Grade 12 learners' performance on direct algebraic equations vis-à-vis word problem equations: A case study of one school in Oshana Region, Namibia

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Abstract
The purpose of this study was to compare the Grade 12 learners' performance in Direct Algebraic equations and Word Problem equations. Data were collected from school X in Oshana region. The study sought answers to the following two questions: "How does the performance of learners in Word Problem Equations (WPE) compare with Direct Algebraic Equations (DAE)?" and "What is the correlation between the performance of learners in WPE and DAE?". The mixed method was used to collect the data from the sample from 19 learners who were randomly selected to take part in this study. The study employed written tests as instruments for data collection in this study. It was found that both qualitative and quantitative data indicated a lower performance in WPE as compared to DEA. On the relationship between the performance of learners in DAE and WPE the study found a weak positive correlation (r=0.446). The study also found t that the weaker comprehension of WPE was fueled by learners' limited fluency in translating the wordy mathematical problems into direct equations that they could then manipulate algebraically.

Keywords: *direct algebraic equations; word problem equations, performance, Namibia*

Background of the problem

Mathematics was to become a compulsory subject in Namibian schools in 2012 (Ministry of Education, 2010). Reed (2009)notes that mathematics possesses the ability to equip learners to develop a passion for problem solving. It also encourages learners to opt to study science and mathematics courses at tertiary level. However despite this claim, the learners at secondary school phase still continue to underperform in mathematics especially in the topic on algebraic manipulation (Robert, Samuel, & Samuel, 2018). This poor performance is of great concern to teachers and public at large and needs an intervention to enhance learner performance in mathematics.

In contemporary Mathematics Education many methods of teaching and learning are problem solving centred. This allows problems to be contextualized (Robert, Samuel, & Samuel, 2018). Algebra is one of the topics in the school curriculum and has been found to negatively impact learners' performance.

According to Reed (2009) and Ellis (2014), algebraic problems can be classified into two: word problem equations and direct algebraic equations. Therefore, it can be argued that any algebraic problem can be stated into two ways; that is, as a word problem equation where the learner has to translate the problem into a mathematical context. On the other hand there are direct algebraic equations where the learner has to use direct algebraic manipulations without necessarily having to contextualize and synthesize the problem (Paige & Simon, 2009). Literature in other parts of the world (Carraher & Schliemann, 2011; Nathan, 2012) has it that the learners tend to perform better in direct algebraic equation problems as compared to word problem equations. However, the local literature in Namibia such as (Robert, Samuel, & Samuel, 2018), seem to suggest that the performance of learners in Algebra seems to be very low. This situation calls for interventions in order to seek means by which low student performance on algebra questions could be mitigated.

Statement of the problem

Panasuk & Beyranevand (2010) indicate that the demands for Algebra increases as learners move to the next grades. Allegations from literature (Ministry of Education, 2010;

Panasuk & Beyranevand, 2010) have it that there is poor performance in Algebra particularly in solving different kinds of equations among Grade 12 extended learners. Also, Ministry of Education (2010) holds the opinion that Grade 12 learners perform poorly in Algebra as compared to any other topic in Mathematics. Therefore, it can be argued that if unattended, this the learners' poor performance in solving different kinds of equations will ultimately affect their overall performance in Mathematics.

It appears that there is a need to compare this group of learners' performance in direct algebraic equations against their performance in algebraic equations expressed as word problems. Therefore, this study was carried out to establish how the performance of learners in the Direct Algebraic Equations (DAE) compared with performance on Word Problem Equations (WPE). The study also attempted to establish the correlation between the learners' scores in direct algebraic problems vis-à-vis their scores in algebraic word problems.

Research questions

The following research questions were addressed in this study:

1. How does the performance of learners in WPE compare with their performance in the DAE?
2. What is the correlation between the performance of learners in WPE and DAE?

Limitations of the study

The successful data collection of this study depended on the willingness of the participants (both learners and teachers) to participate in the study. It was anticipated that some participants in this study might not take part due to some other activities of the time. Since the data was drawn from a particular school only, the results of this study might not be generalized to other populations of different settings.

