austria, Finland, Liechtenstein and Norway (OECD, 2004).

In Nigeria three outcomes of research on gender differences in mathematics are delineated. First, there are studies that indicated significant gender difference in mathematics achievement in favour of males (Awofala, 2011; Awofala, 2010; Akinsola & Awofala, 2009). Second, some studies showed significant gender difference in mathematics achievement in favour of females (Ozofor, 2001; Ogunkunle, 2007). Third, there are studies that exhibit no significant effect of gender on achievement in mathematics (Arigbabu & Mji, 2004; Fatade, Nneji, Awofala & Awofala, 2012; Awofala & Anyikwa, 2014). While the first and the second categories suggest the existence of differential experiences of boys and girls within and outside the mathematics classroom the third category has come up with the conclusion that gender differences in achievement in mathematics are disappearing. In the US, research evidence indicates that gender gap in mathematics achievement has been narrowing (Perie, Moran, & Lutkus, 2005) in which girls have reached parity with boys in mathematics (Hydea & Mertzb, 2009) while in Australia gender differences in mathematics achievement are reducing and shifting (Forgasz, Leder, & Vale, 2000). In addition, Vale (2009) found that many studies conducted between 2000 and 2004 in Australasia showed no significant effect of gender on students' achievement in mathematics though males were more likely to obtain higher mean scores than females. Lubienski, Robinson, Crane and Ganley (2013) ''found that boys' and girls' mathematics proficiency does not significantly differ at the start of kindergarten, but a significant advantage for boys is evident at the top of the achievement distribution by the end of kindergarten. This disparity spreads throughout the distribution (i.e., to the lower percentiles of achievement), and the average gap peaks at roughly 0.24 SDs in Grades 3 and 5'' (p. 636).

It is apparent that the canonical gender differences in mathematics achievement are declining world-wide and, perhaps, do not have any practical importance for the future (Awofala & Anyikwa, 2014), the inconsistent findings regarding gender differences in mathematics in Nigeria have shown the need for more investigations particularly in the area of mathematical proficiency. Unlike the developed countries of the world, where researches into mathematical proficiency had reached an appreciable level, there were paucity of studies in Nigeria on students' mathematical proficiency and mathematical proficiency gender related issues. In addition, the inconclusive findings regarding gender differences in achievement/performance in mathematics in Nigeria have further provided the needed drive for the study.

Purpose of the Study

The present study investigated Nigerian senior secondary school students' mathematical proficiency, the differences in mathematical proficiency between male and female students, and the relationship between mathematical proficiency and performance in mathematics.

Research Questions

Specifically in this study, the following research questions were addressed:

1. What is the level of mathematical proficiency among Nigerian senior secondary school students?

2. Is gender a factor in performance in mathematics and mathematical proficiency among Nigerian senior secondary school students?

3. What are the relationships among conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, productive disposition and performance in mathematics of senior secondary school students?

4. What are the composite and relative contributions of dimensions of mathematical proficiency (conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition) and gender to the explanation of the variance in the senior secondary school students' performance in mathematics?

Method

The study made use of quantitative research method within the blueprint of descriptive survey design. The participants in this study were 400 senior secondary school year two students (198 males and 202 females) from ten elitist senior secondary schools in Education District IV of Lagos State, Nigeria. Their age ranged from 14 to 19 years with mean age of 16 years. The students belonged to the high socio-economic status group. For the purpose of primary data collection, six instruments were used and they include: Mathematics Proficiency Test (MPT), Mathematics Conceptual Understanding Checklist (MCUC), Mathematics Procedural Fluency Checklist (MPFC), Mathematics Strategic Competence Checklist (MSCC), Mathematics Adaptive Reasoning Checklist (MARC), and Mathematics Productive Disposition Inventory (MPDI). In addition, secondary data relating to students' performance in mathematics were retrieved from their records in the schools.

The MPDI consisted of 24 items anchored on a four-point scale ranging from: Strongly Agree -4, Agree -3, Disagree -2, to Strongly Disagree -1. The MPDI was developed along the submission of Siegfried (2012). Siegfried (2012) submitted that mathematics productive disposition is a multi-dimensional construct which consists of the following dimensions: affect, beliefs, identity, mathematical integrity, risk taking, goals, motivation, and self-efficacy. So each sub-construct of the mathematics productive disposition has three items. The internal consistency reliability coefficient of the MPDI was computed using the Cronbach alpha (α) with a value of 0.89. The items which make up each of the components of productive disposition are displayed in Appendix I.

The MPT has three sections: A, B, and C. Section A requested students' demographic data such as age and gender. Section B was for basic Conceptual Knowledge involving three questions requiring short answers while Section C was made up of problem solving and processes of five questions, two of which are routine problems while the other three questions are non-routine problems. The problems were taken from three themes in senior secondary school mathematics curriculum and they include Number and numeration, Algebraic processes, and Geometry. The MPT was scored over one hundred (100). Section A had no marks. Section B bore 15 marks (a correct definition bore three marks and giving an example to support the definition bore two marks making five marks for each question). Section C bore eighty five (85) marks. Questions in Section C were scored according to complexity. Thus, question one bore four (4) marks, question two bore 15 marks (10 marks for problem solving and 5 marks for explanation of solution procedures). Question three bore 6 marks while questions four and five were scored 30 marks each. The internal consistency reliability coefficient of the MPT was computed using the Kuder-Richardson 20 with a value of 0.78.

