

Research Article

An Error Analysis of Students' Algebraic Problem-Solving among Senior High School Students in Ghana

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Abstract: This study examined the types and causes of errors students commit in solving algebraic word problems. The study adopted a descriptive qualitative case study design with 97 senior high school students in Ghana. Data were collected through an Algebra Achievement Test (AAT) and interviews with students. Quantitative data were analysed using descriptive statistics, and qualitative data were thematically analysed employing a deductive approach to provide in-depth insight. The results revealed five categories of errors: reading, comprehension, transformation, processing skills, and encoding errors, as proposed by Newman's Error Hierarchy. Transformation errors were the most frequent, followed by processing skills errors, whereas encoding errors were the least common. The causes of errors included carelessness, misinterpretation of mathematical terms, rote memorisation, inadequate practice, and ineffective teaching approaches. The study concluded that students' errors in algebra are systematic and influenced by both learner-related and instructional factors. It was recommended that teachers focus more on conceptual understanding and problem-solving strategies than on allowing students to memorise concepts.

Keywords: error analysis; algebra word problem; Newman's error hierarchical model; Ghanaian Senior High School

1. Introduction

Mathematics is fundamental to human development and forms the basis of many fields, including the sciences, engineering, technology, and economics (Maass et al., 2019). The study of mathematics is crucial and significant in various levels of education due to its immense contribution to students' skills for critical thinking, communication, and creativity (Kilpatrick, 2014; Laurens et al., 2018). Mathematics influences everyday decision-making, problem-solving, and logical reasoning, and its applications extend beyond the classroom. Literacy in mathematics equips people with the skills they need to thrive in a rapidly changing world, empowering individuals to make informed decisions. The critical thinking and problem-solving abilities that mathematics education fosters apply to many facets of life and contribute to individual development (Sulai & Sulai, 2020). Furthermore, mathematics serves as the basis for many scientific fields and is a valuable tool for comprehending various subjects and languages. Thus, mathematics is vital to human reasoning and logic and is a fundamental discipline that attempts to understand and predict the universe.

A country's framework for development in innovation, economic growth, and technological advancement relies heavily on mathematics (Obafemi et al., 2023). Mathematical proficiency increases a country's competitiveness in the global economy (Maass et al., 2019; Sulai & Sulai, 2020). Countries that prioritise mathematics education are better positioned to foster innovation, drive technological progress, and compete in the global economy (Abd Algani, 2022). To address complex issues such as healthcare, infrastructure development, economic resilience, and climate change in every country, the requirement of mathematically educated populace must not be underestimated. Thus, improving mathematics education is crucial for both individual achievement and the larger socioeconomic development of countries. However, in Ghana, some studies (Abreh et al., 2018; Nugba et al., 2021) have reported that a large number of pre-tertiary students still struggle to excel in mathematics,

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despite mathematics being an indispensable tool for STEM. According to Chua and Mosha (2015), students' difficulty in excelling in the subject is a result of the subject content, instructional strategies, teaching aids used, student beliefs, background or culture, and the teacher's degree of subject-matter competence. Generally, students' poor performance in mathematics can be attributed to environmental, emotional, and societal influences.

Algebra is a cornerstone of mathematics education, serving as a critical foundation for advanced mathematical concepts and real-world problem-solving. It is often considered a gatekeeper subject, with success in algebra being a predictor of future academic and career opportunities. It provides students with tools to model and solve problems, develop logical reasoning, and understand abstract relationships. Arcavi et al. (2017) cite the following as the objectives of classroom algebra: "expressing generalisations, establishing relationships, solving problems, exploring properties, proving theorems, and calculating" (pp. 2–3). Students who struggle with algebra are less likely to pursue advanced mathematics courses or STEM fields, limiting their career prospects. According to Jupri and Drijvers (2016), students face several challenges while learning and applying algebraic concepts to other mathematical areas.

The seriousness of these difficulties is confirmed by West African Examination Council (WAEC) Chief Examiners' reports, which show that both Senior High School (SHS) and Basic Education Certificate Examination (BECE) students in Ghana continue to make several errors when working with algebra. According to the WAEC report in 2020, SHS students have continuously shown a lack of proficiency in algebra. The report highlighted weaknesses in "translating word problems into a mathematical statement and solving problems in ratio and proportion." A similar report in 2021 revealed challenges in "drawing a Venn diagram from a given information and completing tables for the multiplication of modular arithmetic" (West African Examination Council, 2021). Recent WAEC reports also show BECE students demonstrating poor algebraic skills, such as poor control of multiple variables, improper bracket expansions, poor control over fractional tasks, incorrect simplification, and inappropriate use of the order of operations (Basic Education Certificate Examination, 2021).

These challenges faced by students in algebra could lead them to commit errors when solving algebra problems. Errors may occur because of conceptual misunderstanding, lack of procedural knowledge, or careless slips during problem-solving. The persistence of such errors year after year suggests the need for systematic investigation. The evidence from national examinations shows that the majority of students do not simply perform poorly by chance but rather make recurrent, patterned errors that must be studied carefully. By identifying the types of errors students make and the reasons that account for them, teachers and curriculum developers will be better positioned to design effective interventions that target the actual difficulties students face. Therefore, this study aims to investigate common errors students make when solving algebraic problems and identify the underlying causes of these errors. From these assertions, the following objectives and questions were designed to guide this investigation among SHS at Agric Nzema.

Considering this, the main objective of the study is to identify the types of errors and causes committed by students in solving algebraic problems. And the research answers the following research questions: (1) What types of errors do students commit when solving algebraic problems? (2) What are the underlying causes of the errors made by students in solving algebraic problems?

