



An Overview of Empirical Research on the Impact of Gender, Word Problems, and Item Differential Functioning on Students' Mathematics Achievement

P. A. U. Ossai
Department of Guidance and Counselling
(Measurement and Evaluation),
Delta State University, Abraka

ABSTRACT

The progress and advancement within the realm of science and technology are intricately intertwined with the discipline of mathematics. The effective teaching and learning of mathematics have been influenced by various factors, as extensively discussed in existing literature. This review specifically addresses the concepts of Item Differential Functioning (DIF), word problems, and gender, and their interconnectedness with students' achievements in mathematics. The examination of students' achievement concerning gender reveals a lack of consistent trends. At times, achievement favors either male or female students; however, in many instances, the gender-based differences are not statistically significant. The challenge of word problems in mathematics presents obstacles for students, contributing to their struggles in the subject. Furthermore, students' subpar performance in mathematics can also be attributed to Item Differential Functioning (DIF). To foster equitable learning environments, it is crucial for teachers to ensure that both genders are equally engaged and included in mathematics classes. The teaching and assimilation of word problem-solving skills should ideally commence during foundational levels of education. Lastly, educators should be vigilant in assessing students' response patterns to mathematical test items, particularly to identify instances where Item Differential Functioning may be influencing the results among specific groups of test-takers. By comprehensively addressing these aspects, educators can contribute to enhancing mathematics education, promoting gender equity, and facilitating better achievement for all students.

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INTRODUCTION

Mathematics plays a crucial role in science and technology. Ossai (2020) noted that one of the measures that should be taken to foster growth in science and technology is placing emphasis in the teaching and learning of mathematics. It can therefore, be inferred that the key to national growth depends on science, technology and mathematics.

For some time, students' performances in mathematics have not justified the government's enormous efforts aimed at improving the teaching and learning of the subject. For instance, Asuru (2019) reported that for ten years (2009-2018) only in 2016 and 2017 did students' credit passes in mathematics

exceed 50%. Researchers (Madu, 2012; Udonsa, 2015; Fuadiah, et al, 2017) have identified gender, inadequate foundation, and class size, teacher-related factors as some of the challenges confronting the teaching and learning of mathematics in our educational institutions.

This present work concentrated on the review of gender word problems in mathematics and item differential functioning, status as they relate to students' achievement in mathematics.

Gender Issues in Mathematics

As regards gender and students' achievement in mathematics, reports from

*Corresponding author: Ossai, P. A. U.

✉ aqbadobipeter@gmail.com

Department of Guidance and Counselling, Delta State University, Abraka.

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researchers have been inconsistent (Ossai, 2023). While some studies Patel (2012) Pandei (2017) and Ezeudu (2008), as cited by Elejere, et al. (2018) show significant results in favour of males or females, others Ugwuanyi et al. (2018), Iwendi (2012), Kolawole and Ajetumobi (2014) reported studies that were not significant.

Some studies that showed significant results were conducted by Pandey (2017), Elejere, et al. (2018) and Ossai (2020) Pandei (2017) examined mathematics achievement of secondary. A sample of 243 was randomly selected from government and private secondary schools. The study was guided by four hypotheses. The mean, standard deviation and t-test technique were used in the data analysis. At .01 level of significance, the study showed a significant difference in the mathematical achievement of male and female students. Male students did better than their female counterparts. One of the shortcomings of the study is the size of the sample. Perhaps a larger sample size would have produced a different result.

Likewise, Elejere, et al. (2018) analysed gender disparity in students' performance in mathematics and physics in West African Senior School Certificate Examination (WASSCE). The study adopted an ex-post facto research design to cover the period of 2014-2016. A sample size of 1060 students was randomly selected from all the public secondary schools in Naukka Local Government Area of Enugu State, Nigeria. The scores collected from the different schools were analysed using mean, standard deviation and t-test statistical tools. The study showed significant differences in the mean performances of male and female students in mathematics and physics in 2014-2016 WASSCE. The significant difference was in favour of male students. It was recommended that teachers of both subjects should encourage active female participation in the learning of the two subjects. This study used the same statistical tool as did Pandey (2017). The only difference is the level of significance which was .05.

