

Flawed Reasoning in Solving Algebraic Word Problems among Ghanaian Junior High School Pupils

Joseph Baidoo ^{1*}, Kingsford Bondzie²
University of Education, Winneba

Corresponding Author: Joseph Baidoo uewstudenttasks2021@gmail.com

ARTICLE INFO

Keywords: Word Problems, Flaws, Reasoning, Junior High School Pupils, Effutu

Received : 10, October

Revised : 26, October

Accepted: 11, November

©2024 Baidoo, Bondzie : This is an open-access article distributed under the terms of the [Creative Commons Attribution 4.0 International](https://creativecommons.org/licenses/by/4.0/).



ABSTRACT

Solving algebraic tasks can be a daunting experience for pupils, and this may lead to more reasoning flaws when the problems are presented in both words and numbers. This study explored the types of flaws evident in the reasoning patterns of Ghanaian junior high school pupils when solving algebraic word problems. The qualitative case study design involving 25 pupils was used. These pupils were purposively sampled to complete a teacher-made algebra test. The test data were analyzed thematically. Based on their written responses, it was found that the pupils' reasoning in solving algebraic word problems was flawed by seven different categories of errors. These errors included confusion between constants and variables, multiplication and exponents, equations and inequalities, sharing and subtraction, miscalculations, and the incorrect use of algebraic rules. The findings suggest that pupils' flaws stem from a lack of both conceptual and procedural fluency. The findings suggest that pupils' flaws stem from a lack of both conceptual and procedural fluency. Therefore, mathematics teachers should use more word problem tasks in their class exercises and homework.

INTRODUCTION

Algebraic word problems form an integral component of the 2019 standards-based mathematics curriculum in Ghana. It is required of teachers to teach pupils algebraic concepts such as forming expressions, performing operations on them, simplifying, factorizing, solving and graphing of linear equations involving binomials and fractions, inequalities, and performing change of subjects are emphasized. These concepts are taught from the junior high school level and continue into senior high school as a core aspect of mathematics (Ministry of Education, 2020). Indicator B7.2.2.1.1 of the curriculum requires that pupils at the junior high level be able to form algebraic expressions from mathematical and real-life contexts upon completing the strand, algebra with its sub-strand, algebraic expressions (Ministry of Education, 2020, p. 53). Similarly, upon completing sub-strand 3 (equations and inequalities) of the same strand, pupils should be able to translate word problems to linear equations in one variable and solve them using different approaches and activities (Ministry of Education, 2020, pp. 58-62). This knowledge of algebra is built upon in senior high school.

Despite the relevance of algebra to school mathematics, students struggle with it, citing it as very challenging (Jupri & Drijvers, 2016). Difficulties related to its multiple meanings of letters and variables, logic, translation to and from arithmetic forms have been reported. Specifically, word problems have been cited as very problematic among the aspects of algebra by researchers (Baidoo & Ali, 2023; James & Adewale, 2015). These challenges have resulted in many errors being committed by students in their quest to overcome the difficulties with algebra, especially algebraic word problems (Sarimanoğlu, 2019). Misconceptions are found in four parts of algebra, namely variables, algebraic expressions, algebraic equations, and story problems as reported by Egodawatte (2011). For instance, Chow and Treagust, (2013) report how students misconceive the plus (+) sign as the usual summation leading, to such errors as simplifying $3x + 4$ as $7x$ and $4 + 3x^2$ as $7x^2$. Similarly, Al-Rababaha, Yew and Meng (2020) found errors where students simplified expressions such as $(m + n)^2$ as $m^2 + n^2$, $2(x - 5)$ as $2x - 5$, $3y + 2$ as $5y$ and $3a + 2y$ as $5ay$. In explaining the possible causes of such errors, Herutomo & Saputro (2014) argue that students sometimes try to apply the procedures used in solving arithmetic problems to the solving algebraic problems.

In the context of Effutu, one of the municipalities in the Central Region of Ghana, statistics from the Examination Unit of the Effutu branch of the Ghana Education Service reveal that the pass rate for BECE performance from 2013 to 2018 is peaked at 54.2%. Pass rate for mathematics is also peaked at 40.5%, suggesting that junior high school pupils in the municipality consistently struggled with mathematics. In algebra, a study by Mills and Mireku (2016) in the Effutu Municipality found poor knowledge and a high difficulty in algebra and its related concepts among junior high school pupils, which could explain their inability to meet the national minimum standards set by the 2012 mathematics syllabus. In a recent study by Baidoo and Ali (2023), JHS pupils in Effutu were found to have serious difficulties when it comes to solving

algebraic word problems involving two context; real life and mathematical. Findings by Baidoo and Ali indicated that these lacked conceptual understanding of expressions involving algebra and this was more pronounced in tasks involving real-life context. Recognizing the importance of algebra in school mathematics and everyday life, the government and educators in Ghana have implemented policies to make the teaching and learning mathematics with algebra being a key aspect, more enjoyable and practical. As such the spotlight has been on literacy, numeracy, and technology as key features of the curriculum reforms (Anku, 2018).