2. Literature Review

This study's theoretical framework is grounded in Newman's Error Analysis (NEA). Newman assumed that every word problem presents several obstacles that must be cleared in order to obtain the correct answer, and that failing to clear one obstacle prevents progress to the next and ultimately prevents the correct answer from being reached (Newman, 1977). This led to the creation of a model known as NEA. According to White (2009), Newman (1977) maintained that when a person attempts to answer a standard written mathematics word problem, then that person must be able to pass over several successive hurdles. They are reading, comprehension, transformation, process skills, and encoding. Because NEA is simple to use, comprehend, and modify, it has gained popularity among educators in New South Wales (NSW).

The definition of the five types of errors proposed by Newman (1997) is: reading errors. If pupils are unable to read a word or symbol in mathematical problems, they will be considered to have made a reading error. They will be unable to proceed with the procedures

necessary to develop problem-solving skills. Comprehension errors occur as a result of a student's inability to understand the overall meaning of the words used in the mathematical problem. As a result, students do not pursue the appropriate paths for problem-solving. Transformation errors: This type of error occurs when students are unable to transform the given question into a mathematically acceptable form and solve it, or when they are unable to represent the information given in the mathematics problem diagrammatically. Process skill errors: Students commit this blunder because they are unfamiliar with or do not know the steps required to complete the operation correctly and accurately. Process skills error refers to the mistake of calculating mathematical processes to get the correct result and recognising the operation. Encoding errors: These are the errors made by students in explaining their conclusion or final answer. Students can answer problems correctly, but they are unable to communicate their solutions using appropriate notation that can be taken as a conclusion.

NEA has gained significant attention in all countries. Numerous study papers have been published in various countries, reporting data analysed in accordance with Newman's recommendations. In Ghana, for instance, Mensah (2017) and Obeng et al. (2024) applied the NEA to investigate students' errors in trigonometry. Particularly in algebra, though studies (Adu et al., 2015; Asase, 2022; Kenney & Ntow, 2024; Ndemo & Ndemo, 2023; Oppong et al., 2024) had likewise applied the NEA to evaluate the errors students commit when dealing with word problems, this study's novelty lies in the use of the new mathematics curriculum assessment which focused mainly on student's ability to solve realistic mathematics problems. In the Western world, too, the NEA model has been adopted by scholars (Annizar & Kumala, 2023; Makgakga, 2023; Mubarakah & Amir, 2024) to investigate various branches of mathematics tasks. These findings provided a solid foundation for improving mathematics instruction. The study's conceptual framework is shown in figure 1 which explains the relationship between each error (starting from bottom-up) committed in solving algebraic word problem.

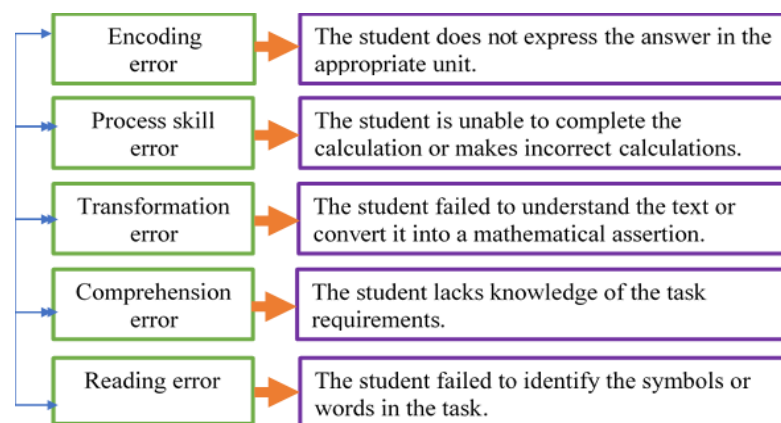


Figure 1. Newman's error hierarchical model.

Note: Modified by authors.

Regarding this, NEA provides a systematic and hierarchical framework for identifying and interpreting students' difficulties in solving mathematical word problems. By distinguishing between reading, comprehension, transformation, process, and encoding errors, the model enables educators to pinpoint specific breakdowns in the problem-solving process and design targeted instructional interventions. Building on extensive international applications, the present study extends the use of NEA within the context of a new mathematics curriculum that emphasizes realistic problem-solving, thereby reinforcing its relevance as both a diagnostic and pedagogical tool for enhancing students' mathematical understanding and performance.

3. Materials and Methods

A qualitative descriptive case study design was used for this investigation. From 256 total of first-year students for the 2024/2025 academic year, who are taught by the first author, a total of ninety-seven (97) students were sampled from the student population for the study using a purposive sampling technique. The purposive sampling technique involves researchers deliberately selecting participants for a study based on their judgment of the typicality or possession of a particular characteristic required for the study. The students (97)

sampled for the study were derived from Li and McKeague's (2013) criteria for determining sample size for a continuous variable.

In this study, the two main instruments were deemed appropriate and were therefore employed by the researchers. These instruments included the Algebra Achievement Test (AAT) and a semi-structured interview based on the NEA model. The Achievement Test used in this study was the AAT, which was purposefully developed and implemented by the researchers to identify the types of errors committed by the students at Agric Nzema SHS. The researchers designed the test as open-ended, as it would allow students the opportunity to present their solutions. The test was made up of five (5) items. The purpose of the AAT was to identify the types of errors students make in solving algebraic problems. With the aid of a pilot test and a review from two experts in mathematics assessment, it was determined that the test duration was fifty minutes. Thus, students should not spend more than ten minutes on a single question. The primary reason for conducting the interview was to provide respondents with the opportunity to explain their perspective on the situation at hand, thereby identifying possible causes of the errors that had been committed. The interview guidelines used by the researchers were based on the conceptual framework depicted in figure 1, which is the NEA model. The AAT and the interview guidelines for study participants are presented in Appendix.

