

An analysis of pre-service mathematics teachers' performance in algebraic expressions

Abstract

The purpose of the study is to analyze the level of performance of some pre-service teachers in algebraic expressions as well as to ascertain the difficulties they undergo when solving algebraic expressions in Ghana. A sequential explanatory mixed method design was employed in the study. An algebraic expressions diagnostic test, and a semi-structured interview were the instruments used in the study. Ninety-five (95) pre-service mathematics-related teachers who offer specialized course in junior high school mathematics and science, and junior high school mathematics and ICT were sampled through a purposive sampling technique for the study. It was discovered that the participants perform below average in the test. A very high percentage error of 77.8% was recorded by the participants in the study. The overall mean and standard deviation for the test were 42.72 and 13.12 respectively. From the result, it was revealed that there is no statistical difference in performance between males and female pre-service mathematics teachers in algebraic expressions. Based on the findings, the researcher recommends that there should be comprehensive professional development services and support for pre-service teachers (PSTs) in algebra. Again, it is recommended that females should be encouraged to partake in science and mathematics related courses and programs.

Keywords: algebraic expressions, mathematics teachers, mathematics performance, pre-service mathematics teachers

Volume 8 Issue 2 - 2024

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Received: January 11, 2024 | **Published:** March 26, 2024

Introduction

Nearly every aspect of human existence incorporates mathematics, hence its significance in our daily life cannot be neglected.¹ In the curriculum of the schools in our nation (Ghana), mathematics is a required subject from preschool to higher school, various disciplines are studied at all levels. Mathematics continues to be a crucial subject in the majority of programs in colleges and universities. Learners must comprehend and grasp the fundamentals of computation to master the subject of mathematics. Mathematics is a subject that cuts across all levels of education in Ghana. It is central to the scientific progress and development of any country in the world.² Students need to have a creative imagination to study mathematical challenges because mathematics is not just about logic. Mathematics serves as a tool to sharpen the mind and improve thinking and problem-solving skills; therefore, mathematics is an integral part of the knowledge toolkit and it is central to intellectual development.^{3,4,5} All the descriptions above showed how essential mathematics is across all level of education.

One key reason for teaching mathematics is to help students acquire skills for practical life. Unfortunately, in most cases, students perceived mathematics, most especially algebra inapplicable due to their inability to relate the x's and y's in their everyday life.⁶ Most students believe that the study of algebra by students is done in more abstract and symbolic ways, putting emphasis on understanding and using variables, expressions, and equations in middle schools. For this reason, most pre-service teachers regard algebra as one of the most challenging aspects in mathematics. This contributes to them having difficulties performing tasks in algebraic expressions. Algebra is one of the major aspects of mathematics which is done to promote the acquisition of school mathematics skills and knowledge.^{7,8} One of the main areas in mathematics that challenge students' abilities and drive them to use logical reasoning is algebra. With an emphasis on the use of symbols to describe equations and build links in mathematical operations, emphasis on algebra allows pupils to concentrate on

arithmetic processes.⁹ Makonya,¹⁰ asserted that aside from arithmetic, it is important for one to have a good background in algebra to understand many key mathematical concepts in science, statistics, commerce, and modern technology. Algebra is very significant to the study of mathematics and for that matter, a weak foundation in algebra will practically lead to a poor performance in mathematics.¹¹