Despite these efforts, algebraic learning in Ghana, specifically in the Effutu Municipality, has not been optimal. Several studies have been conducted on the errors made by pupils in algebra, particularly in senior high schools and other municipalities (Adu et al., 2015; Tuffour, 2015; Adu et al., 2017; Nashiru, 2018; Ibrahim & Yaw, 2019; Nashiru, 2018). However, these studies have only focused on the challenges faced by senior high school students and pre-service teachers. Moreover, studies examining the challenges faced by junior high school pupils in solving algebraic word problems are limited (Aforklenu, 2013). Considering the inclusion of algebraic word problems in the new mathematics curriculum for junior high schools, coupled with the wakeup call by NaCCA for a more realistic mathematics education aimed at fostering student innovation, creativity and problem-solving skills (NaCCA, 2019), there is a need for more studies in this area. Though a recent related study was conducted by Baidoo and Ali (2023), the researchers failed to come out clearly what the pupils' flaws were. Baidoo and Ali merely gave an analytical and statistical prove of the problem without pointing out from the pupils' scripts what errors flawed their performance and what could have been done instead. We argue that as much as Baidoo and Ali aimed to assess the pupils' ability in algebra, it was not enough to just report those abilities numerically. Instead, they should have pointed out what went wrong and what should have been done to enhance their performance in solving algebraic tasks. Again, the use of survey design limited their study in the sense that they could not explore further from the scripts what went wrong to gain a deeper understanding of the numerical data gathered.

Therefore, this current study aimed to bridge these research gaps in the earlier studies by exploring the flaws in reasoning exhibited by Ghanaian Junior High School pupils when solving algebraic word problems. It is hoped that a study of this nature will contribute to literature and enlighten teachers, policy makers about the strengths and weaknesses junior high school pupils in solving algebraic word problems, and what could be done in shaping the learning of this important aspect of mathematics. Specifically, the study sought an answer to the the research question, What types of flaws are evident in the reasoning pattern of Ghanaian junior high school pupils when solving algebraic word problems?.

LITERATURE REVIEW

Solving algebraic word problems can be cognitively demanding. The students need to translate the words into mathematical forms, devise a plan, apply them to solve, and finally, reflect on their final answers. These are stages of problem-solving as proposed by Polya (1945). However, since this study sought to examine the types of flaws in the reasoning pattern of pupils in solving these problems, the cognitive Load Theory deemed appropriate. The theory was used to understand how the mental effort used by students accounted for their errors and performance in algebraic word problems. The CLT was propounded by John Sweller in collaboration with Paul Ayres and Slava Kalyuga in the late 1980s. Three key issues are raised in the theory; Intrinsic Cognitive Load, Extraneous Cognitive Load, and Germane Cognitive Load.

The Intrinsic Cognitive Load (ICL) describes the complexity of the algebraic word problem given. Such a task involves multiple stages of finding unknown variables using different operations. Hence, the analysis of the errors helps to identify which of these stages posed the higher intrinsic cognitive load for the students.

The Extraneous Cognitive Load (ECL) talks about the aspect of word problem which are found in the presentation of the word problems, which also pose another cognitive load for students. This means the wording, structure, and correctness of the problem is also a problem on its own for students. Hence, by analyzing their errors, the researcher can understand the aspects like ambiguous phrasing, complex sentence structures, or inadequate information that contributed to the extraneous cognitive load of the students.

Lastly, the Germane Cognitive Load refers to the cognitive load brought by the efforts to devise an appropriate problem-solving strategy and procure to resolve the algebraic word problem. Using error analysis helped the researcher to identify the strategies students employ or the prior knowledge of algebra they fail to activate in solving algebraic word problems.

Hence by using the cognitive load theory, the researcher did not only gain insight into the knowledge of students for problem solving but also the specific cognitive processes that afforded or constrained their solving of algebraic word problems.

METHODOLOGY

This study followed a qualitative research approach using case study as its design. Yin (2017) argued that a case study is particularly appropriate when the researcher seeks to understand a phenomenon within its real-life context. The case study approach was chosen to gain an in-depth understanding of the thought processes and reasoning errors exhibited by the pupils junior High School pupils in solving algebraic word problems. In this study, the “case” was a group of 24 pupils, purposively sampled from a single Junior High School in the Effutu Municipality, whose reasoning patterns, and problem-solving approaches were examined in depth. This particular area was chosen based on findings by Baidoo and Ali (2023), who reported that many JHS pupils in the area struggle with algebraic word problems. The pupils selected for the study

were those who attained a below average score range of 0 to 7 out of a total score of 15.