A split-half method, where total scores from odd-numbered and even-numbered items were computed separately, was employed. These scores were then correlated using the Spearman-Brown formula with the aid of SPSS version 27. The analysis yielded a correlation coefficient of 0.767, indicating a high level of reliability. This suggested that the test instrument was internally consistent and capable of measuring what it was designed to assess (Lotey et al., 2023). To ensure the trustworthiness of this research, three techniques were employed to guarantee the reliability and rigor of this investigation, in addition to the detailed and comprehensive explanations provided in the findings. To promote member checks, which were used to enhance the credibility of this study, each participant's interview transcript was verified, and revisions and additions were requested as necessary. Thus, the findings or interpretations of the research were shared with participants to ensure accuracy and authenticity. Additionally, multiple sources of data (e.g., interviews and scores) were used to provide a comprehensive understanding of the types of errors students commit and the underlying causes of such errors. The researchers engaged in peer debriefing during the analysis, challenging, defending, and validating themes. This was also done to ensure that dependability is achieved. To ensure transferability, the findings of this research were discussed in relation to other relevant literature.

In table 1, the male participants were 49, representing 50.52% of the sample, while the female participants were 48, representing 49.48%. Furthermore, the age range of participants was reported as follows: 30 students, representing 25.77%, were under 16 years old; 42 students, representing 43.3%, were between 16 and 18 years old; and 25 students, representing 30.93%, were above 18 years old. Furthermore, regarding programme of study, the distribution of respondents was fairly balanced across the five programmes. General Science, Agricultural Science, and Business each recorded 20 students (20.62% each). Home Science followed closely with 19 students (19.58%), while General Arts had the lowest representation with 18 students (18.56%).

Table 1. Learners' demographics.

Category	Group	Frequency	Percentage (%)
Sex	Male	49	50.52
	Female	48	49.48
Age	Less than 16	30	30.93
	16 to 18	42	43.30
	Above 18	25	25.77
Program of study	General Science (1GS1)	20	20.62
	Agricultural Science (1AG1)	20	20.62
	General Arts (1GA1)	18	18.56
	Business (1B1)	20	20.62
	Home Science (1HS1)	19	19.58
Total		97	100

The AAT was administered simultaneously to all students instructed by the first author.

The completed test items were gathered and coded for further analysis. In an effort to determine the possible causes of respondents' errors in solving algebraic problems, the researchers subsequently conducted interviews with ten students (two participants from each class) who were purposively selected based on their low marks due to the errors they committed. The interview with each student lasted for ten (10) minutes. Researchers conducted the interviews with students using the interview guidelines for students (see Appendix). Data gathered through the AAT was coded and analysed using descriptive statistics. The results were represented in tables and graphs where necessary. To comprehend, interpret, and categorise the students' errors in the process of answering algebraic word problems, NEA, which serves as the conceptual framework, provided the basis for the analysis. Qualitative data from the semi-structured interviews were analysed thematically using a deductive approach. Audio recordings of the individual discussions were listened to multiple times, and themes that emerged from each discussion were documented in accordance with the NEA model.

Regarding ethical issues, a consent form was also given to students to fill out after the researcher had briefed them about the rationale behind the study. Likewise, participants were guaranteed confidentiality, which implied that no names were required on the survey questionnaire or used during the write-up of this current research. The audio recordings from the focus group discussion were kept confidential and secure throughout all stages of the data analysis procedures. Respondents' classes and names were discarded from the analysis. It was made clear to participants that they had every right to refuse participation in the study or to withdraw from it without facing any repercussions.

4. Results

4.1. The Types of Errors Committed by Students in Solving Algebraic Problems

The students' performance, as depicted in figure 2, shows that most students provided the incorrect answer to test item 2. This was represented by 78% of the sampled population. Furthermore, the majority of students were able to provide the correct answers to test item 1, as indicated by 22%. Most students did not provide an answer to item five, which was also represented by 40%. The total number of errors committed according to table 2 was 42, 44, 63, 55, and 63, respectively, for test items 1, 2, 3, 4, and 5. Additionally, for reading, comprehension, transformation, processing skills, and encoding errors, the following values were recorded, respectively: 18 (6.7%), 49 (18.4%), 97 (36.3%), 93 (34.8%), and 10 (3.7%) for each. 97, which corresponds to transformation errors, was most frequently committed by participants when answering the algebraic word problems, accompanied by processing skills, comprehension, reading, and lastly, encoding.

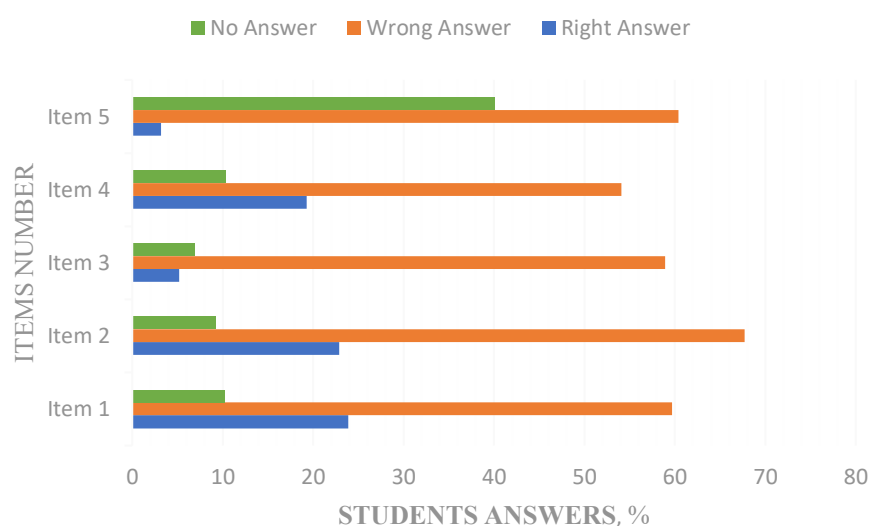


Figure 2. Students respond to the test items.