However, studies have revealed that students in pre-tertiary schools have challenges in solving basic algebra.^{5,12,13} Although it is a matter of fact that basic concepts in algebra are introduced at the basic and secondary school levels, some students, including pre-service teachers have difficulties in understanding algebra due to the claim that it does not have any direct relation to them as compared to the other branches of mathematics.⁶ The subject matter being taught, local and state curricular policies, and student learning characteristics all contribute to the context of teaching and learning, which is essential for teachers' understanding of mathematics is a teaching tool and their application of it in the classroom.^{14,15} The knowledge a teacher possesses in the teaching of algebra goes a very long way to affect learners' algebra content knowledge, hence having impact on their general performance in mathematics.^{16,17} Education stakeholders are quite concerned about how future teachers in Ghana's colleges of education perform in algebra. The subject matter of an algebraic thinking problems success is made up of immeasurable components and being conscious in solving mathematics problems.¹⁸ The learning of mathematics is influenced by aspects related to students, teachers, and schools.¹⁹ The Chief Examiner's Report²⁰ for senior high school mathematics, has stated that, among other topics, most students have weaknesses in the following areas: story problems in mathematics, variations, binary operations, logarithms, and calculus. These are algebra-related areas. The report further has it that to solve work/story problems, students find it challenging to translate them into mathematical statements,²¹ and have shown weakness in using algebra to solve probabilities.²² Almost all the tertiary students in Ghana took

part in the examinations conducted by the West Africa Examination Council (WAEC). In Marpa's⁶ study on pre-service teachers' algebraic expressions, pre-service teachers have an average performance in algebraic expressions.

According to him, one major error of pre-service teachers' is their difficulty to classify polynomials according to degree and translate mathematical phrases into symbols. Considerable study has been done on how well pre-service mathematics teachers comprehend and instruct algebraic expressions. Numerous research has looked at pre-service teachers' pedagogical content knowledge in relation to using algebra tiles. Furthermore, studies have concentrated on pre-service teachers' preliminary algebraic understanding at the start of their programme.²³ Teachers of mathematics and IT have many of the same challenges, especially when it comes to integrating technology into the classroom. The degree of teacher proficiency with technology, uneven access to educational resources, and a lack of training and knowledge about technology use are some of the challenges that mathematics teachers may face when integrating technology into mathematics instruction.²⁴ Furthermore, addressing the intricacy of the curriculum and integrating technology into the classroom are difficulties for mathematics teachers.²⁵ However, students' inability to comprehend technology-based issues and their lack of proficiency with instructional strategies might provide difficulties for IT teachers.^{26,27} To guarantee successful teaching and learning, these obstacles must be addressed by both sets of instructors.

All mathematics teachers have similar challenges when it comes to subject matter expertise, classroom management, transitioning to the teaching profession, beliefs about learning and teaching, pedagogy and content knowledge, time for reflection, prerequisite knowledge, connecting mathematics to real-world applications, adjusting to different teaching styles, managing absences, grading, and taking on the rigorous mathematics curriculum Top 5 Challenges of Being a Maths Teacher and How to Overcome Them | Trade wind Recruitment.^{27,28} Mathematical comprehension issues, a lack of foundational math knowledge, student preparedness, teachers' pedagogical approaches, and the accessibility of resources for teaching problem-solving strategies are just a few of the difficulties faced by mathematics teachers, according to Ghana.^{26,29}

In Ghana, the Chief Examiner's assessment as cited by Asiedu,¹⁹ from the Institute of Education, University of Cape Coast, stated that students' performance in college algebra courses was appalling at the end of the first semester of the 2018/2019 academic year. According to the report, the mean scores for algebra I (12.46%) and algebra II (12.45%) have large standard deviations. The focus of this study therefore was to analyze the level of performance of pre-service mathematics teachers in some selected algebra topics which are treated in the basic schools of Ghana.

Problem statement

Although studies have been conducted on students' performance levels in Ghana, there is no enough studies that analyzed the performance of pre-service teachers' in basic school algebra in Ghana. Hence, this study was conducted to analyze pre-service teachers' performance in basic schools' algebraic expressions topics in the Bagabaga College of Education, Ghana.

Research objectives

The objectives for the study are as follows:

To ascertain the level of performance of pre-service teachers in algebraic expressions.

To determine the challenges pre-service teachers face when solving algebraic expressions

Determine if there is a statistical difference in performance among males and females pre-service teachers in algebraic expressions

Research questions/ hypothesis

The following questions guided the study:

What is the level of performance of pre-service teachers in solving algebraic expressions?

What challenges do pre-service teachers face when performing a task on algebraic expressions?

