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Analysis of Senior High School Student's Errors in Solving Word Problems Using Newman's Error Analysis (NEA) Procedure

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ABSTRACT

The study was intended to analyze Senior High School students' errors in solving algebra word problem using Newman's Error Analysis (NEA). The study employed descriptive qualitative design. 70 S.H.S 1 students were randomly sampled from the three Senior High Schools within the Nkoranza North District. Teacher-made word problem diagnostic test was conducted and Newman's Error Analysis (NEA) checklist used to analyze students' errors in the test. Various descriptive statistics such as Bar graph, pie chart and frequency distribution were used to described the errors committed. The study found that, out of the 623 total errors committed by the 70 students in the 10-item test, 45.4% was on comprehension errors, 34.4% was transformation errors, 13% was process skills errors, 5% was encoding errors and the least being reading errors which is 2.2%. It is recommended that mathematics teachers thoroughly teach the meaning of words used in crafting word problem items and also tailor their strategies towards the changing of word problems into mathematical models and equation. The finding of this study would equip mathematics teachers within the study setting with a scientific based information on the kind of errors students make in solving word problems. This information would then be used as foundation in coming out with strategies to mitigate or curtail the errors students commit in solving word problem.

KEYWORDS: error analysis, Newman's Error Analysis (NEA), word problem

INTRODUCTION

Education is as important to man as water and air are to life and must be acquired by all in this 21st century to be able to compete considerably in this era of science, mathematics and technology (Chen, Van Dooren, Chen, & Verschaffel, 2011; Leh, & Jitendra, 2013). The procedure to attainment of education is as imperative as its outcome (Jupri, & Drijvers, 2016). In Ghana, formal education delivery span through pre-school, primary school, Junior High School (J.H.S), Senior High School (S.H.S) up to tertiary. In all these levels of education, mathematics is taught with increasing difficulty. This is because mathematics skills and knowledge must be mastered as it forms the basis of our daily life, career development, and science and technology (Tambychik, Meerah, & Aziz, 2010). In spite of its importance, mathematics is still considered a difficult subject for students. The Ghana Education Service S.H.S mathematic syllabus contains several topics of which word problem is embedded in almost all the topics owing to its relevance in our daily life.

Word problems are mathematics problems that allow room for students to link the content learnt in the classroom to real- life situations which they would ultimately encounter after vacating the four walls of the school (Dewanto et al. 2017). It goes beyond students' skills to carry out the required mathematical operation, it includes their ability to decipher the text of the word problem (Boonen et al., 2016). Cuevas, (2000) argues that solving word problem is considered an important skill in mathematics which should be acquired by all and sundry. More importantly, word problem activities can be employed to ascertain how well students have mastered a mathematical concept (Khoshaim, 2020). Despite the overwhelming benefits of word problems in the life of students, they view solving word problem as cumbersome and herculean as a result will do everything possible to avoid it in exams and the few who master courage to squarely face it perform poorly (Fatmanissa & Sagara, 2017; Haryanti et al., 2019; Said & Tengah, 2021; Sanwidi, 2018; Anane et al., 2016).

In recent years, 2020 and 2021, the Chief Examiner's Report on core mathematics indicates that many students who sat for WASSCE skirt questions bothering on word problem and the handful of students who attempted such questions were unable to resolve the problems into mathematical models or equations (WAEC, 2020, 2021). The 2015 and 2021 report also has therein that, BECE candidates were also unable to successfully complete questions on word problem (WAEC, 2015, 2021).

The researcher's encounter with S.H.S students and mathematics teachers in the Nkoranza North District brought to light the enormous challenges the students face regarding word problem. The researcher himself is a living testimony to this almost- global canker as he teaches mathematics at the S.H.S since 2017.

The glaring evidence of students challenges available to the researcher coupled with the facts presented in the Chief Examiner's Report occasioned the need to embark on the study to analyze the errors S.H.S one students commit in solving algebra word problem using Newman Error Analysis (NEA) procedure. Identifying errors of students is an important exercise and almost indispensable as it allows teachers to be best informed on the kind of errors their students make and would aid in finding ways to curtail those errors.