Table 2 further shows that the fewest errors were committed in encoding. This demonstrates that students have a high level of efficacy in expressing the answer

appropriately. From table 2, the researcher may conclude that most students' inability to solve algebraic word problems was a result of the errors they made in transformation and processing skills.

Table 2. Types of errors committed and their rank.

Errors	1	2	Test items		5	Total	Rank
			3	4			
Reading error	2	2	7	4	3	18	4th
Comprehension error	9	10	12	4	14	49	3rd
Transformation error	8	14	28	22	25	97	1st
Processing skills error	19	13	15	25	21	93	2nd
Encoding error	4	5	1	0	0	10	5th
Errors total	42	44	63	55	63	267	

4.2. The Causes of Errors Made by Students in Solving Algebraic Problems

In this section, the causes of each error made by students are analysed in subsections based on NEA criteria. Samples of various errors committed are presented as evidence to complement the semi-structured interview, which was designed to provide in-depth findings on the causes of students' errors.

4.2.1. Analysis of Reading Error

Learners make reading errors when they cannot read the symbols or keywords used in the mathematical problem. According to the data collected, the majority of pupils made the most reading mistakes when they tried to respond to question 3. This type of inaccuracy can be caused by pupils misinterpreting the question and not paying sufficient attention to the details when reading it. The reading errors committed by pupils are displayed in figure 3. From figure 3, it is clear that students were able to calculate the cost of a single pack of sweets and chocolate. However, students made some reading errors, and as a result, could not answer the question as it demanded.

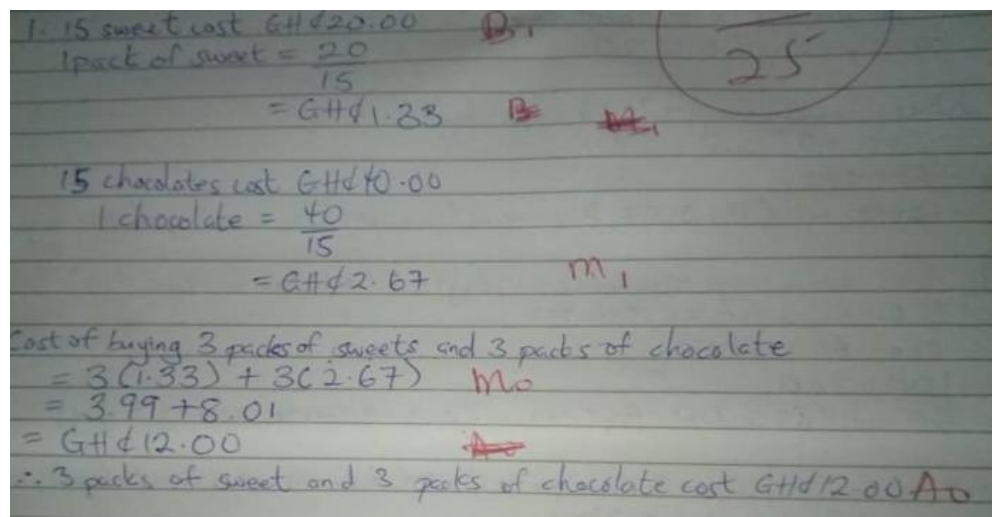


Figure 3. Samples of reading errors.

In question 1, students were asked to calculate the cost of buying three packs of sweets and three packs of chocolates and then determine the total cost using the distributive property. However, unfortunately, students instead calculated the cost of 1 sweet and chocolate due to misreading and their lack of paying attention to the details in the question given. This was confirmed by an interview we had with some of the students.

Researcher: So, please tell me, can you read the question?

Learner 7: Yes, sir.

Researcher: What do you think the question asked you to do, please?

Learner 7: When I can calculate the cost of each sweet and chocolate, it will enable me to find the answer for the three packages of sweets and chocolates as required by the question. That was how I understood the question, sir.

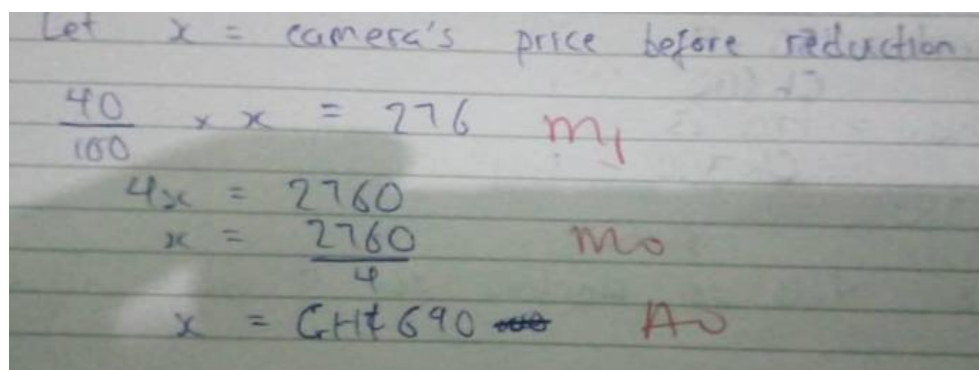
Researcher: Do you now realise where you were at fault in answering question 1 after reviewing your paper?

Learner 7: Yes, sir, the individual cost of sweets and chocolates I calculated was not what the question was demanding from me. I will do better by rereading the question carefully before answering.

It is clear from the interview that the student struggled to understand and describe the concepts used in question 1 before attempting to tackle it. This indicates that students do not actually practise using word problems to solve distributive property questions after their regular class with their teachers. As a result, they were unable to distinguish between the problems they solved in class and the one provided in question 1, which involved a distributive property word problem. As a result, the student hurried to respond to the question but regrettably gave the incorrect response.