The MCUC was developed by the researcher in line with the Mathematics Concepts and Skills Checklist for Grade Level 8 available online at http://www.fldoe.org/ese and the Nigerian Senior Secondary School Year Two Mathematics Curriculum as guides. The checklist was designed to measure students' conceptual knowledge (comprehension of mathematical concepts, operations and relations) and conceptual understanding (ability to apply mathematical knowledge in solving mathematics problems correctly). Note that a student's expression of the required skill(s) in its valid form will be a measure of how well s/he understands the concept. In the scoring a correct expression of each skill whether conceptual knowledge or conceptual understanding bore one mark otherwise zero mark was awarded. Altogether there were 35 skills. 29 of these skills were conceptual understanding related while the remaining 6 skills were for conceptual knowledge. The internal consistency reliability coefficient of the MCUC was computed using the Kuder-Richardson 20 with a value of 0.82.

The MPFC was developed by the researcher in line with the Mathematics Concepts and Skills Checklist for Grade Level 8 available online at http://www.fldoe.org/ese and the Nigerian Senior Secondary School Year Two Mathematics Curriculum as guides. The checklist was designed to measure students' procedural fluency that is skills in carrying out procedures flexibly, accurately, efficiently and appropriately. The instrument showed the theme, the concepts, the big ideas, the level of representation of the procedure measured in terms of expression of relevant skills, the validation of expression of the corresponding skills and the score. In the scoring a correct expression of each procedural skill bore one mark otherwise zero mark was awarded. Altogether there were 35 procedural skills and this gave a total of 35 marks. The internal consistency reliability coefficient of the MPFC was computed using the Kuder-Richardson 20 with a value of 0.78.

The MSCC developed by the researcher has two sections namely the problem solving processes and the procedural processes. The problem solving processes were in line with the mathematical processes identified by the Target Implementation and Planning Supports for Revised Mathematics (TIPS4RM) accessible online at https://www.edu.gov.on.ca/eng/.../lms/tips4rm.html and strategic processes identified by the UK National Strategies, the framework for secondary mathematics available online at www.secondarymathsite.co.uk/Framework%20for%20Mathematics.html. The procedural processes were identified from the Nigerian Senior Secondary School Year Two Mathematics Curriculum. The checklist was designed to measure students' strategic competence that is ability to formulate, represent and solve mathematical problems correctly by relating and connecting previous knowledge or solved problems to present problem or situation. In the scoring a correct expression of each strategic competence skill bore one mark otherwise zero mark was awarded. Altogether there were 25 strategic competence skills and this gave a total of 25 marks. The internal consistency reliability coefficient of the MSCC was computed using the Kuder-Richardson 20 with a value of 0.80.

The MARC developed by the researcher measured students' capacity for logical thought, reflection, explanation and justification. The adaptive reasoning processes were deduced from NRC (2001) which students should exhibit for optimal performance (deduction, statement of facts, comparison, abstraction, and application). In the scoring a correct expression of each adaptive reasoning skill bore one mark otherwise zero mark was awarded. Altogether there were 10 adaptive reasoning skills and this gave a total of 10 marks. The internal consistency reliability coefficient of the MARC was computed using the Kuder-Richardson 20 with a value of 0.82.

The author together with three research assistants administered the MPT and the MPDI to the whole sample in their regularly scheduled classes. Data collected were summarized and analyzed using percentages, means, standard deviations, independent samples t-test, Pearson product moment correlation, and multiple regression analysis.

Results and Discussion

Research Question One: What is the level of mathematical proficiency among Nigerian senior secondary school students?

A total score was computed from the five dimensions of mathematical proficiency. On conceptual understanding, the score ranged from zero to 35, for procedural fluency, the score ranged from zero to 35, for strategic competence the score ranged from zero to 25, for adaptive reasoning the score ranged from zero to 10 while for productive disposition the score ranged from 24 to 96. Altogether for mathematical proficiency, the score ranged from 24 to 201. A score of 112.5 (or approximately 113) is the middle point so higher scores indicate a high mathematical proficiency. Of 400 senior secondary school students, 399 (99.75%) had scores greater than 113 (*M*=139.01, *SD*=9.32, score range: 104-170, 95%*CI*= 138.09–139.92) while 1 had scores (0.25%) equaled 113 (M= 113, SD=0, score range: 113, 95%*CI*=113). A large proportion of these senior secondary school students had high mathematical proficiency. However, the overall *M*=138.95, *SD*=9.40, score range: 104-170, and 95%*CI*= 138.02–139.87 for the entire sample showed high mathematical proficiency of senior secondary school students.

Research Question Two: Is gender a factor in performance in mathematics and mathematical proficiency among Nigerian senior secondary school students?