In fishing out the types of reasoning flaws, a teacher-made diagnostic test was used. The diagnostic test consisted of ten algebraic word problems aligned with the 2020 Ghana Education Service (GES) mathematics curriculum and Aki-Ola Mathematics Textbooks, a widely used GES-recommended textbook (Asiedu, 2017). The test was designed to reveal common reasoning flaws in pupils' solving of algebraic word problems. It was administered in a classroom setting under the supervision of the mathematics teacher and lasted 30 minutes. Following the test, pupils' scripts were analysed to identify recurring reasoning flaws such as misinterpretation of word problems, incorrect translation of statements into algebraic expressions, and inappropriate use of operations. The test instrument was reviewed by two experienced mathematics teachers and pre-tested in a nearby school. The analysis of Cronbach's alpha yielded a value of 0.78, indicating an acceptable level of reliability as suggested by Taber (2018).

RESEARCH RESULT

Research Question: *What types of flaws are evident in the reasoning pattern of Ghanaian junior high school pupils when solving algebraic word problems?*

In order to identify the prevalent errors, the study utilized the first three stages of Mulhern's (1989) error analysis procedure as cited by Seng (2010). This involved an analysis of specific types of errors, and the analysis of the error pattern. During the error analysis procedure, the researcher provided a detailed description of the various errors committed with its trending pattern and the possible flawed reasoning behind such errors. The discussion was done by categorizing the errors into the seven (7) themes identified. Among these errors are discussed below;

Theme 1: Variables and Constant Errors

1. Confusion over constant and variable

One common error identified was that JHS pupils could not identify which aspect of the algebraic word problem translate into the variable (missing letter) or the constant (number that remains at a fixed value throughout). Many of the pupils (23 out of 24) incorrectly identified the unknown quantity and the stated quantity in the word problem. For instance, when asked to write an expression for 'five less than a number' they gave expressions such as '5-r' instead of 'r - 5'. Evidence is shown below;

The image shows three lines of handwritten student work. The first line reads '5 less than a certain number → ... 5-r ...' with a red checkmark and the word 'Error' written next to it. The second line reads '2 more than 5 times a certain number → 2+5x a'. The third line reads '8 times a certain number is subtracted from 5 and the result is multiplied by 2..... (8x a) - 5 + (a x 2)' with 'Confuse a' written in red below the expression.

Figure 1. Confusion over constant and variable.

2. Reversed order of subtraction operation

Another error identified was inability to write subtraction tasks in the order as presented in the word problems. It was revealed that majority of pupils

(19 out of 24) end up reversing the order in which the subtraction is to be written. For instance, when asked to subtract a variable from a constant, they end up subtracting the number from the constant instead affecting their final answer. An example is 'five less than a number' they gave expressions such as '5-x' instead of 'x - 5'. Evidence is shown below;

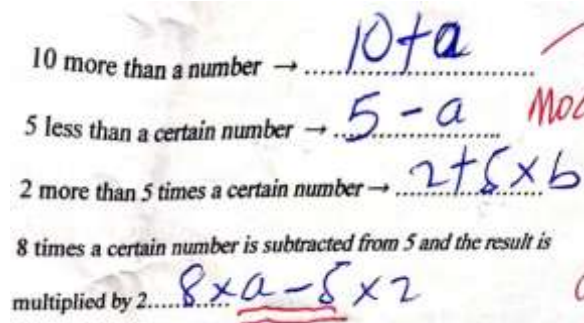


Figure 2. Reversed order of subtraction operation

Theme 2: Multiplication and Exponentiation error

1. Confusion between multiplication and exponentiation

Differentiating between multiplication and exponentiation was a greater challenge. The majority of pupils (16 out of 24) interpreted a square as multiplied by. They could not tell what a square meant and equated it to multiplication. For instance, when asked about a square of a number, the pupil wrote it as '2x' instead of x^2 . Similarly, when asked to write 'twice a number', pupils wrote it as x^2 instead of '2x'. Evidence is shown below;

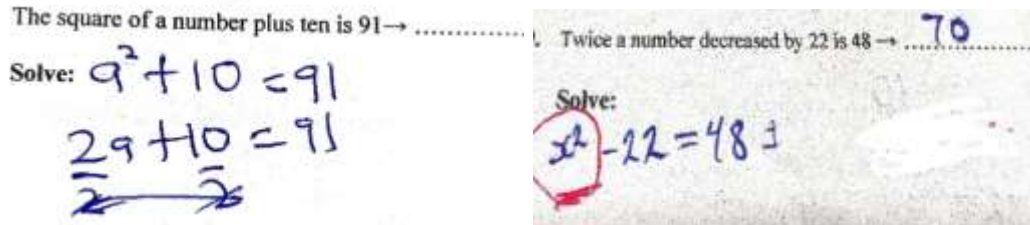


Figure 3. Confusion between multiplicatin and exponentiation.