4.2.2. Analysis of Comprehension Error

Students make comprehension errors when they are unable to understand the overall meaning of the words used in a mathematical problem, which prevents them from solving the task correctly. Although the majority of the pupils could read the question, they had difficulty deciphering it. Question 5 was answered incorrectly by the majority of pupils. Students did not fully understand the overall meaning of the question, nor did they grasp the term “price reduction” used in the question. The following depicts the occurrence of comprehension errors in students’ work. It was evident from figure 4 below that students were unable to solve the problem and obtain the correct answer because they lacked comprehension of the general meaning of the question and the term “reduction” used.



Let x = camera's price before reduction

$$\frac{40}{100} \times x = 276 \quad m_1$$

$$4x = 2760$$

$$x = \frac{2760}{4} \quad m_0$$

$$x = \text{GH¢}690 \quad A_0$$

Figure 4. Samples of comprehension errors.

Students were confused about the term “price reduction” and percentages. Students faced challenges in approaching the given question. This could be a result of students’ lack of understanding of basic concepts, misinterpretation of problem statements, inadequate problem-solving strategies, and, more importantly, how the concepts of percentages were taught to students. Comprehension errors were revealed in the interview below.

Researcher: Which category, in your opinion, difficult, medium, or easy, will you assign to question 5?

Learner 88: Please, sir. I often struggle to understand algebraic questions that involve price reductions expressed as percentages. Such questions are challenging.

Researcher: Tell me what you believe the question is asking you to do?

Learner 88: I am not really sure, sir; these kinds of questions often leave me perplexed.

Researcher: What, then, do you believe to be the main reasons why you find algebraic concepts and applications difficult to understand?

Learner 88: Please, sir, there is a lot.

Researcher: Could you please share your thoughts or knowledge?

Learner 88: Our teacher was rapid when instructing us, answering all the questions himself. If you have any questions for him, he will tell you to meet your friends after class. Additionally, he consistently pays attention to our classmates who excel in mathematics, leaving those of us who struggle behind. Nothing even inspires me to study mathematics in light of this. I do not enjoy learning mathematics because I know that no matter how hard I try, I will never fully understand it, as it is so complex and involves numerous formulas and

numbers.

According to the interview above, students' misconceptions about algebra word problems as being challenging were the leading cause of their mistakes. Teachers' techniques and approaches when instructing students in algebra concepts, especially those involving word problems, also play a role in students' comprehension errors. From such interviews, most students found it challenging to comprehend algebra concepts because they were often presented in an abstract or problem-based manner. In light of this, comprehension errors may arise when teachers do not give sufficient attention to word problems in algebra, thereby solving algebra questions that seem overly straightforward.

4.2.3 Analysis of Transformation Error

Transformation errors occur when students are unable to answer a given problem by converting it into a mathematically acceptable format. This kind of mistake generally occurs when students can read and comprehend the question. However, they are unable to convert it into a mathematical form that is acceptable because they are unable to recall and apply the relevant algebraic ideas, and misuse the fundamental algebraic operations.

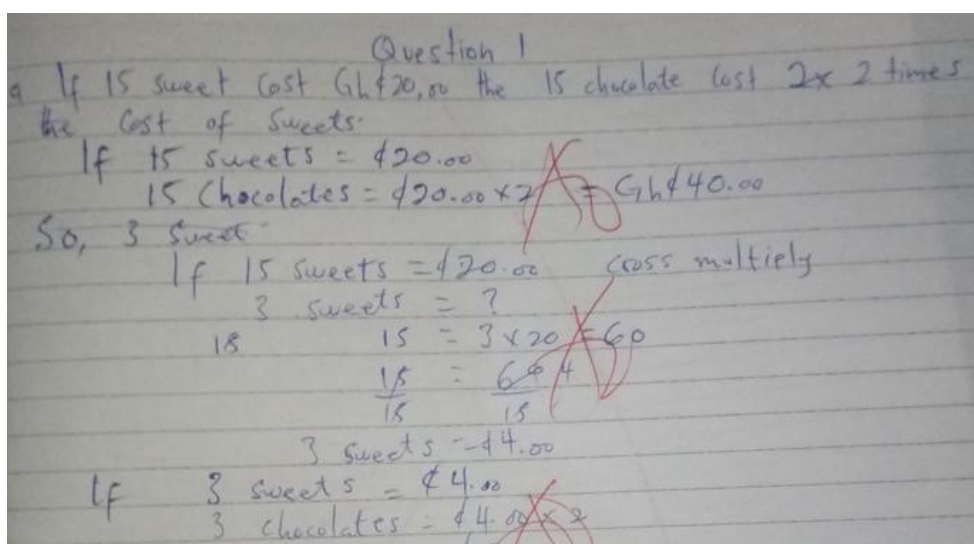


Figure 5. Samples of transformation error.

The causes of these mistakes include learning by rote, which involves memorising formulas rather than comprehending the underlying ideas, and not practicing frequently, which may lead to a lack of familiarity in transforming algebraic word problems into mathematical expressions. The study's results showed that the majority of students' mistakes were transformation errors, which occurred when they tried to complete question 3. From figure 5 above, using task 1 as an example, it could be noticed that students were not able to write the word problem into the appropriate mathematical terms, which could help them to apply the distributive property to solve the question easily, and therefore could not solve it to get the correct answer to the question given. Due to this, students attempted to use their own methods and ideas, which, unfortunately, were not suitable and therefore provided incorrect answers to the problem. The interview below provided details on the reasons for the transformation error.

Researcher: Please, do you really understand Test Item 1?

Learner 32: Yes, please, sir.

Researcher: In that case, tell me, what did you use to solve the question, please?

Learner 32: Sir, please, I used the compound angle identity.

Researcher: Great, so why is your answer wrong?

Learner 32: Sir, please, it is because I used the wrong concept in solving the question.

Researcher: Please, why did that happen?

Learner 32: Sir, I am having trouble writing the statement mathematically. As you can see, I initially equated 15 sweets to 20 cedis, but I lost my way with the second approach. I barely use them, as I do not constantly practice solving algebraic word problems, which makes it difficult for me to translate word problems into mathematical form for an easy solution.