Table cx1 below showed the descriptive statistics of mean and standard deviation and t-test values on mathematical proficiency score and mathematics performance score by male and female senior secondary school students. With respect to the mathematical proficiency score, the female students recorded slightly higher mean score (M=139.36, SD=9.41) than their male counterparts (M=138.53, SD=9.40). However, this slight difference in mean score was statistically not significant (t_{398} = -.88, p=.38). Table 1 below showed that the female students recorded slightly higher mean score (M=21.28, SD=3.23) in conceptual understanding than their male counterparts (M=21.15, SD=3.07) and this difference was statistically not significant (t_{398} = -.42, p=.68).

Table 1. Independent samples t-test analysis of senior secondary school students' performance in mathematics and mathematical proficiency according to gender

	Gender	N	Mean	SD	Df	t	p
Conceptual understanding	Male	198	21.15	3.07			
	Female	202	21.28	3.23	398	-.42	.68
Procedural fluency	Male	198	21.33	3.16			
	Female	202	21.06	3.07	398	.86	.39
Strategic competence	Male	198	14.50	2.41			
	Female	202	15.00	2.94	398	-1.86	.06
Adaptive reasoning	Male	198	6.37	2.69			
	Female	202	6.58	2.72	398	-.78	.44
Productive disposition	Male	198	75.18	7.19			
	Female	202	75.44	6.76	398	-.37	.71
Mathematical proficiency	Male	198	138.53	9.40			
	Female	202	139.36	9.41	398	-.88	.38
Mathematics Performance	Male	198	64.97	14.41			
	Female	202	61.46	14.64	398	2.42	.02

In Table 1, the male students recorded slightly higher mean score (M=21.33, SD=3.16) in procedural fluency than their female counterparts (M=21.06, SD=3.07). The difference was statistically not significant (t_{398} = .86, p=.39). With respect to strategic competence, the female students recorded slightly higher mean score (M=15.00, SD=2.94) than their male counterparts (M=14.50, SD=2.41). However, this difference in mean score was statistically not significant (t_{398} = -1.86, p=.06). Table 1 revealed that female students recorded slightly higher mean score (M=6.58, SD=2.72) in adaptive reasoning than their male counterparts (M=6.37, SD=2.69). This difference in mean score was not statistically significant (t_{398} = -.78, p=.44). With respect to productive disposition, the female students recorded slightly higher mean score (M=75.44, SD=6.76) than their male counterparts (M=75.18, SD=7.19). However, this difference in mean score was statistically not significant (t_{398} = -.37, p=.71). Table 1 revealed that male students recorded higher mean score (M=64.97, SD=14.41) in performance in mathematics than their female counterparts (M=61.46, SD=14.64). This difference in mean score was however statistically significant (t_{398} = 2.42, p=.02). Thus, we concluded that gender was not a significant factor in senior secondary school students' mathematical proficiency even at the mathematical proficiency subscale levels but that gender was a significant factor in performance in mathematics.

Research Question Three: What are the relationships among conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, productive disposition and performance in mathematics of senior secondary school students?

The results in Table 2 below showed the relationship among the mathematical proficiency, mathematical proficiency subscales, gender and performance in mathematics. Table 2 showed that there was a significant positive correlation between the student performance in mathematics and conceptual understanding (Pearson *r*=.132, *p<.01*), procedural fluency (Pearson *r*=.175, *p<.01*), strategic competence (Pearson *r*=.164, *p<.01*), adaptive reasoning (Pearson *r*=.135, *p<.01*), productive disposition (Pearson *r*=.141, *p<.01*) and mathematical proficiency (Pearson *r*=.171, *p<.01*). While there was a significant negative correlation between gender and performance in mathematics (Pearson *r*=.120, *p<.05*) there was no significant correlation between gender and each dimension of mathematical proficiency. The low correlations among the competencies as indicated in Table 2 are desirable in that they represent distinct skills.

Table 2. Correlations matrix for the relationship between mathematical proficiency dimensions, gender and senior secondary school students' performance in mathematics

	1	2	3	4	5	6	7	8
1. P	1							
2. G	-.120*	1						
3. CU	132**	.021	1					
4. PF	.175**	-.043	.179*	1				
5. SC	.164**	.093	.115*	.150*	1			
6. AR	.135**	.039	.125*	.172*	.275**	1		
7. PD	.141**	.019	.195*	.143*	.117*	.157*	1	
8. MP	.171**	.044	.382**	.308**	.307**	.283**	.809**	1
Mean	63.19	1.50	21.21	21.19	14.75	6.48	75.31	138.95
SD	14.61	.501	3.15	3.12	2.70	2.71	6.97	9.40

* Correlation is significant at the .05 level (2-tailed) **Correlation is significant at the .01 level (2-tailed). Note that P=performance in mathematics, G=gender, CU=conceptual understanding, PF=procedural fluency, SC=strategic competence, AR= adaptive reasoning, PD=productive disposition, and MP=mathematical proficiency.

Research Question Four: What are the composite and relative contributions of dimensions of mathematical proficiency (conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition) and gender to the explanation of the variance in the senior secondary school students' performance in mathematics?