Newman (1977) has enacted a procedure to analyze the problems the students encounter in solving mathematics problems and christen it Newman's Error Analysis (NEA). NEA can also be adopted to examine the errors of students in handling higher-order thinking skills in Mathematics (Abdul Halim, Nur Liyana & Marlina, 2015). Newman opined that when a person attempts to answer word problem question in mathematics, then that person has to go through a number of consecutive stages: Reading (or Decoding), Comprehension, Transformation, Process Skills and Encoding.

There are five stages in the solution of mathematical problems, namely (a) reading; which is the ability of students to read mathematical problems given and to identify sentences and mathematical symbols used (b) comprehension; that is the ability of students to understand math problems, (c) transformation; that is the ability of students to determine the method of mathematical solution, (d) process skill; that is the ability of students in following mathematical procedures correctly, and (e) encoding; that is the student's ability to write correct answers according to the question (Newman as cited in Abdul, 2015).

It is absolutely necessary to identify the kind of errors students make in solving word problem before proposing a method or strategy to help mitigate the errors students make in their handling of word problem. Some of the previous studies on error analysis that employed NEA procedure are chronicled below.

Santoso, Farid & Ulum (2017) using NEA procedure to analyze the errors of grade 11 students in solving word problem involving linear programming, arrived at the conclusion that the most errors made by student is transformation error followed by process skills error. They recommended that the analysis of students' error is pertinent in trying to fashion out treatment to limit the kind of errors the students make. This study was done in Indonesia with a sample size of 32 grade 11 students. A similar study conducted in Indonesia by Ayuningtias and Sudihartinih (2020) on the analysis of S.H.S two students' errors in linear program topics, found that out of the five female students sampled, three committed transformation errors, two committed process skills errors and encoding errors. The difference between these two studies and this current study is the location and the sample size used. This current study is carried out in Ghana with a sample of 70 S.H.S 1 students comprising experimental and control groups.

In Nigeria, another study was conducted to analyzed the errors class six pupils make in solving word problems involving fraction by Zakariyya and Beji (2018). Their study turned out that the most errors committed by the pupils were process skills and encoding errors with 23.9% and 21.8% respectively according to Newman Error Analysis hierarchy. They recommended in their study that; mathematics teachers should endeavor to analyze the worksheets of pupils to identify errors that would aid to correct misconceptions and to adapt ways that can help manage the errors of students.

Another research was undertaken in Indonesia to analyze High School Students errors in trigonometry word problem based on the Newman hierarchical model by Wardhani and Argaswari (2021). Wherein they discovered that, the most errors made by students were process skills errors (29.8%), econding errors (29.8%) and transformation errors (22.63%). Transformation error, process skills error and encoding error were committed by low, average and high mathematics achievers in solving exponential word problem (Hidayah & Rejeki, 2022).

Newman error procedure was again employed by Bayos (2019) to analyze the errors of grade seven students in mathematical word problem involving fraction wherein he found that, transformation error was most committed by students followed by process skills errors which were 50.6% and 33.6% respectively. Similarly, comprehension, transformation, process skills and encoding errors were predominantly committed by students in solving word problem involving least common multiple and greatest common divisor (Lestari & Nahdataeni, 2022).

Yang, Sherman and Murdick (2011) posited that analysis of learners' errors is paramount for mathematics teachers as it can be used to enact ways to limit the errors of learners. They suggested that mathematical vocabulary, comprehension and conceptual development be taught.

Similarly, Luneta and Makonye (2010) assumed that poor mathematics performance is closely related to errors committed by students and their misconceptions.

Despite the growing interest around the globe with regards to error analysis in word problem, there is scanty literature on error analysis in word problem in the Ghanaian setting. This study intends to analyze S.H.S 1 students' errors in solving algebra word problems in Nkoranza North District, Ghana.