Ho: There is no difference in performance among male and female pre-service teachers in algebraic expressions.

Literature review

The area of mathematics known as algebra is concerned with how to express mathematical issues. One of the main mathematical subjects used to encourage the acquisition of information and abilities in school mathematics is algebra.⁷ It is the interplay between numbers, operations and variables.¹ Algebra is one of the branches of mathematics which uses letters and symbol to represent figures and quantities.³⁰ In Ghana, algebra is covered at every educational level, from primary school up to postsecondary education. Algebraic expressions, linear equations, relations, mapping, and functions are only a few of the subjects covered in the Basic school's algebra curriculum. Higher mathematics topics like Geometry, Trigonometry, Calculus, and even Statistics are thought to be built based on Algebra. Algebra is very significant to the study of mathematics; for that matter, a weak foundation in algebra will practically lead to poor performance in mathematics.¹¹ Algebraic expressions are one of the important aspects of basic school curriculum mathematics. In the basic schools for instance, algebraic expressions are taught throughout all levels junior high school (JHS) 1 through JHS 3). It can be found in almost all fields of mathematics. Algebraic expressions in the basic schools have no much difference from the senior high topics. Topics such as factorization, substitutions and change of subjects, linear expressions, patterns, etc are all considered as algebraic expressions. It is anticipated that after studying these algebraic concepts in their mathematics classes, basic school students would possess at least the fundamental algebraic knowledge and abilities required at their level and will be better prepared for future mathematics courses in higher educational institutions.

Algebra has received a lot of attention due to its fundamental significance, numerous applications, and ramifications in elementary school mathematics and higher mathematics.¹ The depth and breadth required in algebra are demonstrated by the list of topics included in the mathematics curriculum for secondary schools in Ghana. Algebraic expressions 1 and patterns and sequences are the topics covered in Form 1 (Senior High School/Senior High Technical School); algebraic expressions 2 (with two or more unknowns); linear equations 1 (with one variable); Patterns and sequences; and algebraic formulae; linear equations 2; linear inequalities and graphs of functions; quadratic expressions and equations; and the straight line (linear function); (Ministry of Education, 2012). In the colleges of educations in Ghana, College Algebra 1 & 2 which consist mainly on basic and senior high school algebra are done. The main rationales for these courses is to help refresh or revise pre-service teachers' basic algebraic concepts in mathematics. Algebra consists of variables, while algebraic expressions contain variables, constants, and

operations (mathematical) symbols such as add, minus, multiply, and divide.^{31,33,34} One may ask, “Why algebra?” Algebra is very significant in so many aspects, for example in businesses, algebra can be used to determine the finances, which includes the annual expenses. Algebra has been utilized by several retailers to forecast the demand for a specific product and then place their purchases. Additionally, there are personal uses for algebra such as calculating annual taxable income, bank interest, instalment payments, and mortgages.

In arithmetic (mathematics), we often apply operations to numbers and acquire results after each operation; in contrast, while addressing an algebraic problem, we typically do not start by using the given numbers, performing computations with them, and then obtaining a numerical answer. To make sense of algebraic expressions and how to manipulate them, research in the area of teaching and learning algebra has shown how crucial it is to comprehend the structure of arithmetic expressions.¹⁹ Transition from arithmetic to algebra is difficult for students because the development of symbol sense has given too little explicit attention in current algebra education.³⁵ When it was believed that students had mastered the essential arithmetic skills, algebra was usually introduced. In addition, algebra has typically been developed independently of arithmetic without benefiting from their close relationship.

Methods

A sequential explanatory mixed-method design was employed in the study. This design distinguishes itself by collecting quantitative data, analyzed it before collecting and analyzing the qualitative aspect.³⁶ Data was analyzed using both descriptive and inferential statistics. The population of the study comprised pre-service teachers of Bagabaga college of Education which was made up of one thousand

nine hundred and eighty-six students. A total of 95 pre-service teachers offering JHS mathematics and science, and JHS mathematics and ICT were purposively sampled for the study. This method was appropriate at this stage because it allowed the researcher to assess the trainees with the requisite knowledge for assessment.