The results in Table 3 below showed that the independent variables (gender (G), conceptual understanding (CU), procedural fluency (PF), strategic competence (SC), adaptive reasoning (AR) and productive disposition (PD) jointly contributed a coefficient of multiple regression of .845 and a multiple correlation square of .715 to the prediction of senior secondary school students' performance in mathematics. By implication, 71.5% of the total variance of the dependent variable (performance in mathematics) was accounted for by the combination of the six independent variables. The results further revealed that the analysis of variance of the multiple regression data produced an *F*-ratio value significant at 0.001 level ($F_{(6, 393)} = 164.18$; $p<.001$). The results of the relative contributions of the independent variables to the prediction of senior secondary school students' performance in mathematics was that procedural fluency was the most potent significant positive contributor to the prediction of students' performance in mathematics (β = .579, *t* = 21.34, *p*=.000), while conceptual understanding made the next significant positive contribution to the prediction of the dependent variable (β = .474, *t* = 17.44, *p*=.000). Strategic competence made the next significant positive contribution to the prediction of the dependent variable (β = .447, *t* = 16.50, *p*=.000). Adaptive reasoning made the next significant positive contribution to the prediction of the dependent variable (β =.092, *t* = 3.40, *p*=.001). While productive disposition made the next significant negative contribution to the prediction of the dependent variable (β =-.075, *t* = -2.78, *p*=.006), gender made the least significant negative contribution to the prediction of senior secondary school students' performance in mathematics (β =-.060, *t* = -2.19, *p*=.029).

Table 3. Model summary, coefficient and t-value of multiple regression analysis of mathematical proficiency dimensions, gender and the outcome measure (performance in mathematics)

Model summary
Multiple R= .845
Multiple R^2= .715
Multiple R^2 (Adjusted)= .710
Standard Error Estimate= 2.71
F=164.18, *p*<.001

Model	Unstandardized coefficients		Standardized coeff.	t	Sig
	B	**Std Error**	**Beta**		
Constant	.586	2.20		.267	.790
G	-.602	.275	-.060	-2.19	.029
CU	5.815	.333	.474	17.44	.000
PF	6.551	.307	.579	21.34	.000
SC	4.819	.292	.447	16.50	.000
AR	.547	.161	.092	3.40	.001
PD	-.141	.051	-.075	-2.78	.006

Note that G=gender, CU=conceptual understanding, PF=procedural fluency, SC=strategic competence, AR= adaptive reasoning, and PD=productive disposition.

Afterwards, a stepwise regression analysis was used to determine the contribution of each of these variables in predicting performance in mathematics. A reduced model explaining the predictive capacity of the six variables (gender, adaptive reasoning, procedural fluency, strategic competence, conceptual understanding, and productive disposition) on performance in mathematics is outlined in Table 4 below. Model 1, which includes only procedural fluency scores, accounted for 24.9% of the variance in senior secondary school students' performance in mathematics. The inclusion of conceptual understanding into Model 2 resulted in additional 49.1% of the variance being explained. This means that conceptual understanding alone accounted for 24.2% of the variance in students' performance in mathematics. The inclusion of strategic competence into Model 3 resulted in additional 69.4% of the variance being explained. This means that strategic competence alone accounted for 20.3% of the variance in students' performance in mathematics. The inclusion of adaptive reasoning into Model 4 resulted in additional 70.5% of the variance being explained. This means that adaptive reasoning alone accounted for 1.1% of the variance in students' performance in mathematics. The inclusion of productive disposition into Model 5 resulted in additional 71.1% of the variance being explained. This means that productive disposition alone accounted for 0.6% of the variance in students' performance in mathematics. The inclusion of gender into Model 6 resulted in additional 71.5% of the variance being explained. This means that gender alone accounted for 0.4% of the variance in students' performance in mathematics.

The results of the present study have highlighted four main findings. These findings relate to determining the level of mathematical proficiency among senior secondary school students; determining whether differences existed between male and female students in mathematical proficiency and performance in mathematics; ascertaining whether there existed significant correlations among dimensions of mathematical proficiency and performance in mathematics; and ascertaining composite and relative contributions of dimensions of mathematical proficiency and gender to the prediction of senior secondary school students' performance in mathematics. Majority of the senior secondary school students in this study had high mathematical proficiency (*N*=399, *Mean*=139.01, *SD*=9.32) while only one student showed moderate proficiency level in mathematics. The high mathematical proficiency in the entire sample might be because of the type of school sampled for the study. All the schools used in this study were elitist schools as they were either owned by private organisations, individuals or higher institutions of learning in Lagos State, Nigeria. These schools are historically known for high reputation in academic excellence and have won prizes for high academic performance in science and mathematics. The high mathematical proficiency among the majority of the senior secondary school students was in contrast with previous findings (National Assessment of Educational Progress, 1999) which showed low level of mathematical proficiency among high school students in the United States. This finding partially supported previous findings (Wu, 2008) which showed high level of procedural fluency but low level of conceptual understanding and strategic competence in mathematics among Chinese students. This was contrary to the finding of Kinnari (2010) which showed that level of mathematical proficiency among first year engineering students was low. In addition, findings from South Africa had revealed that the level of mathematical proficiency of grade six classes was very low (Ally (2011). The results of this study was contrary to the findings from Malaysia which showed that level of mathematical proficiency in three areas of conceptual understanding, procedural fluency, and strategic competence for 14-year-old students was very low (Khairani & Nordin, 2011). Ally and Christiansen (2013) found that in South Africa opportunities to develop procedural fluency are common, but generally of a low quality; that opportunities to develop conceptual understanding are present in about half the lessons, but also are not of a high quality; and that overall opportunities to develop mathematical proficiency are limited, because learners are not engaging in adaptive reasoning, hardly have any opportunities to develop a productive disposition, and seldom are given the opportunity to engage in problem-solving which could develop their strategic competence.