RESEARCH METHODOLOGY

The study employed descriptive qualitative design. 70 S.H.S 1 General Art students were randomly sampled from the three S.H.S schools within the Nkoranza North District. The instruments used were Newman's Error Analysis (NEA) checklist and a teacher-made word problem diagnostic test. The test contained 10 items and was administered within 60 minutes and scored out of 30. The NEA checklist was used to analyzed the errors in the solutions of students to the test. Descriptive statistics such as bar graph, pie chart and frequency table were used to describe errors committed by students.

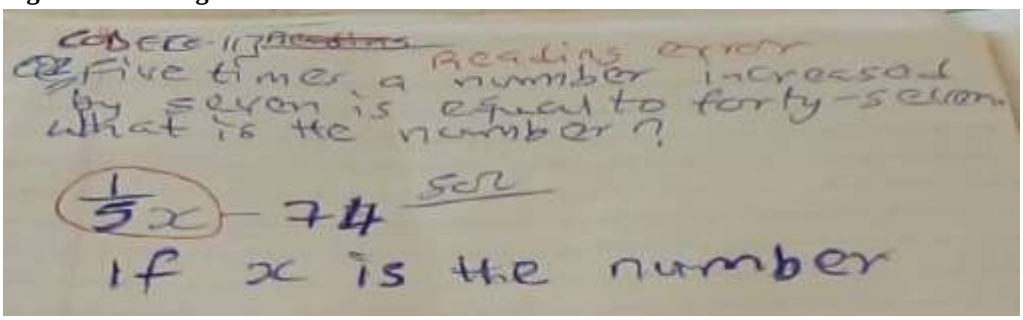
RESEARCH RESULTS

Teacher-made diagnostic test containing 10 items was conducted to analyze the errors S.H.S 1 students make in solving word problem in. The analysis was done using Newman's Error Analysis (NEA). Newman (1979) identified five errors that characterizes students' solutions to word problem. Namely: reading error, comprehension error, transformation error, process skills error and encoding error. Errors were analyzed item by item for each of the 70 students. Below are extracts of students' errors identified in the test:

Reading error

Reading error occurs when students misread terms, symbols or important words in the problem. It can also be viewed as students' inability to read at all. Identifying reading errors from the scripts of participants was the toughest among the other errors. In order to be sure if students committed reading error, the researcher moved a step further to get participants who were suspected to have committed reading error to read. Out of the reading exercise, the reading errors were identified and classified accordingly. Below is an extract of reading error identified from the test.

Figure 1: Reading error of E-11

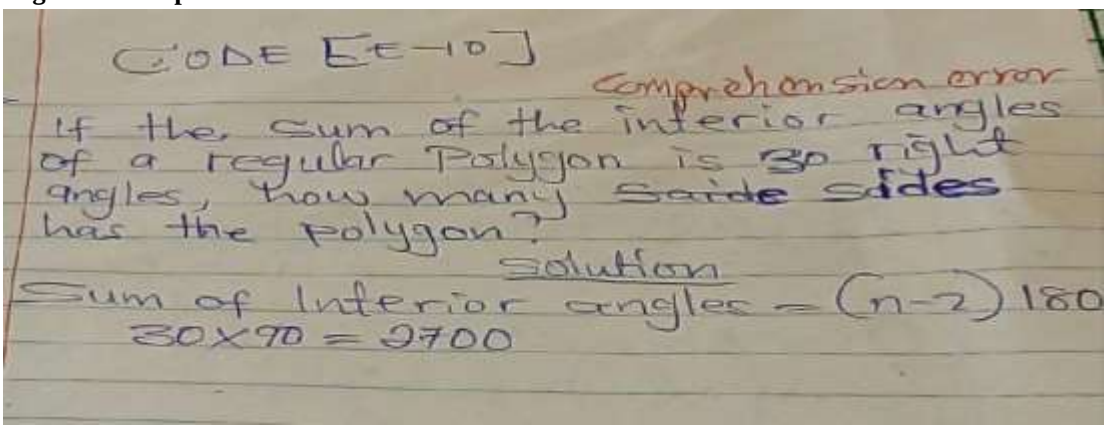


Source: author's own development

Comprehension error

Comprehension is seen as the ability of students to understand and decipher the mathematical terms used in the question having successfully read the problem. It is the second hurdle students must surmount to appropriately solve a word problem. Comprehension error happens when students are unable to understand what the question demands of them or unable to continue the process or write what is known from the question as what is asked. Below is a sample of comprehension error identified from participant's script in the test.