Additionally, our instructors do not provide us with more examples concerning this type of question.

According to the interview, it is clear that a large portion of the transformation errors students made were due to their method of learning algebraic concepts (rote learning). Students also frequently struggle with converting word problems into mathematical statements because they do not regularly practice applying the distributive properties they have learned to solve algebraic problems.

4.2.4. Analysis of Process Skill Error

This error is made by students who do not know how to operate to get the correct answer. The failure to accurately compute mathematical operations to arrive at the required outcome and recognise the operation is known as a process skills error. The second most frequent mistake students make when tackling algebraic problems, according to the data collected, is an error in processing skills. Question 4 was where students made the most errors in processing skills. Sometimes, students who understand the working procedure also misuse the arithmetic operation signs, leading to inaccurate responses because they are in a hurry to finish more questions. Here is an example of a student's processing skills error identified in question 5.

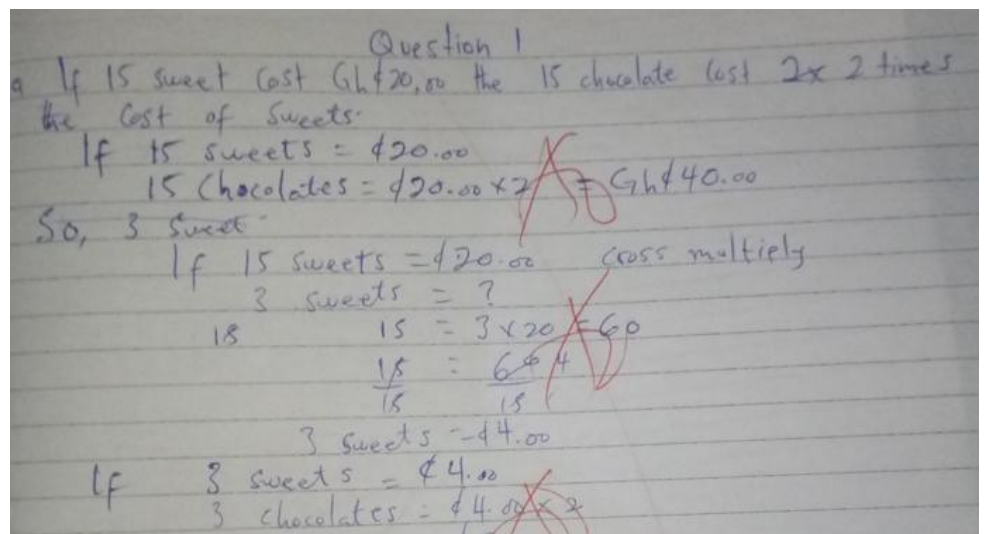


Figure 6. Samples of processing skills error.

It is evident from figure 6 that the student applied the concept of division without realising that it was not relevant to question 5 in terms of algebra. One student also came up with the concept, but regrettably, they misapplied the arithmetic division, leading to an incorrect response. The interview below confirmed the underlying reasons for failures in processing skills.

Researcher: Please, why is your answer 455?

Learner 73: Sir, I first multiplied 100 by 276 and went through the process to get that answer, please.

Researcher: Great, so tell me, is your answer right or wrong?

Learner 73: Sir, please, it is wrong.

Researcher: Why did you get a wrong answer, please?

Learner 73: Sir, please, it is because I used the wrong procedure.

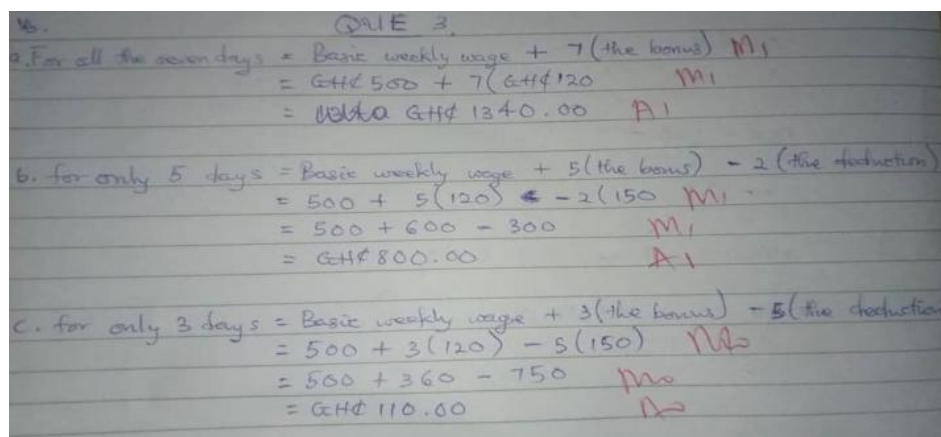
Researcher: So why did you use that approach?

Learner 73: I wrote the wrong answer, though my procedure was correct.

Based on the aforementioned interview, the majority of processing skills errors are caused by students' carelessness and failure to follow the proper procedure to get the correct responses.

4.2.5 Analysis of Encoding Error

This error, known as encoding, happens when learners can solve the problem correctly but are unable to articulate the solution in a way that may be accepted as a conclusion. This kind of mistake may be caused by students' carelessness in answering questions quickly, their inability to pay attention to the details of a question, or their misreading of the instructions related to a question. The majority of students made encoding mistakes when they tried question 2. Evidence of students' work incorporating encoding errors is shown below, taken from question 3.



16. **Q.3**

a. For all the seven days = Basic weekly wage + 7 (the bonus) M_1
 $= \text{GH¢} 500 + 7(\text{GH¢} 120)$ M_1
 $= \text{GH¢} 1340.00$ A_1

b. for only 5 days = Basic weekly wage + 5 (the bonus) - 2 (the deduction)
 $= 500 + 5(120) - 2(150)$ M_1
 $= 500 + 600 - 300$ M_1
 $= \text{GH¢} 800.00$ A_1

c. for only 3 days = Basic weekly wage + 3 (the bonus) - 5 (the deduction)
 $= 500 + 3(120) - 5(150)$ M_1
 $= 500 + 360 - 750$ M_1
 $= \text{GH¢} 110.00$ A_1

Figure 7. Samples of encoding error.