Table 4. Summary of stepwise regression results with gender and dimensions of mathematical proficiency entered for final model explaining performance in mathematics

Model	Predictors	B	SEB	β	t	p	R	R^2	F	p
1	constant	37.33	1.827		20.43	.000	.499	.249	131.96	.000
	PF	5.647	.492	.499	11.49	.000				
2	constant	16.039	2.159		7.43	.000	.701	.491	191.84	.000
	PF	6.185	.407	.547	15.20	.000				
	CU	6.067	.441	.495	13.76	.000				
3	constant	-.817	1.972		-.41	.679	.833	.694	299.99	.000
	PF	6.536	.317	.578	20.65	.000				
	CU	5.798	.343	.473	16.92	.000				
	SC	4.871	.300	.452	16.22	.000				
4	constant	-2.874	2.017		-1.43	.155	.840	.705	235.85	.000
	PF	6.552	.312	.579	21.03	.000				
	CU	5.828	.337	.475	17.28	.000				
	SC	4.898	.296	.455	16.57	.000				
	AR	.607	.162	.102	3.74	.000				
5	constant	-.645	2.133		-.30	.762	.843	.711	194.19	.000
	PF	6.565	.308	.580	21.28	.000				
	CU	5.867	.334	.478	17.55	.000				
	SC	4.860	.293	.451	16.59	.000				
	AR	.588	.161	.099	3.66	.000				
	PD	-.151	.051	-.081	-2.97	.003				
6	constant	.586	2.196		.27	.790	.845	.715	164.18	.000
	PF	6.551	.307	.579	21.34	.000				
	CU	5.815	.333	.474	17.44	.000				
	SC	4.819	.292	-.447	16.50	.000				
	AR	.547	.161	.092	3.40	.001				
	PD	-.141	.051	-.015	-2.78	.006				
	Gender	-.602	.275	-.060	-2.19	.029				

The findings relating to gender differences in mathematical proficiency and performance in mathematics showed that in the present study male and female senior secondary school students did not show comparable mean scores in performance in mathematics but recorded comparable mean scores on each of the dimensions of mathematical proficiency. Thus, while gender differences in mathematical proficiency were not significant, gender difference in performance in mathematics in this study was statistically significant. The non-significant gender differences in mathematical proficiency on one hand were in agreement with previous study findings (Arigbabu & Mji, 2004; Awofala & Anyikwa, 2014; Fatade, Nneji, Awofala & Awofala, 2012) in advanced mathematics and numeracy among preservice mathematics teachers and adult learners but ran contrary to other previous findings (Awofala, 2008a; Awofala, 2008b; Awofala, 2010; Awofala, 2011; Akinsola & Awofala, 2009; Ozofor, 2001; Ogunkunle, 2007) which revealed the existence of significant gender differences in mathematics. On the other hand, the significant gender effect on secondary students' performance in mathematics re-echoed the dwindling parlance that males were better in mathematics than females. Samuelsson (2010) found that there was no significant effect of gender on each of the dimensions of mathematical proficiency. The implication of the present study findings regarding gender is that gender differences in mathematical proficiency are no longer important and are dissipating but that subtle differences might still exist in performance in mathematics. This difference might be as result of differential treatment of both male and female students which in most cases favoured the male gender in the mathematics classroom.

The results exhibited in Table 2 showed that there was a significant positive correlation between the student performance in mathematics and conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, productive disposition and mathematical proficiency. The results also showed that while there was a significant negative correlation between gender and performance in mathematics there was no significant correlation between gender and each dimension of mathematical proficiency. There was a significant positive correlation between adaptive reasoning and strategic competence and between productive disposition and strategic competence. This agreed with the findings of Wu (2008) which showed that conceptual understanding, procedural fluency and strategic competence were correlated. The low but significant correlations among the dimensions of mathematical proficiency in this study showed that each dimension of mathematical proficiency is distinct. This result coincided with the finding of Samuelsson (2010) which indicated low but significant correlations among these competencies except the correlation between conceptual understanding and strategic competence which was high.