Theme 3: PEDMAS/BODMAS Error

1. Misapplication of PEDMAS/BODMAS principles

Another common error had to do with applying the rules of BODMAS (Bracket, Of, Division, Multiplication, Addition, and Subtraction) or PEMDAS (Parentheses, Exponents, Multiplication and Division, and Addition and Subtraction) in solving algebraic word problems that involved more than one different operational signs (+, -, \times , \div). Most pupils (21 out of 24) when asked to write an expression for '2 more than 5 times a number' wrote it as "2 + 5 \times x." yet simplified it as "7 \times x resulting in their final answer as '7x' instead of 2 + 5x.

Theme 4: Grouping of Like Terms Errors

1. Summation of constants and variables

The misapplication of the principles of BODMAS or PEMDAS resulted in another common error where pupils (20 out of 24) applied the procedures used in solving arithmetic problems to solving algebraic problems These pupils

added the variable to the constant resulting in a single quantity. For instance, when simplifying “ $x + 10$ ” ended up with ‘ $10x$ ’. Similarly, pupils simplified the expression, ‘ $x + x + y + y$ ’ as $2x + 2y$ resulting in ‘ $4xy$ ’ which is incorrect. Evidence is shown below;

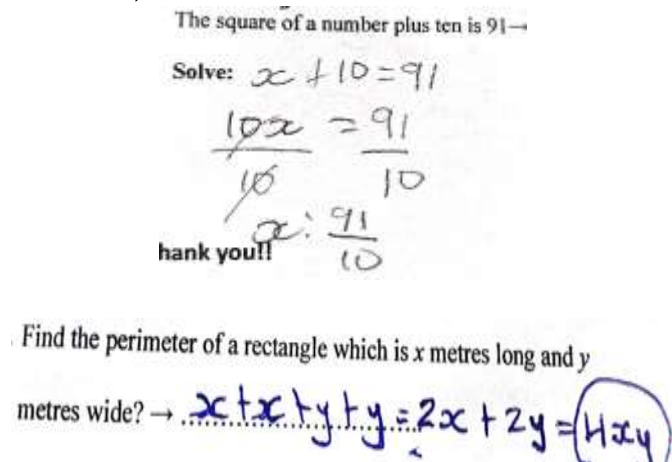


Figure 4. Error of summation of constant and variable.

Theme 5: Simplification Errors

1. Computational error

Pupils also miscalculated or carelessly performed computations on numbers leading to wrong solutions. This error was identified among 15 out of 24 of the pupils. Similarly, others introduced values that were not initially mentioned in the question. For instance, when solving the equations, ‘ $10 + 2x = 40$ ’, the pupil did; ‘ $10 + 2x = 40$ ’ then ‘ $2x = 40 - 10$ ’ and ‘ $x = 30/2$ ’. However, this was carelessly simplified as ‘ $x = 20$ ’ instead of ‘ $x = 15$ ’. Evidence is shown below;

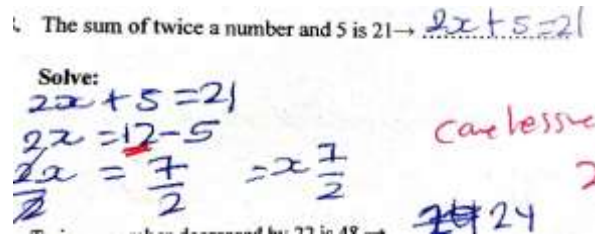
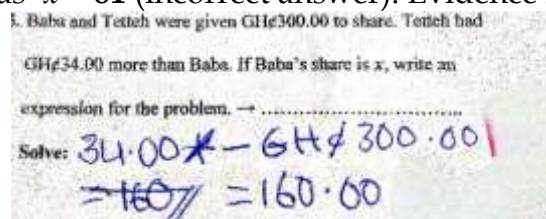


Figure 5. Computational errors.