Also, Ossai (2020) examined gender differentials in mathematics using item difficulty index. An ex-post facto research design was adopted. A sample size of 140 students (70

males and 70 females) was randomly selected from final year students of government-owned secondary schools in Delta and Edo States. The research participants responded to the objective test items in mathematics administered by the West African Examinations Council (WAEC) in May/June 2010. Mean and percentage were used to answer the research questions while the t-test statistics was used to test the hypotheses. The study showed a significant difference in the mean item difficulty on the basis of gender. The mathematics test items were more difficult to female students. It was recommended that mathematics teachers should make efforts to identify students' pattern of responses to mathematics test items so as to know the group of test-takers that need special attention. Ossai's study differs from the ones already reviewed in the sense that item difficulty indices were used instead of raw scores.

It appears that the studies reviewed paid little or no attention to the affective qualities. This is an integral part of continuous assessment. Ossai (2014), Ossai (2013) and Ossai (2023) stressed the need for examination scores to be reported to reflect the all-around development of learners.

The review on gender/sex and students' achievement in mathematics has no clear direction. Significant results can be in favour of any of the sexes. Slight improvement can also be associated with any of the genders.

Word Problems in Mathematics

It appears that solutions to plain mathematics problems seem easier to provide unlike word problems in mathematics. For example, the task " $2x-1, =19$ " can easily be solved to produce the answer " $x=10$ ". However, if the same task is framed thus: the difference between two times a certain number and one is nineteen, it becomes a little difficult to translate it into simple algebraic form as already stated.

The West African Examination Council (WAEC) Chief Examiner's Report (2017, 2018, 2019 & 2020) showed, among others, that candidates had challenges with algebraic expressions and word problems. This observation is similar to Gardenia, Sherman, Juandi, Dablan and Kandaga (2020) who examined the mathematical communication abilities of class VIII students and the errors made by students when solving linear equations

*Corresponding author: Ossai, P. A. U.

✉ aqbadobipeter@gmail.com

Department of Guidance and Counselling, Delta State University, Abraka.

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that involve two variables. Students were expected to translate mathematical ideas into language and symbols. The study showed that students with low mathematics skills did poorly compared to those with medium mathematics skills.

Other studies on mathematics and word problems were conducted by Dayal and Chandra (2016), Boone, et al. (2016) and Ossai (2020). Each of the studies was reviewed as follows, Dayal and Chandra conducted a study on primary school teachers' skills in solving word problems in mathematics. The aim of the study was to. Find out whether in service primary school teachers apply real world knowledge in solving word problems in mathematics. Thirty four in service teachers enrolled in a primary mathematics teaching methods course at a Fijian University participated in the study the teachers responded to some exercises in mathematics word problems after face-to-face workshop sessions. The first word problem was termed "nonesensical" while the other two contained some technical errors. Findings from the study suggest that in service primary school teachers do not apply real world mathematical knowledge when solving word problems. The scholar in this study admitted that the result of this investigation has some limitations. One of them is the smallness of the sample size while the other is the language skill of the research participants who used English as a second language.

Ossai (2020) examined relationship between students' scores on plain questions and worded problems in mathematics. The purpose of the study was to correlate students' scores on plain questions and scores on worded problems. The correlational study had a sample size of 122 final year senior secondary school students in Bayelsa and Delta States, South-south Nigeria. Two research questions and one null hypothesis guided the study. Ten mathematics questions were adopted from mathematics paper or paper 1 from 2009, 2010 and 2011, conducted by the West African Examination Council (WAEC). The May/June WAEC-conducted examination is meant for students enrolled for the West African Senior School Certificate Examination (WASSCE). Arithmetic, algebra, statistics, trigonometry and geometry were covered in the study. The ten

mathematics questions were in two parts, namely, five plain questions and five word problems. Thus, each subject in the study responded to plain questions and word questions, consequently, there were two sets of scores, one from plain questions, the other from word questions. The two sets of scores obtained by research participants were correlated using the product moment correlation statistics. The analysis showed that there was no significant relationship between students' scores on plain questions and word questions. Thus, students found it difficult to attempt word questions in mathematics. The mean scores by the students was higher on plain questions, compared to word questions. This trend is consistent with what exists in the literature earlier reviewed. Perhaps, students' scores in Ossai's study must have been affected by the covid pandemic. Ossai et al. (2020) reported that the covid pandemic disrupted academic activities across the globe.

Boonen, et al. conducted a study on Word Problem Solving on Contemporary Mathematics Education. Data were collected from 80 Dutch sixth-grade students from eight elementary schools in the Netherlands. There were 42 boys and 39 girls. Their mean age was 11.72years. The participants were classified into two groups, namely, 41 less successful word problem solvers and 39 group of successful word problem solvers. A test used contained mental arithmetic, complex applications, measurement and geometry. The test was word problems in mathematics. Analysis of variance ($2 \times 2 \times 2$) was used to analyse the responses made by the research participants. The result showed that successful problem solvers did not show a higher problem solving performance than less successful problem solvers. However, successful problem solvers had the upper hand in the test scores. This was primarily because of their ability in reading comprehension. The authors recommended that skills in reading comprehension should be given emphasis during problem solving instruction. It should be noted that the study was silent on performance based on sex even though the sample was made up of both sexes.