Figure 2: Comprehension error of E-10

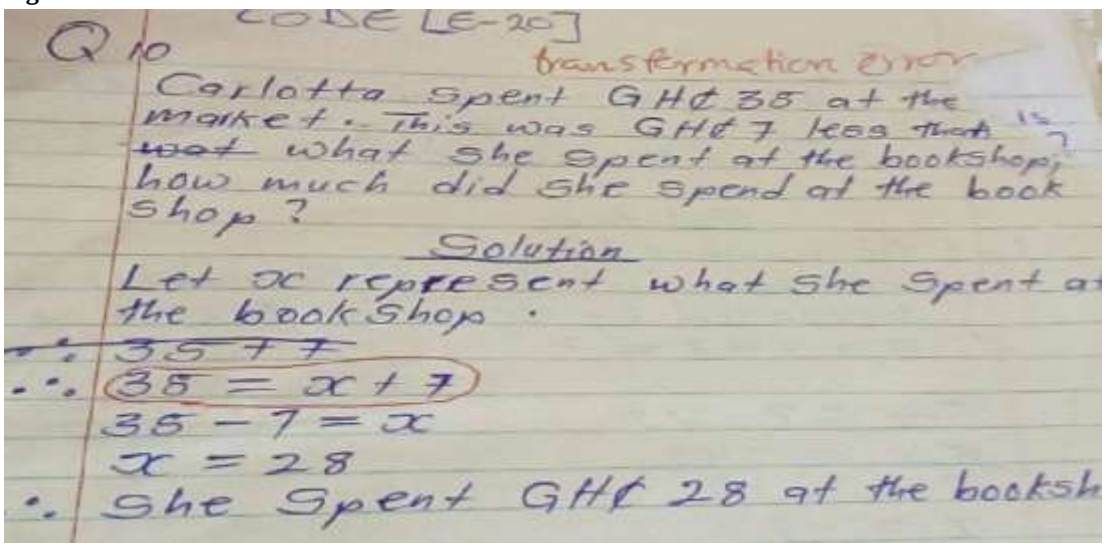


Source: Author's own development

Transformation error

Transformation error occurs when students fail to convert the given word problem into mathematical model or equation from which the problem can be resolved. Below is a sample of transformation error in the work of participant from the test.

Figure 3: Transformation error of E-20

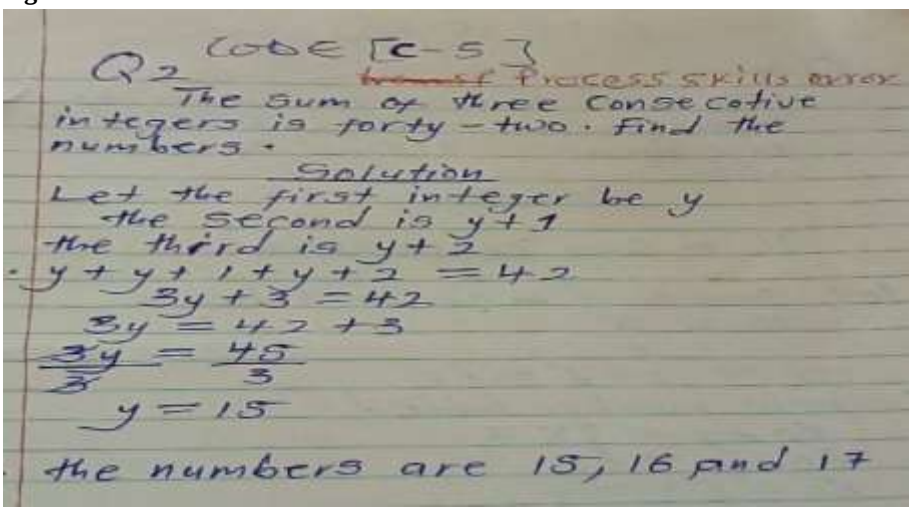


Source: Author's own development

Process skill error

Process skill error is committed when students do wrong calculations or unable to complete a procedure or continue but is not right. The pictures below present samples of process skill error identified in the works of participant.