Results and discussions

Table 1 shows the mean and standard deviations of pre-service teachers' in the various competencies. The means and standard deviations for the various competencies shows the level of performance of PSTs in the various competencies in algebraic expressions. Section C (substitution and change of subjects) has the highest mean of 12.85 with a standard deviation of 5.19. Section D (factorization) recorded the lowest performance with a mean of 7.12 and a standard deviation of 4.00. This shows that a lot of PSTs has difficulties in algebraic factorizations. The other sections recorded a mean of 10.78 and 11.98 in Section A and Section B respectively. These means simply show that apart from Section C, where participants scored slightly above the average marks, and their performance in the other three competencies were below average (Tables 1&2).

Table 1 How participants performed in each aspect of the test

Competences	Mean	Standard deviation
Translation of algebraic word problem	10.78	5.23
Simplification of algebraic fractions	11.98	5.28
Substitution and change of subjects	12.85	5.19
Algebraic factorizations	7.12	4
Overall	42.73	13.16

Table 2 How participants performed in each question

Question number	Attempted		Correctly answered		Wrongly answered	
	Number	Percentage	Number	Percentage	Number	Percentage
1	93	97.89	25	26.88	68	73.12
2	94	98.95	19	20.21	75	79.79
3	82	86.32	21	25.61	61	74.39
4	41	43.16	0	0	41	100
5	79	83.95	16	20.25	63	79.75
6	81	85.26	17	20.98	64	79.01
7	83	87.37	11	13.25	72	86.74
8	83	87.37	26	31.33	57	68.67
9	85	89.47	19	22.35	65	76.47
10	67	70.53	15	22.39	52	77.61
11	91	95.79	30	32.97	61	67.03
12	76	80	20	26.32	56	73.68
13	85	89.47	22	25.88	63	74.12
14	63	66.32	18	28.57	45	71.43
15	59	62.11	13	22.04	46	77.97
16	36	37.89	3	8.33	33	91.67
17	45	47.37	8	17.78	37	82.22
18	17	17.89	3	17.65	14	82.35
19	15	15.79	4	26.67	11	73.33
20	34	35.79	8	23.52	26	76.45

From Table 2, no participant was able to answer question number 4 correctly. The question with the list percentage error was question number 11, having a percentage error of 67%. It can be deduced from Table 2 that the mean percentage error of participants in the study was 78.29%. This high percentage error shows how poorly participants performed in the study (Table 3).

Table 3 shows that on average of 78 pre-service teachers (PSTs) attempted the word problems and as many as 61 of them could not answer the questions correctly therefore having a percentage error of 81.4%. 80 PSTs attempted questions involving algebraic fractions with 62 of the participants committing errors in the process, therefore causing a percentage error of 77.7%, on the aspect of substitution and change of subjects, 75 PSTs attempted it with 54 of them committing errors in the process therefore leading to a percentage error of 72.8%, the last component of the test was on factorization. This aspect was the least attempted. On average, 29 PSTs attempted the questions of which 24 of them committed errors in the process making it a percentage error of 81.2%. From the table, out of the 95 participants who took part in the test, an average of 65 PSTs attempted all the questions with an average of 50 PSTs committing errors in the process. The

overall mean percentage error therefore was 78.29%. This shows that the performance of pre-service mathematics teachers in the test was very poor. These results from the participants supports the claim made by Zapatera & Quevedo,²³ on a similar study on pre-service teachers performance in algebra. From their findings, pre-service teachers' had no knowledge of algebra from their high schools. Similar findings was also made by Marpa,⁶ on the level of performance of pre-service teachers in algebraic expressions. On the part of word problems in algebraic expressions, similar claims were which revealed that students have low level of performance in word problems.⁷ The results on word problems shows that PSTs had a mean percentage error of 81.4% this finding is similar to the finding made by Marpa,⁶ which revealed that pre-service teachers had a mean percentage error of 84.84% in word problems. On the other hand, this finding is in contrast with Owusu,³⁷ which revealed that pre-service teachers have a relatively low percentage error (37.7%) in word problems. Most PSTs perform poorly in the algebraic fractions part. Similar finding was revealed by Son and colleagues.⁵ According to Son and colleagues,⁵ this occur as a result of the student lacking or having inadequate knowledge of numerators and denominators therefore not knowing how to apply the operational signs on them (Table 4).