Literature review

Learners' Performance in Algebra

Passing in Mathematics calls for teachers and learners to share feedback about the current state of knowledge in the area for improvement. This appears to imply that, knowing the learners' performance is a constructive part of learning through which one finds out weather the learner understands the content (Ziegler & Kapur, 2018). This follows the argument that it helps to identify the extent to which the learners understand and figure out how they can master the part they did not understand. However, in the context of learning algebraic manipulation skills, we define failure as errors students make in the application of these Algebraic skills such as solving problems in Algebra.

Performance in Algebra varies depending on individual differences in intelligence, high-intelligence students usually make fewer errors when handling and manipulating algebraic problems compared to low-intelligent students, as creativity and intelligence share a common cognitive base (Ziegler & Stern, 2012). Therefore, supporting the foregoing argument presented in the aforementioned literature, it is possible to argue that the learner's intelligence influences his/her ability to manipulate algebraic expressions. It is therefore imperative that the learners are prepared both knowledge wise and psychologically to cope with this perceived difficult topic.

Teacher-related factors on the learners' performance in Algebra

According to Nhlanhla (2014) the teacher's experience and level of understanding of the concept were some of the factors affecting the performance of learners in Algebra. The argument by Nhlanhla leads to the conclusion that some of the teachers who do not possess enough knowledge of the content, end up making excuses such as "the school was not provided with enough study material to aid the instruction in algebra".

On the other hand Silas (2014) argues that teachers often do not provide the learners with enough practice for them to master Algebra content. It is thus advisable that teachers ensure that learners are provided with enough learning materials that present algebraic practice from different perspectives to ensure that the learners are acquainted with different kinds of situations and contexts that boost their algebraic manipulation skills.

Learner-related factors to their performance in Algebra

A few factors have been identified in the literature as impacting the learners' performance in Algebra. For instance, Nhlanhla (2014) holds the idea that learners lack strategic competencies in solving algebraic problems and equations, they lack conceptual understanding, learners are supposed to master procedures and processes of problem solving rather than becoming obsessed with their finding the correct answer.

In addition, the literature e.g., Zachariah, Komen, George, & George (2012) found that learners also tend to ignore the rules of Algebra that they ought to master and to apply when solving several algebraic problems and equations, ending in confusion and misapplications of rules leading to low performance in Algebra.

The t social factors effect on the learners' performance in Algebra

Some learners are not motivated to do mathematics, while some learners believe that mathematics is a very difficult subject especially Algebra. These learners are discouraged by the feedback they get on the mathematics test.

Additionally, there are learners who believe that mathematics can only be done by certain people and that boys only perform better in mathematics. In some cases, learners also look up to their role model and if they use not to do better in mathematics, thus if their role model has a phobia of mathematics they will be discouraged do mathematics and vice versa (Mayer, 2011). It is therefore, imperative that the learners are role modeled by their teachers to stimulate their interest in learning Algebra and Mathematics.

Learners' performance on Direct Algebraic Equations (DAE)

A limited number of research studies focusing on direct algebraic equations have documented the techniques learners use while solving direct algebraic equations, learners' understanding of and difficulties with solving direct algebraic equations (Lima, 2008; Zakaria & Maat, 2010), the teaching and learning of direct algebraic equations in classrooms (Olteanu & Holmqvist, 2012), relating how direct algebraic equations are handled in mathematics textbooks in different countries (Sağlam & Alacacı, 2012), and the application of the history of quadratic equations in teacher preparation programs to highlight prospective teachers' knowledge (Clark, 2012).

For most learners, direct algebraic equations create challenges in various ways such as difficulties in algebraic procedures, and inability to apply meaning to the equations. Kotsopoulos (2009) suggests that recalling main algebraic facts directly influences a learners' ability while engaged in solving equations. Lima (2008) and Tall (2014) concur that learners' lack of understanding on the procedures of direct algebraic equations, and their understanding based on "procedural embodiments," affect learners' work on direct algebraic equations. Learners tend to assign meaning to equations and solving methods, however, the given meaning is related to the movement of the symbols rather than the mathematical concept. Furthermore, Lima (2008) also documents that learners perceive direct algebraic equations as mere calculations, without paying attention to the unknown as a fundamental applicability of an equation to real-life situations. Therefore, it can be deduced that learners mostly focus on the symbolic world to perform operations with symbols.