The results displayed in Table 3 showed that 71.5% of the variance in senior secondary school students' performance in mathematics was accounted for by the six predictor variables (gender, adaptive reasoning, conceptual understanding, procedural fluency, strategic competence, and productive disposition) taken together. The relationship between performance in mathematics and the predictor variables taken together were high as shown by the coefficient of multiple correlation (R = .845). Thus, the predictor variables investigated when taken together predicted to some extent mathematics performance among senior secondary school students considered in the study. The observed ($F_{(6,\ 393)}$ = 164.18; p<.001) is a reliable evidence that the combination of the dimensions of mathematical proficiency in the prediction of senior secondary school students' performance in mathematics from all indications did not occur by chance with 28.5% of the variance in mathematics performance not unexplained by the current data. Thus, there might be other independent variables which may require further investigations about their contribution to the prediction of senior secondary school students' performance in mathematics and the degree of prediction jointly made by the six independent variables of this study could be substantive enough to assert that senior secondary school students' performance in mathematics is predictable by a combination of the dimensions of mathematical proficiency and gender. Thus, the strength of the predictive power of the combined independent variables (gender, adaptive reasoning, conceptual understanding, procedural fluency, strategic competence, and productive disposition) on the outcome variable was strong and significant to show the linear relationship between the six predictor variables and the total variance in senior secondary school students' performance in mathematics. According to the standardized coefficients the regression model is as follows: Performance in mathematics$_{predicted}$ = 0.586 - 0.060 gender + 0.474 conceptual understanding + 0.579 procedural fluency + 0.447 strategic competence + 0.092 adaptive reasoning - 0.075 productive disposition. On the relative contribution of each of the independent variables to the explanation of variance in senior secondary school students' performance in mathematics, the present study showed that all the six independent variables made statistically significant contribution to the variance in students' performance in mathematics though at varying degrees.

Conclusion

It is worthy of note that 99.75% of the senior secondary school students in this study showed high mathematical proficiency. This high mathematical proficiency may have been influenced by their high conceptual understanding, high strategic competence, high procedural fluency, high adaptive reasoning and high productive disposition in mathematics. No wonder that students from these senior secondary schools performed above expectation in both internal and external examinations conducted by the West Africa Examinations Council and the National Examinations Council in Nigeria. One limitation of the present study is that attempts were not made to do a qualitative analysis of the responses of the students to the mathematics proficiency test which could have revealed students' errors and misconceptions on the mathematics proficiency test and make the work richer. In addition, sampling only the elitist schools for the study may make the generalization of the results of this study to non-elitist schools practically impossible. It is clear there is a dichotomy in the academic performance of elitist and non-elitist schools in Nigeria. Elitist schools are not only known for well trained teachers with qualifications not below first degree and not below second class upper in grade, they are also known for well conducive classroom environment with appropriate instructional materials to foster learning. Since the teachers in these schools are well paid they are as well dedicated to the teaching profession.

Recommendations

The findings of this study are recommended to both the students and the mathematics teachers in that expositions in mathematical proficiency will help students and teachers to understand the 'socio-mathematical norms' taking place in the classroom (Yackel & Cobb, 1996; Yackel, Cobb, & Wood 1991). Socio-mathematical norms involve students' investigation of the mathematics in various solution pathways in an atmosphere of focused attention which permeates contributing to mathematical dialogues, comprehending one another's ideas, and unraveling the imports of those ideas through persistence, challenging and questioning behaviours. However, it will augur well for further research to investigate the mathematical proficiency of non-elitist schools which dominated the length and breadth of Nigeria so as to generalise the results of this study. However, it is hoped that the present study is vital in exposing the level of mathematical proficiency of elitist senior secondary school students as the study findings could serve as a baseline for conducting future studies in mathematical proficiency in Nigeria.

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References

Akinsola, M. K. & Awofala, A. O. A. (2009). Effect of personalisation of instruction on students' achievement and self-efficacy in mathematics word problems. *International Journal of Mathematical Education in Science and Technology*, *40*(3), 389-404. doi: 10.1080/00207390802643169.

Ally, N. (2011). The promotion of mathematical proficiency in Grade 6 mathematics classes from the Umgungundlovu district in KwaZulu-Natal (Master's thesis). Retrieved from http://hdl.handle.net/10413/5791.

Ally, N. & Christiansen, I. M. (2013). Opportunities to develop mathematical proficiency in Grade 6 mathematics classrooms in KwaZulu-Natal. *Perspectives in Education, 31*(3), 106-121.

Arigbabu, A. A., & Mji, A. (2004). Is gender a factor in mathematics performance among Nigerian pre-service teachers? *Sex Roles*, *51*(11), 749–753. doi: 10.1007/s11199-004-0724-z.

Awofala, A. O. A. & Anyikwa, B. E. (2014). Assessing adult learners' numeracy as related to gender and performance in arithmetic. *New Approaches in Educational Research*, *3*(2), 83-92. doi:10.7821/near.3.2.83-92.

Awofala, A. O. A., Arigbabu, A. A. & Awofala, A. A. (2013). Effects of framing and team individualised instructional strategies on senior secondary school students' attitudes toward mathematics. *Acta Didactica Napocensia*, *6*(1), 1-22.

Awofala, A.O.A. (2008a). Women and the learning of mathematics. *African Journal of Historical Sciences in Education, 2*(1), 195–213.