Table 3 Summary of performance

Competencies	Mean attempted	Mean error	Mean percentage error
Word problems	77.8	61.6	81.4
Algebraic fractions	79.8	62	77.7
Substitution and change of subjects	74.8	54.2	72.8
Factorization	29.4	24.2	81.2
Overall	65.45	50.5	78.29

Note: The mean percentage error is interpreted as follows: 0.00 – 20.00 (Very Low); 20.01 – 40.00 (Low); 40.01 – 60.00 (Average); 60.01 – 80.00 (High); and 80.01 – 100.00 (Very High)

Table 4 Independent sample t-test comparing the performance of males and female's pre-service teachers in algebraic expressions

Levene's test for equality of variance		F	Sig.	T	Df	Sig(2-tailed)	Mean difference
Scores obtained by PSTs in algebraic expressions	Equal variances assumed	0.04	0.842	0.164	93	0.87	0.53475
	Equal variances not assumed			0.166	33.018	0.869	0.53475

From Table 4 the significant value is 0.842 and the alpha value is 0.05 this implies that the significant value is greater than the alpha level and based on this, the t-value for the column labelled "equal variances assumed" is chosen. More so, the significant (2-tailed) value is 0.870 which means that it is greater than the alpha level of 0.05; hence there is no statistically significant difference in performance in algebraic expressions for male and female pre-service teachers. From the t-test males (mean = 42.61, SD = 13.31) do not have higher performance in algebraic expressions than females (mean = 43.14, SD =12.93); $t(93) = 0.164, P = 0.870(2\text{-tailed})$. From the figures displayed in Table 4.11, there is no statistical significant difference in the performance of males and females PSTs in algebraic expressions, therefore the researcher fails to reject the null hypothesis. This revelation contradicts the findings of earlier researchers,³⁸⁻⁴⁰ which revealed that males generally performed better in mathematics than females, this study revealed that there is no statistical difference in performance among males and females PSTs,⁴¹⁻⁴³ that males PSTs do not perform any better in mathematics than their females' counterparts.

Interview results for the challenges and reason why pre-service teachers perform poorly in algebraic expressions

From the interview, some pre-service teachers admitted that sometimes they find it difficult to comprehend certain questions. According to them, most of the algebraic word problem were always confusing them. They were unable to understand what the questions expect from them. According to one of the trainees coded (PST 1) when asked why he answer question numbered 4 wrongly: "I assumed that my mother is 12 years older than me even if my age is 2 times so for that matter I assumed that my age should be x". The interview results reviewed that most pre-service teacher's lack both the basic skills and procedural knowledge in solving algebraic expressions. Others also express challenges in dealing with algebraic expressions with higher powers. PST4 stated that "my algebraic expressions knowledge is very low when it has to deal with variables with high powers" he also added that "The powers maybe say a high power reducing to a low power so the..... I find challenges in solving that". Some also blamed the basic school teachers for not laying much emphasis on the topic. From the interview, the following challenges were outlined: difficulty in grouping like terms, lack of emphasis by the teachers, lack of procedural knowledge, inadequate knowledge of indices. The lack of basic concepts as listed above is one of the major challenges identified by the researcher. This issue was also revealed in an earlier study.⁹