Vaiyavutjamai (2009) proposed that learners' difficulties with direct algebraic equations stem from their lack of instrumental understanding and relational understanding of the specific mathematics associated with solving direct algebraic equations. They suggest that while teacher-centred instruction with strong emphasis placed on the manipulation of symbols, rather than on the meaning of symbols, increases learner performance on solving direct algebraic equations, their (relational) understanding would still be quite low, and they could develop misconceptions.

Learners' performance in Word Problem Equations (WPE)

Olteanu & Holmqvist (2012) content that application problems habitually appear in the form of words, Judi & Robert (2017) reckon that equations are considered helpful in tracking learners' understanding of procedures and detecting differences among learners' solutions of word problem equations. These

studies have to some extent exposed the fact that solving algebraic word problems equations can be challenging for the majority of learners because the prescribed algebraic system generates a serious barrier to generating equations that represent the relationships within the problems.

Seling (2016) on the other hand, notes that learners' challenges depend, not only on a formal algebraic outline in the solution phase, but also on the linguistics form of the word problems in the comprehension phase. Literature (e.g., Cai, Mayer, Wand, & Nie, 2011; Koedinger & Nathan, 2010) hold the idea that the process of solving algebraic word problem equations consists of a "comprehension phase and solution phase". This means, in the comprehension phase, a problem-solver attempts to understand and then forms the text base of the problem, using words as an internal representation. Additionally, in the solution phase, she or he expresses this internal representation externally and applies the rules of Algebra to reach a conclusion.

A number of research studies (Koedinger & Nathan, 2010; Seling, 2016; Olteanu & Holmqvist, 2012; Judi & Robert, 2017) have offered evidence that WPE could be a challenge to many learners. Additionally, Acosta-Tello (2010) indicates that learners' difficulties in solving algebraic word problem equations stem from the difficulties they have in symbolizing meaningful relationships within algebraic equations whereas Judi and Robert (2017) attributed the word problem-solving difficulties to the learners' psychological processes of words in the problem, the presence of cue words and the magnitude of the numbers which affect the learners' abilities to comprehend and provide a solution to the algebraic problem.

In addition to the foregoing, the text comprehension factor could be the main issue for learners in solving word problems (Xin, 2008). However, Nhlanhla (2014) stresses that inadequate mapping of phrases retards learners' abilities of solving word problems. Additionally, Koedinger & Nathan (2010) point out that students make errors because they fail to see how the situational aspect of the problem is related to the formal expressions in their attempt to produce the proposed internal representations. There is hence a need for teachers to offer professional support and guidance in these areas. Despite the fact that language forms the problem's text and bears the significant factors that affect the comprehension process as stated in the foregoing, Stacey and MacGregor (2009) claim that learners' difficulties with word problems also arise from failing to understand the algebraic logic of a problem.

It is therefore clear on the basis of studies cited in this section that researchers argue that due to prior experiences with arithmetic word problems, learners perceive the problem-solving process as a series of calculations and shift their thought process from algebraic thinking to arithmetic thinking when solving algebraic word problem equations. It can also be deduced that it is possible that learners read, understand and accept challenging questions but become confused when translating the story problem to mathematical statements thereby using the substitution method to solve mathematical statements leading to unsatisfactory performance in Algebra.

In summary, the literature review indicates that learners' performance in Algebra is not satisfactory due to the fact that some teachers do not provide enough learning materials to learners for them to practice more to minimize errors made by learners when solving algebraic problems. Also, it was noted that learners themselves also tend to ignore the rules of algebra when solving algebraic problem, since their desire is just to find the correct answers as opposed to knowing the right procedures that are applicable when solving the problems. The literature also indicates that learners find it difficult to translate the word problems into arithmetic problems.

However, based on the available literature, it appears that researchers did not compare the performance of learners in the two categories of Algebra (Direct algebraic equations and Word problem equations). According to the DNEA (2017), in the Grade 11-12 syllabus, algebra makes up 35 percent of the assessment. This implies that learners need to be comfortable with Algebra as a topic to avoid compromising their overall performance.