Item Differential Functioning and Students' Achievement in Mathematics

*Corresponding author: Ossai, P. A. U.

✉ aqbadobipeter@gmail.com

Department of Guidance and Counselling, Delta State University, Abraka.

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Another factor that can affect students' responses to mathematics test items is differential item functioning. Odili (2013) as cited by Ossai (2015) posited that differential item functioning is a psychometric condition in which a test item presents differential difficulty to testees of the same subject matter ability simply because they come from different sub-population of test takers.

Some scholars have conducted researches on differential item functioning with reference to students' responses to mathematics. One of such studies was conducted by Madu (2012). Madu (2012) researched on gender-related differential item functioning in mathematics multiple choice test items. The test items were used by the West African Examinations Council (WAEC) Final year students numbering 1671 were drawn from Nsukka Local Government Area of Anambra State, South-east Nigeria. The research participants were made to respond to 50 multiple choice test items in mathematics organised by WAEC in May/June, 2011. The study showed that 39 items functioned differentially with respect to gender.

Liu (2017) studied differential item functioning in large scale mathematics assessment. The study was aimed at comparing the capability of the Rasch Model to Traditional Approaches. The sample consisted of 731 U. S. Eight Grade students that took the 2011 Trends of International Mathematics and Science Study (TIMSS) mathematics assessment. According to the author, the Rasch Trees model allows researchers to identify DIF using the reference and final groups that are not pre-specified but may emerge as a result of the combinations of the observed covariates using variables chosen for comparison. The results showed that the Rasch Trees model exhibited the same capability to detected DIF items in comparison with logistic Regression and the Rasch measurement mode. Besides, a significant DIF related to ethnicity was detached using the Rasch Trees mode. The study concluded that DIF could be associated with students' ethnic background, not only gender, as widely reported in literature.

Gyamfi (2023) examined differential item functioning of performance-based assessment in mathematics for senior high schools (SHS) in Ghana. The study was aimed

at validating performance-based assessment in mathematics (quantitative reasoning) for senior high schools for differential item functioning (DIF). The study used descriptive research design embedded in the Graded Response Model (GRM) of item response theory (IRT). A multi stage sampling technique was used to sample 750 SHS students from a population of 7498 SHS students in the Western Region. Three categories of schools (A,B and C) were used. A quantitative test consisting of reasoning items developed by the researcher was used in the study. The items were meant to assess the proficiency of students in transformation, descriptive statistics, measurement, geometric construction and linear equations. The selected students took a performance-based test. The responses were scored by three WAEC examiners. Research questions were answered using the Graded Response Model (GRM) of the IRT. The winGen software was used in analysis of data. A multi multivariate test and a t-test statistical tools were also used. Analysis was done on the basis of gender and school category. DIF was found only in linear equations item. This was associated with school categories A and C. The use of performance-based assessment was recommended for use in both colleges of education and universities.

From the review, it is apparent that the widely reported factors (gender, location, SES, admission mode, etc) are not the only challenges students face in the learning of mathematics. DIF band word problems in mathematics are other crucial areas. It should be noted that detecting items differentially among examinees is not enough. Efforts should be made to accommodate guessing and also check skewness in test scores (Ossai, 2016; Ossai & Enwefa, 2020).

Summary (Highlight)

Students' achievement on the basis of sex or gender has no clear direction. Significant or non-significant result can be associated with any of the sexes.

Plain problems in mathematics are easier to solve compared to word problems. Both young and adult learners find word problems in mathematics challenging. This is an area in mathematics that teachers should give special attention to.

*Corresponding author: Ossai, P. A. U.

✉ aqbadobipeter@gmail.com

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Item differential functioning in mathematics is a product of IRT. Students' can perform poorly in mathematics test items because the items do not function properly among different groups of test-takers. Teachers, need to check the pattern of students' responses to test items in mathematics and take appropriate steps.

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*Corresponding author: Ossai, P. A. U.

✉ agbadobipeter@gmail.com

Department of Guidance and Counselling, Delta State University, Abraka.

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*Corresponding author: Ossai, P. A. U.

✉ aqbadobipeter@gmail.com

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