2. Disregard for negative integers

The study also found that most pupils (20 out of 24) did not have any reverence for negative signs in the solving of algebraic word problems. As a result, answers that were supposed to be negated were ignored and viewed as same. For instance, a pupil solved: $x + 10 = 91$ as $x = 10 - 91$ (incorrect order) and finally simplified it as ‘ $x = 81$ ’ (incorrect answer). Evidence is shown below;



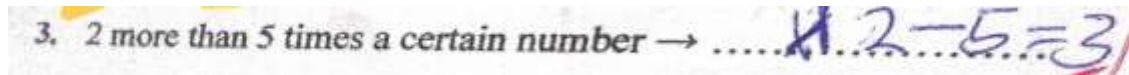


Figure 6. Disregard for negative integers

3. Sharing as Subtraction

This error was peculiar to all (24 out of 24) pupils who attempted the question that read ‘Baba and Tetteh were given GH¢300.00 to share. Tetteh had GH¢34.00 more than Baba. If Baba’s share is x , write an expression for the problem. Attempting to write an expression for the problem, 15 pupils simply used their knowledge of subtraction to simply take away one person’s share from the total without considering how much more the other person had than others in the total share. For instance, pupils simply wrote the answer as ‘If Baba’s share is x , then Tetteh’s share will be $300 - x$. Again, when asked to write ‘an expression for ‘ x apples shared by four people, pupils interpreted it as simply taking away from the quantity given and expressed it as “ $x - 4$ ”. Evidence is shown below;

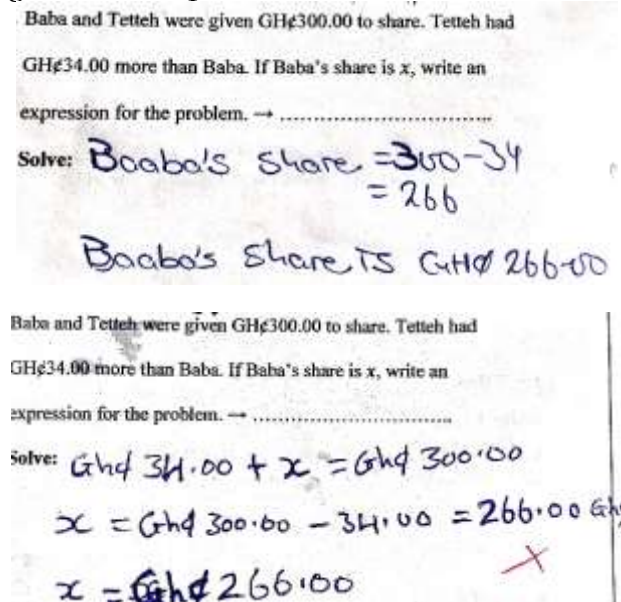
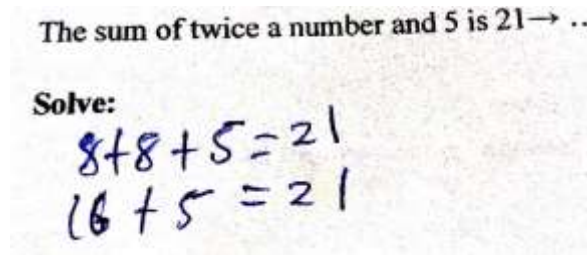


Figure 7. Sharing as Subtraction Error.

Theme 6: Misapplication of Algebraic Rules

1. Conceptualization over expression/equations.

Another aspect of the errors that caught the researcher’s attention was that the majority of the pupils had a way to figure the answer out through they could not express them mathematically. Could we consider this as a deficiency? The researcher believes everything works according to set rules and guidelines hence mathematics is no exception. The algorithm justifies pupils’ answers and helps to know their thinking. In the context of this study, it was surprising to note that 16 of the pupils were able to find the correct answers for missing variables without setting up any expressions or equations for the word problem given. For instance, most pupils solved the ‘sum of twice a number and 5 is 21’ as ‘ $8+8+5 = 21$ ’. Though they could not derive the expression, they practically knew it was twice of 8 added to 5 which gives 21.



and

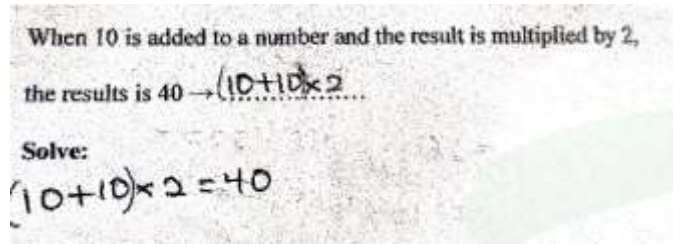


Figure 8. Reversed order of subtraction operation.