Awofala, A.O.A. (2008b): Sex, Blood type and the relationship between mathematics self-efficacy and achievement in senior secondary school. *African Journal of Historical Sciences in Education*, *2*(2), 94 – 104

Awofala, A. O. A. (2010). *Impact of personalised instruction on senior secondary school learning outcomes in mathematics word problems.* Unpublished Ph.D Thesis. University of Ibadan, Nigeria.

Awofala, A. O. A. (2011). Is gender a factor in mathematics performance among Nigerian senior secondary students with varying school organization and location? *International Journal of Mathematics Trends and Technology, 2*(3), 17-21.

Awofala, A. O. A. (2012). An Analysis of the new 9-year basic Education mathematics Curriculum in Nigeria. *Acta Didactica Napocensia, 5*(1), 17-27.

Awofala, A.O.A, Fatade, A. O. & Ola-Oluwa, S. A. (2012). Achievement in cooperative and individualistic goal-structured junior secondary school mathematics classrooms in Nigeria *International Journal of Mathematics Trends and Technology, 3*(1), 7 – 12.

Carpenter, T., & Lehrer, R. (1999). Teaching and learning mathematics with understanding. In E. Fennema & T. Romberg (Eds.), *Mathematics classroom that promote understanding* (pp. 19-32). Mahwah, NJ: Erlbaum.

Casey, M. B., Nuttall, R. L. & Pezaris, E. (1997). Mediators of gender differences in mathematics college entrance test scores: A comparison of spatial skills with internalized beliefs and anxieties. *Developmental Psychology, 33,* 669-680.

Common Core State Standards Initiative (CCSSI). (2010). *Common Core State Standards for mathematics*. Retrieved from http://corestandards.org/asserts/ CCSSI_Math%20Standards.pdf.

Else-Quest, N. M., Hyde, J. S. & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin, 136*(1), 103-127.

Fatade, A. O., Nneji, L. M., Awofala, A. O. A. & Awofala, A. A. (2012). Mode of entry and gender as determinants of Nigerian pre-service teachers' performance in degree mathematics and science courses. *International Journal of Mathematics Trends and Technology, 3*(3), 103-109.

Forgasz, H. J., Leder, G. C., & Vale, C. (2000) Gender and mathematics: Changing perspectives. In K. Owens & J.A. Mousley (Eds.). *Research in mathematics education in Australasia 1996-1999*. Turramurra, NSW: Mathematics education research group of Australasia inc.

Gersten, R., Beckman, S., Clarke, B., Foegen, A., Marsh, L., Star, J. R., & Witzel, B. (2009). *Assisting students struggling with mathematics: Response to intervention (RTI) for elementary and middle schools* (NCEE 2009-4060). Retrieved from National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education website: http://ies.ed.gov/ncee/wwc/publications/ practiceguides/.

Hiebert, J., Carpenter, T., Fennema, E., Fuson, K., Wearne, D., Murray, H., Olivier, A., & Human, P. (1997). *Making sense: Teaching and learning mathematics with understanding,* Portsmouth, NH: Heinemann.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize mathematics performance. *Science, 321*(5888), 494–495. doi:10.1126/science.1160364.

Hyde, J. S., Fennema, E., & Lamon, S., (1990). Gender differences in mathematics performance: A meta-analysis. *Psychological Bulletin, 107,* 139-155.

Hydea, J. S. & Mertzb, J. E. (2009). *Gender, culture, and mathematics performance.* Retrieved from http: / /tctvideo. madison.com/uw/gender.

Ifamuyiwa, S. A. & Akinsola, M. K. (2008). Improving senior secondary school students' attitude towards mathematics. *International Journal of Mathematical Education in Science and Technology*, *39*(5), 569-585.

Khairani, A. Z. & Nordin, M. S. (2011). The development and construct validation of the mathematics proficiency test for 14-year-old students. *Asia Pacific Journal of Educators and Education, 26*(1), 33-50.

Kinnari, H. (2010). A study of mathematics proficiency. Scientific Bulletin. Series, *Mathematical Modeling in Civil Engineering*, 23-27. Retrieved from Research Library. (Document ID: 2241240311).

Kyriacou, C., & Goulding, M. (2006). *Mathematics education: a systematic review of strategies to raise pupils' motivational effort in key stage 4 mathematics*. London: University of London, Institute of Education, Social Science Research Unit, EPPI-Centre [Online] Available at: http://eppi.ioe.ac.uk/cms/LinkClick.aspx?fileticket=rOESCjDkP0c%3d&tabid=714&mid=1646&language=en-US [Accessed 4 February 2011].

Lubienski, S. T., Robinson, J. P., Crane, C. C. & Ganley, C. M. (2013). Girls' and boys' mathematics achievement, affect, and experiences: Findings from ECLS-K. *Journal for Research in Mathematics Education*, *44*(4), 634-645.

MacGregor. D. (2013). *Developing mathematical proficiency*. EPS, Literacy and Intervention, Academy of Math.

McGraw, R., Lubienski, S. T., & Strutchens, M. E. (2006). A closer look at gender in NAEP mathematics achievement and affect data: Intersections with achievement, race/ethnicity, and socioeconomic status. *Journal of Research in Mathematics Education*, *37*, 129-150.