The foregoing situation causes learners' poor performance. If intervention is not done, will compromise the learners'

performance to a greater extent. This is due to the fact that learners will continue to experience problems with formulating equations and applying algebraic rules in algebraic problems which will affect them negatively in the overall performance.

It is therefore against the foregoing that this study sought to assess the learners' performance in WPE as well as in the DAE to find out whether a relationship exists between the two. This was done to find ways to mitigate the problem of poor performance in Algebra as a topic in the syllabus. The literature review shows that it is of great significant to study the learners' performance in DAE and WPE.

Methodology

The study used a mixed method approach; i.e. both the qualitative and quantitative methods were utilized to collect data from the participants. The population of this study was all Grade 12 learners taking the mathematics extended syllabus at one selected secondary school in Oshana Region. Random sampling was used to choose the participants, to ensure that every learner had equal chance to participate in the study. The sample consisted of 19 learners. The study utilized two written tests one test was on the DAE while the other was on WPE. These tasks were similar to those that are used in assessing mathematics at Grade 11 in the Namibia Senior Secondary Certificate O-level (NSSCO) curriculum. However these were expressed as real life situation problems. All learners took both tests at an interval of four weeks between the two tests. Their marks in the two tests were correlated. The learners' responses were also presented analysed qualitatively by attempting to understand the reason why the learners responded the way they did in order to draw closer to the reasons why they responded the way they did.

Findings

Biographical information of participants

This section presents the biographical information of the participants. The study drew data from 19 participants of which 8 were males and 11 females. This appears to suggest that there were more females than males in the study, which could be true for the population considering that a random sample was used and each participant had an equal chance of being selected from the population.

Comparison of learners' performance on the WPE and DAE

This section presents the data comparing the learners' performance on WPE and DAE. This, section is divided into two further sections, one section consists of analysis quantitative data regarding the comparison of learners' performance in WPE and DAE and another one consists of analysis of qualitative data derived from the responses of the learner to the test regarding the comparison of learners' performance in WPE and DAE. The aim of this section is to give the response to the first research question posed in this study (i.e., How does the performance of learners in WPE compare with that on the DAE?).

Comparison of learners' performance on the WPE and DAE tests

This section commence by presenting the comparison of the mean marks of the learners in the WPE and DAE tests. The mean score of WPE was 9.95 whereas the mean score for DAE was 10.74; this seems to suggest that learners performed slightly well in DAE than in WPE. This finding seems to support Stacey and MacGregor (2009) who said that most learners perform better on the DAE compared to the WPE. Further, Seling (2016) argued that most learners struggle in converting word problems into arithmetic problems resulting into wrong answers, a situation that affected their performance negatively.

However, there were some learners that could have performed well in DAE, but they failed to follow the instructions. As a result they ended up answering part of the questions which resulted in the loss of marks. From the results it is clear that the learners do understand and can solve the DAE but they are still struggling to solve WPE.