2. Ambiguity between expression/equations and inequalities

It was found that most pupils (20 out of 24) could not tell whether the word problem was an expression or equation through the questions were sub-headed accordingly. Through test items specifically stated that “form (write) algebraic expressions or linear equations for these word problems’ yet pupils ended up writing them using inequality operational sign (<,>). For instance, in writing algebraic expression for ‘10 more than a number, the pupils wrote it as “ $10 > x$ ”, which can be interpreted as ‘10 is greater than a number’. Similarly, “five less than a number” was written as “ $5 < x$ ”. It could be seen that most of the pupils were still applied the interpretations of inequalities when solving equation and expressions on linear equations. Evidence is shown below;

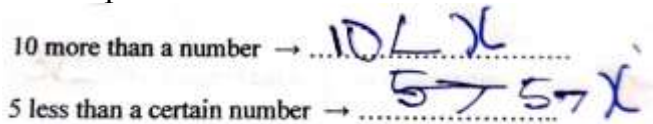


Figure 9. Algebraic expressions as inequalities error.

3. Confusion with inequality signs (> or <)

Aside from misinterpreting algebraic expressions and equations as inequalities, 18 pupils also had challenges using the inequality signs correctly. The symbol > is mostly interpreted as ‘greater than’ while < is viewed as ‘less than’. However, the researcher believes context matters here. Depending on the context in which they are being used, in line with the direction of the sign with respect to the quantities being compared, a suitable interpretation is given. The study found that even at the junior level, pupils still get confused as to which sign is ‘less than’ or ‘greater than’. In their workings, it was realized that where they interpreted the question as demanding ‘less than’ they ended up using greater than symbols instead and vice versa. Evidence is shown below;

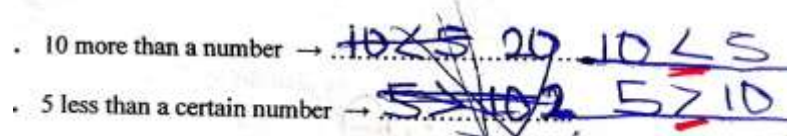


Figure 10. Confusion over inequality signs.

Theme 7: Misinterpretation of algebraic phrases and sentences

1. Misunderstanding of phrases

Various phrases and clauses in the algebraic word problem were misinterpreted by most pupils (21 out of 24). Among these were;

- a. "More than" as "multiplication". For instance, when asked to write "2 more than a number plus 5", they wrote it as " $x \times 2 + 5$ " which mathematically means "twice a number and 5"
- b. The term, "Multiplied" is interpreted as "plus"
- c. The term, "is/gives" is interpreted as "greater than"
- d. The process of "Adding two variables" is interpreted as their product. Example $x + y = xy^1$
- e. The term, "Square of a number" is interpreted as square root. Example,
- f. 'Mathematical interpreter'; where the pupils re-write the same word problem but replaces the mathematics keywords in the problem with its appropriate mathematical terms.

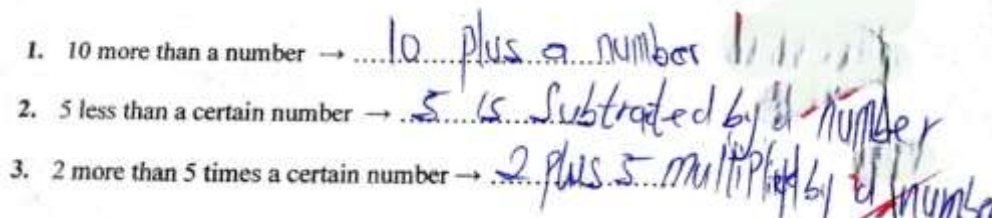
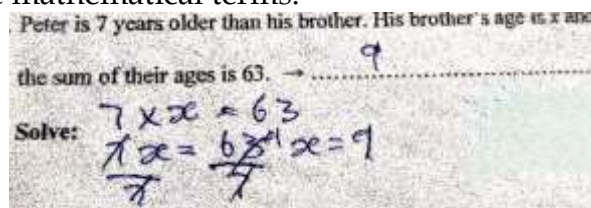


Figure 11. Misunderstood phrases.

2. Direct sentence order translation of word problem

The last of these errors involved pupils writing the algebraic expressions and equations required using the grammatical order in which the terms in the word problem are presented rather than focusing on the literary and logical meaning embedded in the problem. For instance, in writing an equation for "twice a number minus 22 is 48", the student solved as $2(x - 22) = 48$, expanded as $2x - 44 = 48$, simplified as $2x = 48 + 44$ to $2x = 92$, divided through by 2 to give the value of x as 46, which is incorrect. This is because logically and mathematically, this answer is not feasible since twice of 46 = 92 and 92-22 give 70, not satisfying the equation where the left-hand side equals the right-hand side. Similarly, when asked to write an equation for "twice a number plus 5 is 21", they wrote it as $2(x+5) = 21$. This Evidence is shown below;

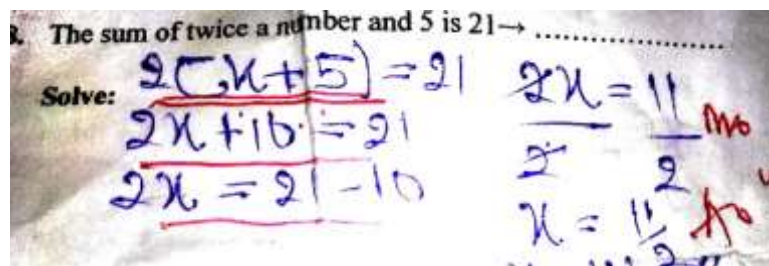


Figure 12. Direct sentence translation error.