Figure 4: Process skill error of C-5

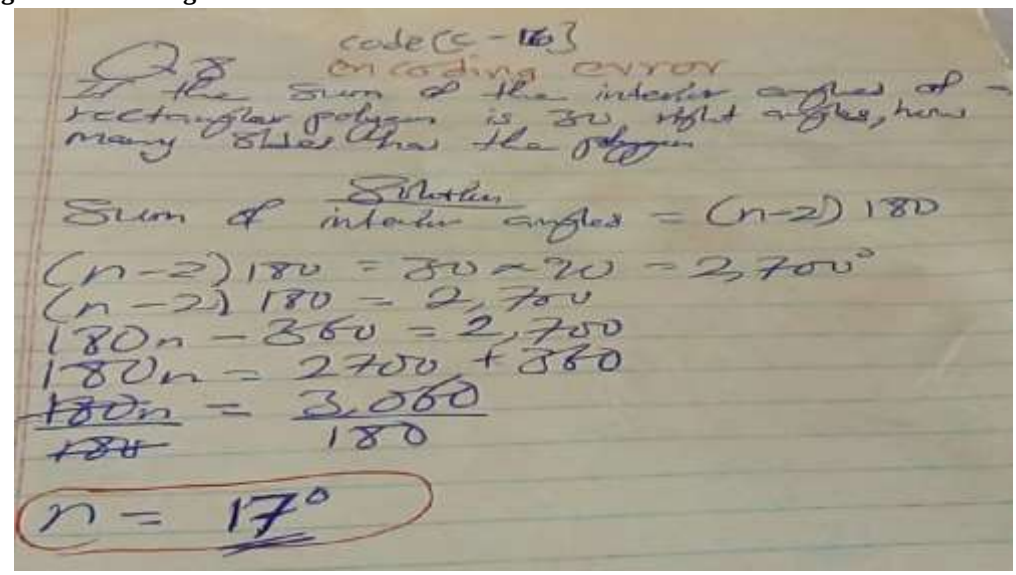


Source: Author's own development

Encoding Error

Encoding is the last stage in resolving word problem. Encoding error occurs when the answer to a question is not accurately written. For instance, writing an angle without its accompanying degree as the unit or writing mass with "cm" attached as its unit. When an answer doesn't take it correct form, then encoding error has occurred. Below are samples of encoding errors committed by participants in the pre-test.