According to figure 7 above, students were able to complete the first four steps of Newman's model. However, due to their haste, negligence, and failure to double-check, they were unable to present their conclusions in a way that could be considered an answer. The interview we conducted below validated the causes of the aforementioned error.

Researcher: Do you really understand question number 3?

Learner 92: Yes, please.

Researcher: In your opinion, is Item Test 1 easy, medium, or difficult?

Learner 92: Sir, please, it is easy.

Researcher: Is there any way in your calculations that you made a mistake?

Learner 92: No, please, I made no mistake.

Researcher: What did you think prevented you from getting the full mark for Item Test 3?

Learner 92: Sir, please, I made a mistake in solving the C part. Instead of using 4 to multiply 150, I used 5 to multiply 150.

Researcher: Why did that happen, please?

Learner 92: Kindly, sir, I thought it was straightforward; therefore, I did not take the time to check the answers and solutions when I finished because I was under pressure to answer every question.

The conducted interview did reveal that the majority of encoding errors made by students are caused by a lack of attention to detail in the questions, carelessness, inaccurate computations, and a hasty decision to answer more questions.

5. Discussion

5.1. The Type of Errors Committed by Students in Solving Algebraic Problems

The study's findings revealed that students committed various types of errors when solving algebraic word problems, including reading, comprehension, transformation, processing, and encoding errors. Among these, transformation errors were the most frequent, followed closely by errors in processing skills. This indicates that although students were able to read and partially comprehend the given problems, many struggled to translate them into appropriate mathematical representations and apply the correct procedures to arrive at accurate solutions. The prevalence of transformation errors suggests that students often resort to rote learning rather than developing a deep conceptual understanding of algebraic principles. This finding is consistent with Newman's (1977) observation that transformation errors typically occur when learners fail to reformulate word problems into symbolic

mathematical language. This finding is consistent with Oppong et al.'s (2024) investigation, which examined the types of algebraic errors made by 250 pre-service mathematics teachers in Ghana. The findings revealed that transformation errors were the most prevalent, occurring in 75.6% of cases, confirming the current study's findings.

Processing skills errors, which were the second most common, highlight the difficulties students face in executing mathematical operations correctly, even when they understand the problem. This finding supports Clements (1980), who stressed that a lack of procedural fluency and over-reliance on mechanical computation often led to persistent mistakes. Such errors in this study were further attributed to carelessness, rushing through questions, and poor arithmetic accuracy. This finding is confirmed by Obeng et al. (2024). Comprehension errors were also evident, particularly in items that required students to interpret technical terms such as price reduction. This demonstrates that language and contextual understanding play a critical role in solving algebraic word problems. As highlighted by previous studies (Daroczy et al., 2020; Mallika & Ali Mohammed, 2024), the linguistic complexity of mathematical problems often hinders students' comprehension and contributes to poor performance.

Reading errors, though less common, showed that some students misinterpreted symbols or overlooked important details in the questions. The finding on reading errors aligns with Obeng et al. (2024), which reported fewer of this kind of errors when high school seniors solved trigonometry word problems. Encoding errors, the least frequent, suggested that while students could work through the initial steps of problem-solving, they struggled to present their final answers in a mathematically acceptable form. This finding aligns with the NEA framework, which identifies encoding as the last critical stage where students must communicate their answers clearly and correctly. However, this result did not corroborate Oppong et al.'s (2024) findings, which indicated that encoding error was the second-highest error committed by participants in their study.

5.2. The Causes of Errors Made by Students in Solving Algebraic Problems

The analysis of students' work, supported by interview data, revealed that the errors committed were primarily influenced by several underlying factors, ranging from instructional practices to students' own approaches to learning mathematics. Each type of error (reading, comprehension, transformation, processing, and encoding) was associated with distinct causes that reflect both cognitive and affective challenges faced by learners. Reading errors were mainly caused by students' inability to read and interpret mathematical symbols or keywords carefully. This is consistent with Newman's (1977) observation that careless reading and inattentiveness often prevent learners from fully grasping the requirements of problems. In this study, students admitted to rushing through questions without rereading, which resulted in misinterpretation. Comprehension errors were found to stem from students' difficulty in understanding the overall meaning of the problems and specific mathematical terminologies, such as reduction and percentages. This finding aligns with Verschaffel et al. (2020), who argue that the language of mathematics often poses barriers to comprehension, particularly when word problems involve abstract or unfamiliar terms. The interviews revealed that ineffective instructional approaches, such as teachers moving too quickly through lessons, as observed by Lotey et al. (2025) in their ICT professional development study, or giving more attention to high-achieving students, exacerbated these challenges.

Transformation errors were primarily attributed to students' over-reliance on rote learning, lack of regular practice, and difficulties in translating word problems into mathematical expressions. This echoes the work of Kenney and Ntow (2024) in Ghana, where both high and low achievers in mathematics made transformation errors the most. Transformation errors often arise because students memorise formulas without understanding how to apply them to varied problem contexts. In the present study, learners admitted that they struggled to recall and apply algebraic concepts correctly, further highlighting weaknesses in conceptual understanding. In this investigation, processing skills errors were mainly caused by carelessness, inappropriate application of arithmetic operations, and students' tendency to rush through tasks. Even when students understood the problem, they frequently failed to follow the correct procedures to obtain accurate results. It was observed that such errors are common among learners who lack procedural fluency or who fail to double-check their work. This finding was also noted in Kenney and Ntow's (2024) study, particularly among low achievers. Additionally, encoding errors were caused by students' negligence in presenting final answers in the correct mathematical form. Some students solved problems correctly but failed to communicate their solutions effectively. This

aligns with Newman's (1977) error framework, which highlights that even when students succeed in earlier stages of problem-solving, carelessness or lack of attention to detail may prevent them from expressing a valid conclusion. This support for the result is also depicted in the study by Obeng et al. (2024), which likewise depicts encoding error as minimal among participants solving trigonometry word problems.