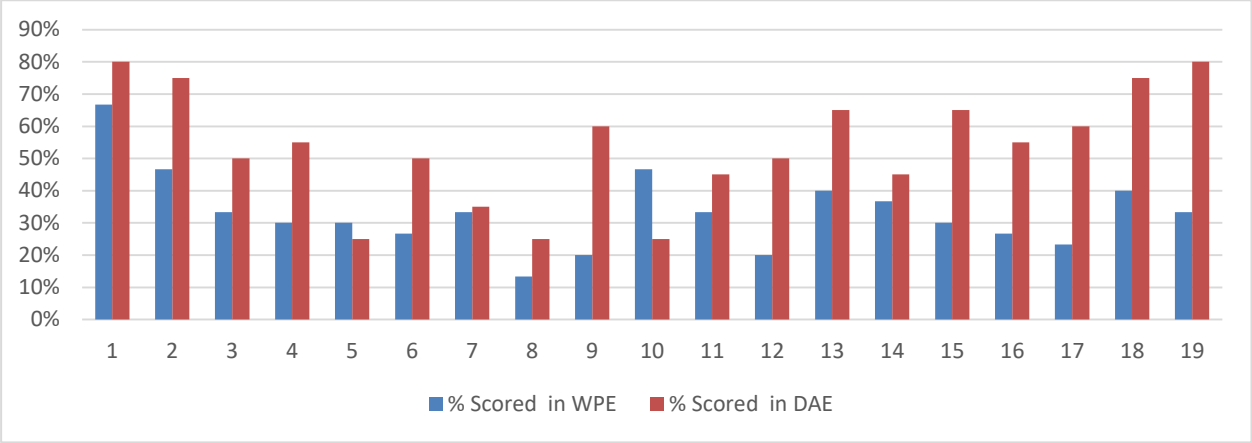

Figure 1: Comparison of learners' scores on WPE and DEA

From Figure 1, 17(89.5%) of the learners performed better in DAE compared to WPE. However, 2(10.5%) of the learners performed better on the WPE test than on the DEA. The results seem to suggest better learner performance on the DEA than on the WPE.

Figure 2 shows a comparison of the five-point summaries for the DAE and WPE tests.

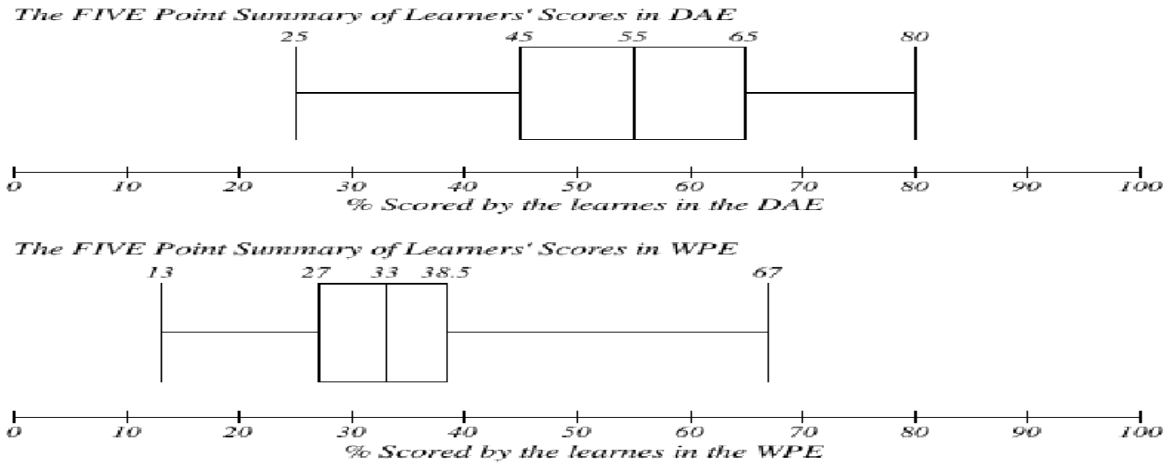

Figure 2: The five-point summaries for the DAE and WPE tests

As indicated in Figure 2, the learners' scores on the DAE were concentrated more on the right while the five-point summary of the WPE were concentrated more on the left. The lowest percentage scores were 13% and 25% on the WPE was and the DAE respectively, suggesting better learner performance on the DAE. The same trend is seen when one scrutinises the lower quartile the median and the upper quartile values. They were all higher for the DEA as compared to those of the WPE suggesting better performance on the DAE compared to that on the WPE. Further, in the highest score, on the WPE was 67% as compared to 80% on the DAE , again revealing a better performance in DAE compared to WPE. The results in this study support Lima's (2008) suggest that learners perform better on DAE compared to WPE. According to Lima this is because most learners lack the strategies to convert mathematical word problems into mathematical equations.

Figure 2 also shows that the DAE scores are distributed on the right reflecting a tendency towards negative skewness whereas the scores on the WPE are more concentrated on the left suggesting a positive skewness. This appears to show that in general learners scored high marks in the DAE compared to the WPE

The Quantitative data regarding the performance the comparison of learner's performance in WPE vs DAE

This section presents the quantitative data from the written tests regarding the comparison of learners' performance on WPE and DAE Mean score of the WPE. Figure 3 presents the comparison of the answers produced by a learner on the question assessing the same concepts on both the WPE and DAE tests.