Figure 5: Encoding error of C-16



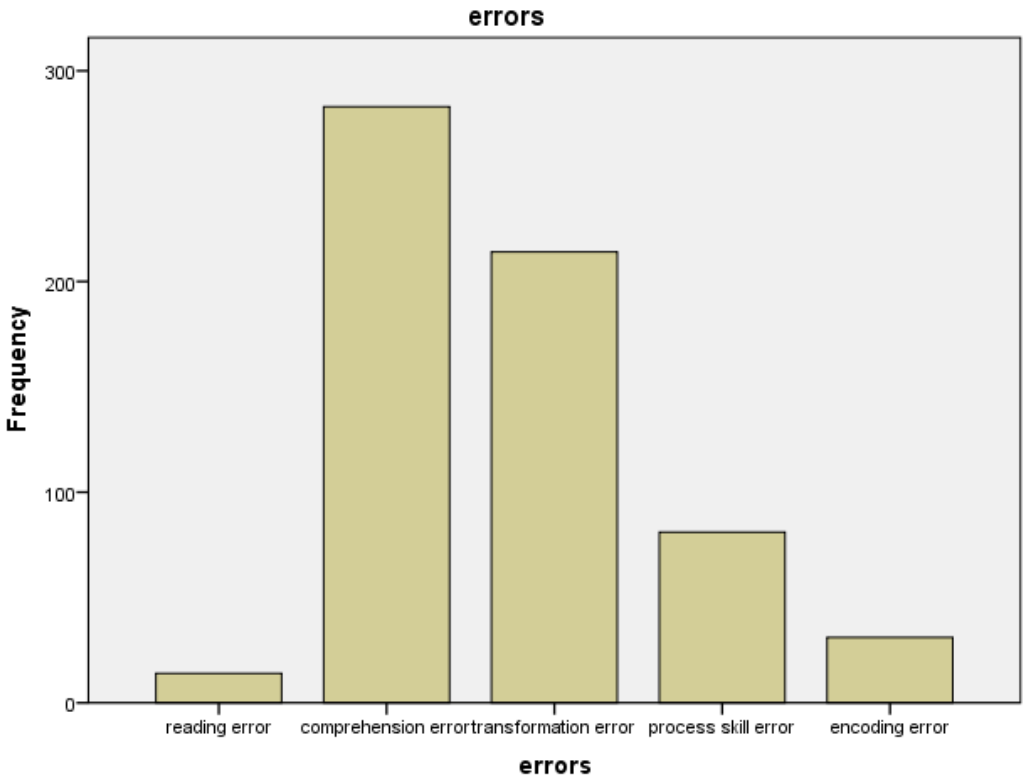
Source: Author's own development

Table 1: Item by item analysis of errors committed by participants in the test

Errors committed by Students	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Total	%	R
Reading Error	0	2	0	2	4	0	0	3	0	3	14	2.2	5TH
Comprehension error	35	30	26	26	32	25	32	20	25	32	283	45.4	1ST
Transformation error	10	25	30	29	20	15	18	20	30	17	214	34.4	2ND
Process skills error	6	4	9	6	8	10	15	10	5	8	81	13.0	3RD
Encoding Error	5	2	3	5	6	4	0	3	1	2	31	5.0	4TH
Total	56	63	68	68	70	54	65	56	61	62	623	100	