Based on the conclusions drawn from the study, several recommendations are put forward. Mathematics teachers should pay greater attention to developing students' problem-solving skills by incorporating more algebraic word problems into their instructional practices. Instead of focusing predominantly on procedural drills, teachers should encourage students to translate problems into mathematical expressions and guide them to understand the underlying concepts. It is also essential that teachers slow down the pace of delivery, provide adequate support for weaker students, and adopt differentiated teaching methods that cater to the needs of all learners. Schools and administrators should further support these efforts by organising regular mathematics workshops, remedial programs, and peer-learning opportunities to assist students who struggle, particularly those in non-science programs.

Curriculum developers and educational authorities should integrate more mathematics-related activities into programs such as Home Science, Business, and General Arts. This will ensure that students in these areas are not disadvantaged and that the disparity in performance across programs is reduced. Moreover, gender-sensitive approaches to teaching mathematics should be encouraged to boost the confidence of female students and improve their participation in problem-solving activities. Finally, students themselves should be motivated to develop positive attitudes toward mathematics, practise regularly, and avoid relying solely on rote memorisation, but instead focus on conceptual understanding and accuracy in problem-solving.

6. Conclusions

The study aimed to investigate the types and causes of errors students make when solving algebraic word problems. Students committed five main types of errors when solving algebraic problems, namely reading, comprehension, transformation, processing skills, and encoding errors. Transformation errors were the most frequently committed, followed by processing skills errors, while encoding errors were the least common. This suggests that students' main difficulties lie in translating algebraic word problems into mathematical form and in executing correct procedures. Additionally, the causes of errors were found to be diverse. Reading errors were mainly due to carelessness and inattentiveness; comprehension errors were linked to difficulties in interpreting key mathematical terminologies; transformation errors were attributed to rote learning and lack of practice; processing skills errors were caused by carelessness and incorrect use of operations; and encoding errors were a result of haste and poor attention to detail. Interviews further revealed that ineffective teaching strategies, overemphasis on fast learners, and students' negative perceptions of mathematics contributed to these errors. Students' errors in solving algebraic problems are not random but systematic, with errors in transformation and processing skills being the most prevalent. This highlights a lack of conceptual understanding and procedural fluency in algebra among many students. Also, the causes of errors stem from both student-related and teacher-related factors. Students' reliance on rote memorisation, inadequate practice, and carelessness significantly contributed to their errors, while ineffective teaching methods and insufficient emphasis on word problems also played a critical role.

Although this study provides valuable insights into the nature and causes of students' errors in algebra, it is subject to certain limitations that must be acknowledged. Firstly, the research was conducted in a single institution, Agric Nzema Senior High School. This geographical restriction limits the extent to which the findings can be generalised to all senior high schools in Ghana, as different schools may operate under varying socio-cultural, economic, and instructional conditions that influence students' performance in mathematics. Secondly, the study concentrated exclusively on first-year senior high school students and was restricted to selected fundamental algebraic concepts, specifically linear equations, inequalities, and algebraic expressions. More advanced areas of algebra, such as polynomials, quadratic equations, and functions, were deliberately excluded. Consequently, the findings may not fully reflect the broader spectrum of errors that students encounter across the entire senior high school mathematics curriculum. Methodologically, the study employed NEA as the sole diagnostic framework for categorising errors. While the NEA is widely recognised as a valuable tool for error identification, the exclusion of alternative error analysis models limits

the depth and breadth of interpretation that could have been achieved through the triangulation of analytical approaches.

While this study has provided meaningful insights into the types and causes of errors students commit in algebraic word problems, it is limited in scope to one school. Future research could therefore expand to multiple schools or districts to enhance the generalisability of the findings. Further investigations should also explore the extent to which teaching methodologies and teacher-related factors contribute to specific types of errors, and how these can be addressed through targeted interventions. In addition, researchers may consider examining the effectiveness of specific remedial strategies, such as problem-solving workshops, peer tutoring, or the use of ICT-based learning tools, in reducing students' errors and improving their algebraic competence. Longitudinal studies can also help track how students' errors and problem-solving skills evolve, particularly as they progress through different levels of education. Lastly, comparative studies between schools in urban and rural contexts may provide deeper insights into how contextual factors influence the nature and frequency of errors in solving algebraic problems.

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Appendix

Questions

1. A pack of 15 sweets cost GHC 20.00 and a pack of 15 chocolates cost GHC 40.00. Write down an expression to find the cost of buying 3 pack of sweets and 3 packs of chocolates and hence find the total cost using the distributive property.
2. A farmer has twice as many goats as sheep. Altogether, the animals are 54. Form an equation to represent this situation and determine how many goats and sheep the farmer has.
3. A supermarket pays its sales personnel on a weekly basis. At the end of the week, each sales person receives a basic weekly wage of Gh 500, less Gh 150 for every day he was absent, and plus a bonus of Gh 120 for every day he worked. How much did a man earn in a week in which?
 - i) he worked for all the seven days
 - ii) he worked for only 5 day
 - iii) he worked for only 3 days?
4. Ama is collecting seashells on the beach. On her first day, she collected 1 seashell. Each day after that she collected 2 more seashells than the previous day. How many seashells will she have on the fifth day? Generate a pattern and use it to formulate mathematical expression.
5. A local computer store is having a promotional sale on digital cameras. After a 40% price reduction, you purchase a digital camera for GHS276. What was the camera's price before the reduction?

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