DISCUSSION

The study revealed that the reasoning pattern of Ghanaian junior high school pupils in solving algebraic word problems is flawed by various errors, stemming from both conceptual misunderstanding and procedural mistakes. One of the most common issues identified is misunderstanding of variables and constants. This issue, which leads to difficulties in setting up and solving algebraic expressions, aligns with the findings of Rudyant et al. (2019) and Booth et al. (2017), who stress that understanding variables is foundational to mastering algebra. Similarly, Bush and Karp (2013) and Egodawatte (2011) highlight how misconceptions about variables are common at the intermediate level and serve as barriers to solving algebraic problems. In this study, pupils' confusion between variables and constants often resulted in incorrect representations of the problems, making it difficult to progress to the solution.

Another significant flaw observed was the confusion between multiplication and exponentiation. This was evident when pupils mixed up operations, a challenge also noted in the BECE Chief Examiner's reports (2011-2018), which pointed out that pupils frequently fail to apply BODMAS (Brackets, Orders, Division and Multiplication, Addition and Subtraction) correctly. Chow and Treagust (2013) and Al-Rababaha et al. (2020) argue that a clear distinction between multiplication and exponentiation should be emphasized in teaching. The misapplication of BODMAS rules, especially in problems such as "sum of twice a number and 5 is 21" further exacerbated errors. Lin et al. (2015) and Rittle-Johnson and Schneider (2014) recommend that teachers encourage pupils to justify each step in their problem-solving process, reinforcing the importance of following the correct order of operations.

Additionally, the study identified frequent errors involving like terms. Many pupils incorrectly combined terms such as $3x + 4$, mistakenly treating it as $7x$. This error reflects a tendency to treat algebraic expressions like arithmetic operations, as noted by Herutomo and Saputro (2014), who observed that pupils often fail to recognize that terms with different variables or powers cannot be combined. Sarimanoğlu (2019) similarly identified this misconception and emphasized the need for explicit teaching on the rules for simplifying algebraic expressions. The improper handling of like terms further contributes to confusion and inaccurate solutions in algebraic word problems.

The study also uncovered simplification errors, particularly with the distributive property. Pupils often misapplied this property, as seen when they simplified expressions like $2(x - 5)$ incorrectly as $2x - 5$ instead of the correct $2x - 10$. Al-Rababaha et al. (2020) noted similar issues in their study, highlighting how

pupils frequently make arithmetic errors during simplification. These errors suggest a need for more focused instruction on simplification techniques and the distributive property to avoid common mistakes.

Finally, a major flaw in pupils' reasoning was their misinterpretation of algebraic phrases in word problems. Many pupils struggled to correctly translate the words into algebraic expressions, which is critical for solving word problems. Bush and Karp (2013) and Rittle-Johnson and Schneider (2014) emphasize the importance of teaching pupils how to carefully read word problems, identify key phrases, and use those to correctly formulate algebraic expressions. This difficulty in interpretation can lead to significant errors, especially when pupils overlook important details in the problem.

CONCLUSIONS AND RECOMMENDATIONS

It is worthy to note that the findings of this study have shown, based on pupils written response, that the learning of algebra, specifically algebraic word problems among Junior High School Pupils in the Ghanaian context, is flawed by many conceptual and procedural errors. To address this, it is important for teachers in Effutu and beyond to expose pupils to more word problem tasks as part of their daily assessment routines. They should also allow pupils to explain the reasoning behind their answers when solving algebraic problems. Lastly, teachers are encouraged to adopt error analysis as an instructional approach to help their pupils identify and reflect on the flaws in their own thinking.

ADVANCED RESEARCH

This study used only pupils in basic eight from one school. Hence, it would be more comprehensive if future studies consider using all the junior high school pupils in the area.

ACKNOWLEDGEMENTS

We are grateful to all the pupils and teachers who assisted us in gathering the data for this study.

REFERENCES

- Adu, E., Assuah, C. K., & Asiedu-Addo, S. K. (2015). Students' errors in solving linear equation word problems: Case study of a Ghanaian senior high school. *African Journal of Educational Studies in Mathematics and Sciences, 11*, 17-30.
- Adu, E., Mereku, D., Assuah, C., & Okpoti, C. (2017). Effect of multimedia courseware with cooperative learning on senior high school students' proficiency in solving linear equation word problems. *African Journal of Educational Studies in Mathematics and Sciences, 13*, 1-11.
- Aforklenu, D. K. (2013). Junior high school students' difficulties in solving word problems in algebra in Tema Education Metropolis.