Ncube,⁴⁴ in his classification of challenges faced by students in algebraic expressions, classified this issue as poor foundation in mathematics. According to him, this challenge is due to students having a weak foundation in mathematics. Most of the errors made by students in mathematics is caused by the lack of conceptual and procedural knowledge.³⁴ Another change which was identified is the lack of emphasis by the teachers. This finding agrees with earlier study conducted by Bautista.⁴⁵ Mathematics teachers are often in a hurry to complete the course outline or syllabus by so doing not really paying attention to the pace of their students. From the test solutions of the participants, grouping of like terms was identified as one of the challenges PSTs displayed. This revelation was also made by Marpa.⁶ From the interview, participants expressed challenges working with higher order of variables. They claim it confuses them when they find same variable with different powers. This finding is similar to what was revealed by Marpa.⁶ According to him, pre-service teachers have difficulty working with higher power of variables. Another challenge that was observed is language proficiency. Participants displayed poor communication skill during the interview session. This was revealed in earlier studies (Fatawu et al., 2023; Owusu et al., 2023). According to Owusu et al. (2023) deficiency in language serves as barrier in questions involving word problems.

Conclusion

The study essentially hinged on the notion that teachers' algebraic knowledge affects learners' performance in algebra and mathematics in general (Wilmot, 2016), and for a teacher to transmit knowledge adequately in the classroom, it depends on the level of knowledge acquired at his or her college level. Though the study concentrated on pre-service teachers of Bagabaga college of education in the Sagnarigu district in the northern region of Ghana with a specific focus on level 300 pre-service mathematics teachers' performance and challenges in algebraic expressions, the outcome of the study can be generalized with some inferences towards improving pre-service mathematics teachers' performance in basic algebra. The study concluded on the following findings: It can be concluded that the general performance of pre-service teachers in algebraic expressions is poor.

In particular, pre-service teachers' knowledge in algebraic word problems and factorization is very poor. The study has made it clear that pre-service mathematics teachers have below average performance in algebraic expressions. From the study, there was no statistical difference in performance in algebraic expressions between males and females' pre-service teachers'. The study has also brought to light the various challenges pre-service mathematics teachers undergo when solving algebraic expressions. Challenges such as background of the student, working with higher order of a variables, lack of procedural and conceptual skills, inability to translate algebraic word problems into mathematical equations and expressions, difficulty in finding Least Common Multiples (LCM) of numbers, grouping of like terms, among other challenges, were revealed from the study.

Recommendations

Based on the findings of the study, it is recommended that a comprehensive training and support in algebra for PSTs should be carried out in the colleges of education. Providing extensive training in algebra to future teachers is crucial. This training should not only cover the content (mathematics itself) but also effective teaching methods (pedagogy). Understanding both what to teach (content) and how to teach it (pedagogy) is fundamental to creating an engaging and effective learning environment. Therefore, to improve upon the performance of pre-service teachers in algebraic expressions, the

following should be considered; content knowledge development, pedagogical training, differentiated instructions. To reduce the challenges pre-service teachers, go through when solving algebraic expressions, it is recommended that a combination of targeted training, practical experiences, and support mechanism should be made available.

Implication of the study

To investigate pre-service teachers' knowledge level in algebraic expressions, the best variable to look at is the level of performance of pre-service teachers in algebraic expressions. There is the need for colleges of education tutors to take their time during lesson delivery because majority of the pre-service teachers' have a weak background in mathematics due to the previous schools (basic and senior high schools) attended. Basic and high schools' mathematics teachers should focus more on the use of real-life situations during algebra lessons delivery because students find it difficult to link most of the algebraic concept to real life situations therefore making them to have little or zero interest in algebra.

Acknowledgments

Data generated or analysed during this study are available from the authors upon request.

Authors contribution

Conceptualization, formal analysis – Isaac and Elawoe

Data curation – Isaac, Dennis and Elawoe

Methodology – Isaac and Dennis

Writing, review and editing – Isaac, Dennis and Elawoe

Validation – Isaac, Dennis and Elawoe

Investigation, visualization – Isaac and Elawoe

Original draft – Dennis.

Conflicts of interest

The authors declare no conflict of interest.

Funding

No funding was received for this study.

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