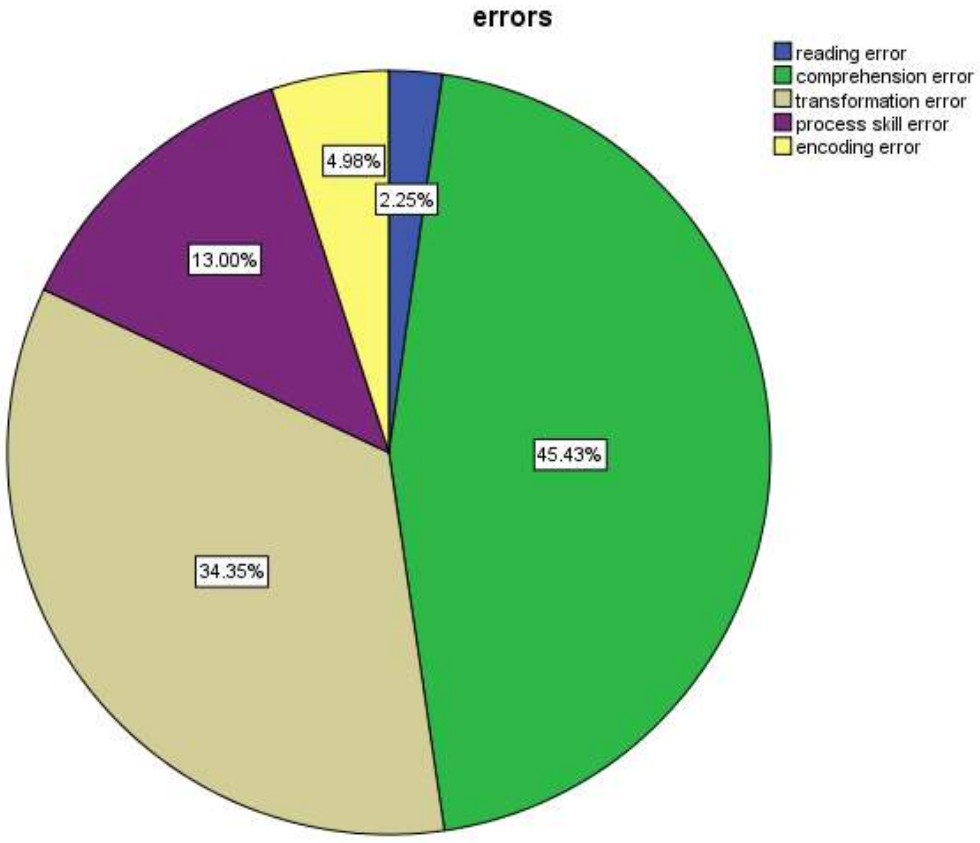
Source: Author's own development

Figure 6: A bar graph displaying the errors committed by students in the test



Source: Author's own development

Figure 7: A pie chart showing the errors committed by students in the test



Source: Author's own development

DISCUSSION

Participant with code E-11 whose error is shown in figure 1 above misread 'five times' as 'one-fifth' and could not pronounce 'forty-seven' at all. The student was presented with a number of the pre-test questions to read and that didn't seem easy for him as he struggled and fumbled throughout. It was therefore clear that the student committed reading error and was appropriately classified as such in accordance with NEA checklist used for identifying the errors. It is also evident from the script that, his inability to read hampered his effort to do something about the problem.

The expected answer to the question 1 (five times a number increased by seven is equal to forty-seven. Find the number?) from the test handled by E-11 is presented below;
If the number is *y;* five times the number gives 5*y;* increased by seven yields $5y + 7$ and finally equal to forty-seven produces the equation; $5y + 7 = 47$. Collecting like terms and dividing both side of the equation by 5 will leave $y = 8$. ∴ The number is 8.

In figure 2, participant E-10 managed to write the formular for sum of interior angles of a polygon correctly as $(n-2)\,180$ and also got '30 right angles' as $30 \times 90 = 2700$ right. At this point, no further effort was made by the participant to find the value of *n* which represent the number of sides of the polygon. The inability of the participant to continue the process clearly indicate lack of clue as to what is expected of him by the question. After quoting the formular for sum of interior angles of a polygon and also getting 2700° which is equal to the sum of the interior angles of the polygon in question, the next step was to equate the formular to 2700° and proceed to solve for the value of *n* as shown below;

$$(n-2)180 = 2700;$$

multiplying to remove the bracket gives;

$$180n - 360 = 2700$$

Collecting like terms and dividing both sides of the equation by 180 leaves $n = 17$

∴ The number of sides of the regular polygon is 17. The above is the supposed solution to the question 8 (if the sum of the interior angles of a regular polygon is 30 right angles, how many sides has the polygon?) from the pre-test which E-10 was unable to complete due to lack of understanding of the question. The participant's error was appropriately captured as comprehension error in line with NEA checklist used for the analysis.

Participant with code E-20 in figure 3 above clearly was able to read and comprehend the problem and knew clearly what was asked of him. He was able to define a letter to represent the amount Carlotta spent at the bookshop but failed to transform the problem to mathematical equation accurately. The pre-test question 10 was "Carlotta spent 35 Ghana cedis at the market. This was 7 Ghana cedis less than what she spent at the bookshop; how much did she spend at the bookshop?" the student defined *x* to represent the amount Carlotta spent at the bookshop but wrongly captured the equation as $35 = x + 7$ instead of $35 + 7 = x$ or $35 = x - 7$ which would have yielded 42 Ghana cedis as the amount Carlotta spent at the bookshop. Despite the wrong equation, the participant went ahead with the process to get an answer which is automatically wrong because of the wrong equation. It is clear the participant knew what he was doing only that his effort was thwarted by the wrong transformation of the problem. The error was identified as transformation error using the NEA checklist.

Participant C-5 in responding to question 2 (the sum of three consecutive integers is forty-two. Find the numbers.) from the test, successfully went through the first three hurdles; reading, comprehension and transformation as shown in figure 4. The accurate description of the three integers showed reading and comprehension success. The equation was appropriately written as $y + (y + 1) + (y + 2) = 42$ and further simplified as $3y + 3 = 42$. At this point, instead of transposing $3y + 3 = 42$ as $3y = 42 - 3$ it was wrongly grouped as $3y = 42 + 3$ and that was purely a process skill error. The participant in carrying 3 across the equal sign still maintained its positive status against principles of arithmetic. The error committed by the participated was graded as process skill error as he passed the transformation stage and whatever error happens afterwards before the final answer is seen as process skill error.