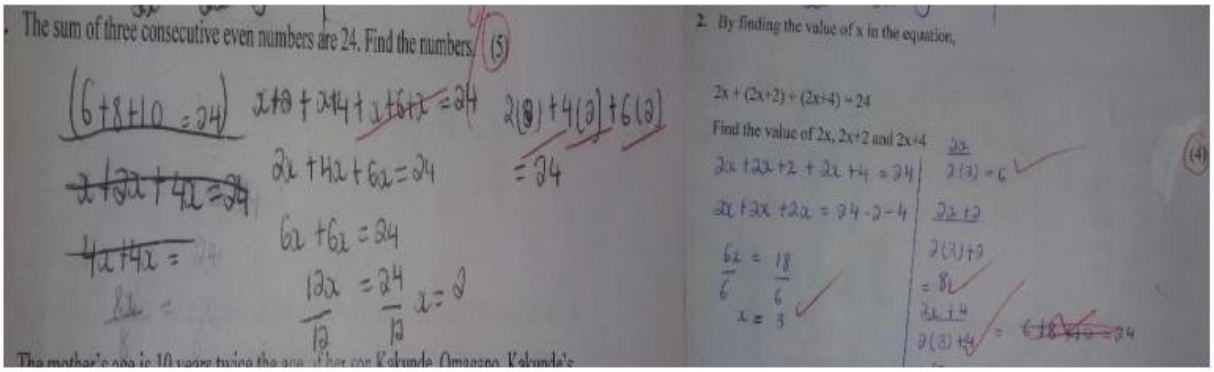

Figure 3: Learner 1's working on question … on the WPE and DAE tests

As seen from Figure 3 Learner 1's answers to Question 2 of both WPE and DAE were different, despite the fact that these were essentially the same, except one was in word form while the other was a direct problem. Learner 1 solved the direct problem successfully getting all the marks, but failed to translate the WPE to DAE. It seems Learner 1 failed to recognise the mathematical concepts reflected in the word problem to enable Learner 1 to construct the required equation that would have led ultimately to the desired solution. This therefore suggests that the learner was not competent in WPE despite the fluency illustrated in DAE.

Figure 4 compares the answers for Learner 2, on the same task of DAE and WPE. The idea is to understand the reasoning that guided the learner in giving the answers to both the questions.

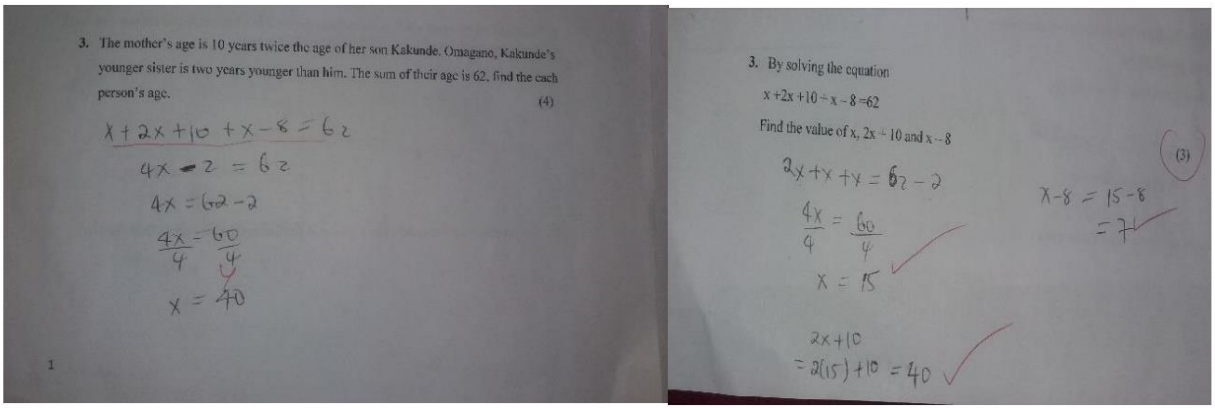

Figure 4 Answers by Learner 2 in both the WPE and DAE tests

Again as in the case of Learner 1 Learner 2 also answered well the DAE but failed to answer the WPE despite the fact that these were assessing the same task. Thus, according to the answers provided, Learner 2 could also not translate the mathematical problem stated in word to provide the correct direct equation that should be solved to produce the anticipated correct answer. This suggests a weak WPE grasp as compared to DAE. Based on the foregoing, it appears that the learners are performing relatively weaker in WPE compared to DAE.