National Assessment of Educational Progress. (1999). *The nation's report card*. Retrieved January 18, 2010, from http://nces.ed.gov/nationsreportcard/pdf/main1996/1999452.pdf

National Council for Curriculum and Assessment (2014). *Mathematics in early childhood and primary education (3–8 years).* Research report No.18, 35 Fitzwilliam Square, Dublin 2.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (2001). *Adding it up: Helping children learn mathematics.* J. Kilpatrick, J. Swafford, and B. Findell (Eds.). Mathematics Learning Study Committee, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press. Retrieved from http://www.nap.edu/catalog/9822.html.

OECD (2004). *Learning for tomorrow's world – first results from PISA 2003.* Paris: OECD. [Online] Available at: http://www.oecd.org/dataoecd/1/60/34002216.pdf [Accessed 7 February 2011].

Ogunkunle, L. A. (2007). Effects of gender on mathematics achievement of students in constructivist and non-constructivists groups in secondary school. *ABACUS, Journal of Mathematical Association of Nigeria, 32*(1), 41-50.

Ostler, E. (2011). Teaching adaptive and strategic reasoning through formula derivation: beyond formal semiotics. *Sutra: International Journal of Mathematics Science Education*, *4*(2), 16 – 26.

Ozofor, N. M. (2001). *Effect of two modes of computer aided instruction on students' achievement and interest in statistics and probability*. Unpublished Ph.D. Thesis, University of Nigeria, Nsukka, Nigeria.

Pajares, F. & Graham, L. (1999). Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. *Contemporary Educational Psychology*, *24*, 124-139.

Perie, M., Moran, R., & Lutkus, A.D. (2005). *NAEP 2004 trends in academic progress three decades of student performance in reading and Mathematics.* Washington D. C. National Center for Education Statistics.

Samuelsson, J. (2010). The impact of teaching approaches on students' mathematical proficiency in Sweden, *International Electronic Journal of Mathematics Education, 5*(2), 61-77.

Shafer, M., & Romberg, T. (1999). Assessment in classroom that promote understanding. In E. Fennema & T. Romberg (Eds.), *Mathematics classroom that promote understanding* (pp. 159-184). Mahwah, NJ: Erlbaum.

Siegfried, J. M. (2012). *The hidden strand of mathematical proficiency: defining and assessing for productive disposition in elementary school teachers' mathematical content knowledge.* An unpublished PhD Thesis, University of California, San Diego and San Diego State University, USA.

Vale, C. (2009). *Trends and factors concerning gender and mathematics in Australasia.* Retrieved from http://tsg.icmell.org/document/get/169.

Wu, Z. (2008). Using the MSA model to assess Chinese sixth graders' mathematics proficiency. *Journal of Mathematics Education*, *1*(1), 74-95.

Wu, Z. & An, S. (2008, July). *Using the model-strategy-application approach to developing pre-service teachers' knowledge and assessing their progress in math methods courses.* Paper presented at 11th International Congress on Mathematics Education. *Monterrey, Mexico*.

Wu, Z. & An. S. (2007, January*). Sharpening teaching ability in mathematics classrooms.* Paper presented at Association of Mathematics Teacher Educators (AMTE) 11th Annual Conference. Irvine, CA.

Yackel, E. & Cobb, P. (1996). Socio-mathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education 27* (4), 458–77.

Yackel, E, Cobb, P. & Wood, T. (1991). Small-group interactions as a source of learning opportunities in second-grade mathematics. *Journal for Research in Mathematics Education 22* (5), 390–408.

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Appendix I. Mathematics Productive Disposition Inventory

S/N	ITEMS	SA	A	D	SD
1	**Affect** I enjoy learning mathematics				
2	I enjoy problem solving in mathematics				
3	I feel happy when asked to complete a difficult mathematical task				
4	**Beliefs** Mathematics is only meant for people with mathematical mind				
5	I should be able to solve a mathematics problem within a few minutes				
6	Mathematicians are engaged in problem solving when they do mathematics				
7	**Identity** There is a turning point in my life that made me look at mathematics differently				
8	I feel as though my mathematical experiences are steady or more like a roller coaster				
9	I have both low and peak experiences in mathematics				
10	**Mathematical Integrity** I check the solution to know when I have satisfactorily completed a problem				
11	I know when I cannot solve a mathematics problem				
12	Understanding mathematics problem is the most difficult part of problem solving				
13	**Risk Taking** I feel comfortable asking questions about someone else‘s solution to a mathematical problem				
14	I am willing to share new ideas in mathematics, if, in doing so, I may expose mistakes I made				
15	I feel most certain about my solution to a mathematics problem				
16	**Goals** I like trying/learning new things in mathematics or doing more of things I can do already				
17	Effort plays a part in my learning of mathematics				
18	My goal in mathematics is to get a better grade than most of the other students				
19	**Motivation** I am curious about discoveries in mathematics				
20	Learning mathematics makes my life more meaningful				
21	I find mathematics tasks very challenging				
22	**Self-efficacy** I feel confident about solution to the mathematical problem 5x+4=0				
23	I am confident about my own mathematical abilities				
24	I am confident I will do well on mathematics test				