Participant C-16 went through the entire procedure well in responding to question 8 (the sum of the interior angles of a regular polygon is 30 right angles, how many sides has the polygon?) as shown in figure 5. However, in writing the final answer to the question the student erred by writing 17° as the number of sides of a polygon. It is an angle that is measured in degree and not number of sides of polygons. The correct form of the answer should have been 17 and not 17° as advanced by the participant. The error committed is strictly encoding error per the NEA checklist used for the analysis.

Figure 6 displays a visual overview of the errors the 70 students have committed in the test. It can be seen that the highest error committed is comprehension error which stood at 283, followed by transformation error which is 214. Process skill error is 81, encoding error is 31 and the least error committed is 14 which is reading error. Figure 14 below is a pie chart displaying the errors committed in the pre-test.

Figure 7 is a pie chart throwing more light on the errors students committed in the pre-test. A whopping 45.43% of the errors committed represent comprehension error. 34.35% of the 623 total errors committed were found to be transformation error. Process skill error is 13.00% as shown in the chart above. Whereas 4.98% of the errors were encoding error and reading error was the least error committed and was 2.25% of the total errors committed.

Table 1 above shows the analysis of the errors committed by students in the pre-test which consisted of 10-

word problem items and was taking by both the control and experimental groups within 60 minutes. It was scored out of 30 and converted to 100%. The number of participants were 70 and every participant committed at least one error.

Out of the 623 errors committed, comprehension error constituted 283 equalling 45.4 % of the total errors, followed by transformation error which amounted to 214 making 34.4% of the total errors committed. Process skill error constituted 13.0% of the total errors committed. Encoding and Reading errors recorded 5.0% and 2.2% of the total errors committed respectively.

It should be noted that, not more than one error was ascribed to a participant responds to an item. The errors are hierarchical and so priority was given to the first error committed and not the subsequent ones on the same item. No error was ascribed to an item that was left unattended to by a participant.

It is clear from the table that, reading error was the least committed and that is not news because a student in S.H.S 1 should not have reading difficulty. However, some still do. It can also be argued that process skill error and encoding error were less committed because participants were hugely stuck at the comprehension and transformation levels.

The high comprehension errors (45.4%) recorded confirms the earlier work of Haerani, Novianingsih & Turmudi (2021), where they found 28% comprehension errors made by students and representing the highest of the errors made. It however contradicts the findings of Wijaya, Heuvel-panhuizen, Doorman & Robitzsch (2014) and Bayos (2020), wherein they recorded 42% and 50.6% of comprehension and transformation errors respectively. Wijaya et al, (2014) and Hairani et al, (2021), all found comprehension errors and transformation errors to be the two most committed errors by the students which is in agreement with the data displayed in table 1.

CONCLUSIONS AND IMPLICATIONS

It is found from the study that a total of 623 errors were committed by the 70 students in the test. Out of which 14 (2.2%) were reading errors, 283 (45.4%) were comprehension errors, 214 (34.4%) transformation errors, 81 (13.0%) were process skills errors and 31 (5.0%) were encoding errors. Conclusion can be drawn that the errors committed most by S.H.S 1 students in Nkoranza North District are comprehension errors and transformation errors. Reading error is the least committed error.

The conclusion reached implies that, in teaching word problem, teachers should prioritize teaching the meaning of the vocabularies used mostly in crafting word problem items. Transforming problems into mathematical models or equations should also be given attention by teachers and students alike. English teachers should also emphasise comprehension in their English lessons. GES and head of schools within the district can organise workshops to educate teachers on the need to analyse students' errors as knowing the errors of students will help in designing appropriate strategies in addressing those errors. Further studies can be conducted to unearth the kind of strategies that can be adopted to remedy the errors students exhibit in solving word problems.

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