- Al-Rababaha, Y., Yew, W. T., & Meng, C. C. (2020). Misconceptions in school algebra. *International Journal of Academic Research in Business and Social Sciences*, 10(5), 803-812
- Anku, S., E., (2018). Revamp mathematics education in Ghana. *Scribbr* https://www.ghana.gov.gh/ghana/revamp_mathematics_education_ghana.
- Asiedu, P. (2017). *Mathematics for junior high schools (Form 1, 2 and 3)*. Accra: AKI-OLA Publications
- Baidoo, J., & Ali, C. A. (2023). Students' mathematics and real life contexts in solving algebraic word problems. *Al-Jabar: Jurnal Pendidikan Matematika*, 14(2), 483-500.
- Booth, J. L., McGinn, K. M., Barbieri, C., & Young, L. K. (2017). Misconceptions and learning algebra. In *And the Rest is Just Algebra* (pp. 63-78). Springer, Cham.
- Bush, S. B., & Karp, K. S. (2013). Prerequisite algebra skills and associated misconceptions of middle grade students: A review. *The Journal of Mathematical Behavior*, 23(3), 613-632.
- Chow, T.-C., & Treagust, D. (2013). An intervention study using cognitive conflict to foster conceptual change. *Journal of Science and Mathematics Education in Southeast Asia*, 36(1), 44-64
- Egodawatte, G. (2011). *Secondary School Students Misconception in algebra*. Ph. D. Teaching and Learning Ontario Institute for Study in Education, Department of curriculum, University of Toronto.
- Herutomo, R. A., & Saputro, T. M. (2014). Analisis kesalahan dan miskonsepsi siswa kelas VIII pada materi aljabar. *Edusentris*, 1(2), 134-145.
- Ibrahim, F. I., & Yaw, O. (2019). Senior High School Students' Challenges in Solving Word Problems Involving Linear Equation in One Variable in Tamale Metropolis.
- James, A. O., & Adewale, O. A. (2015). Relationship between senior secondary schools students' achievement in mathematical problemsolving and intellectual abilities tests. *European Scientific Journal*, 8(15), 169-179
- Jupri, A., & Drijvers, P. (2016). Student difficulties in mathematizing word problems in algebra. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(9), 2481-2502.
- Lin, C. L., Jung, M., Wu, Y. C., She, H. C., & Jung, T. P. (2015). Neural correlates of mathematical problem solving. *International journal of neural systems*, 25(02), 1550004.

- Mills, E. D., & Mereku, D. K. (2016). *Students' performance on the Ghanaian junior high school mathematics national minimum standards in the Efutu Municipality. African Journal of Educational Studies in Mathematics and Sciences*, 12, 25-34.
- Nashiru, A., Alhassan, I. N., & Sadiq, Z. A. (2018). Translate Word Problems into Algebraic Expressions: The Case Study of George Polya's Problem Solving Model. *ADRRI Journal of Physical and Natural Sciences*, 2(2), 1-25.
- National Council for Curriculum and Assessment (NaCCA). (2020). Curriculum for basic schools (7-10). Retrieved from <https://nacca.gov.gh/assets/files/curriculum/Curriculum%20For%20Basic%20Schools.pdf>
- National Council of Teachers of Mathematics. (2015). *What is the role of calculators in the elementary grades? A Position of the National Council of Teachers of Mathematics*. Retrieved from <http://www.nctm.org/Standards-and-Positions/Position-Statements/Calculator-Use-in-Elementary-Grades>
- Polya, G. (1945). *How To Solve It*. USA: Princeton University Press.
- Rittle-Johnson, B., & Schneider, M. (2014). Developing conceptual and procedural knowledge of mathematics.
- Sarimanoğlu, N. U. (2019). The investigation of middle school students' misconceptions about Algebra. *Studies in Educational Research and Development*, 3(1), 1-22.
- Seng, L. K. (2010). An error analysis of Form 2 (Grade 7) students in simplifying algebraic expressions: A descriptive study. *Electronic Journal of Research in Education Psychology*, 8(20), 139-162.
- Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education*, 48, 1273-1296.
- Tuffour, G. K. (2015). *Enhancing students' understanding in translating word problems into algebraic equations – a case study at Navrongo community vocational training institute in the Ghana* (Doctoral dissertation, University Of Education, Winneba.).
- Yin, R. K. (2017). *Case study research and applications: Design and methods*. Sage publications.