Also, notwithstanding the foregoing, Figure 5 illustrates a comparison of Learner 3's response to bot the DAE and WPE asking the same task.

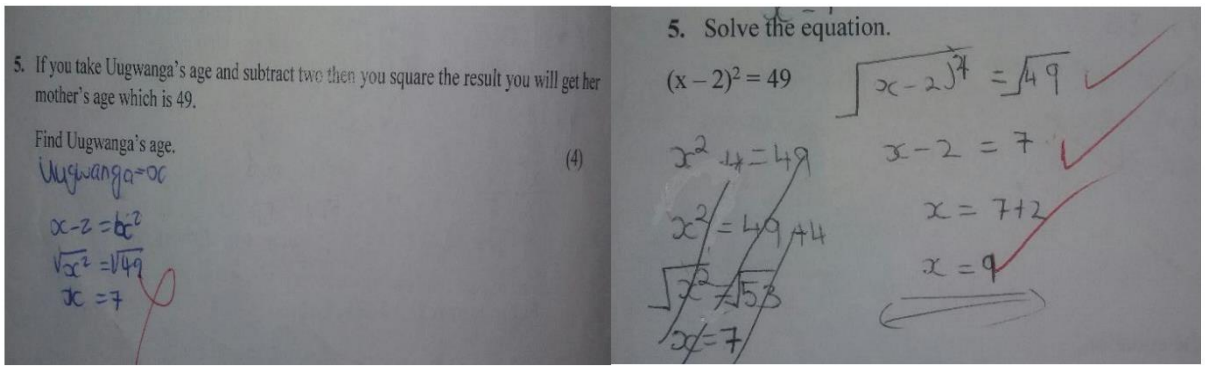

Figure 5: Learner 3's response on DAE and WPE on the same task

Figure 5 shows that Learner 3 failed to construct the equation from the given statement, but the same learner solved the same statement problem when it was given in the DAE. This seems to suggest a poor grasp of WPE compared to DAE. It also appears that the greatest challenge the learners were experiencing was to construct equations that needed to be solved in order to solve the given problem.

The findings presented in figures 3, 4 and 5, seem to support Acosta-Tello's (2010) findings with regard to learners' difficulties in solving algebraic word problem equations. Acosta-Tello is of the view that these difficulties stem from the difficulties they have in symbolizing meaningful relationships within algebraic equations. Moreover, Judi and Robert (2017) attributed the word problem-solving difficulties to the learners' psychological processes of words in the problem, the presence of cue words and the magnitude of the numbers affect the learners' ability to both comprehend and provide a solution to the algebraic problem leading to poor performance in WPE compared to DAE.

On the basis of both the quantitative and qualitative information gathered, the data revealed that learners performed relatively better on DAE compared to WPE. Moreover, the qualitative data indicated that the greatest challenge among the learners that prevented them to perform better in DAE is the fact that they were unable to understand the problem to convert it into a mathematical language and/or using mathematical symbols, which is prerequisite to solving WPE.

The quantitative and qualitative data presented revealed that the learners' performance in DAE was better as compared to WPE. Therefore, to answer Research Question one of this study (How does the performance of learners in WPE compare with that in the DAE?), both the quantitative and qualitative data revealed that the performance of learners in DAE was better than in WPE.

The relationship between the learners' performance in DAE and WPE

This section presents and discusses the data regarding the relationship between the learners' performance on DAE and WPE. This was done in an endeavour to respond to the Research Question 2 (What is the correlation between the performance of learners in WPE and DAE?). The Scatter Plot, Pearson's Correlation Coefficient and the Coefficient of Determination were used to answer question 2 of the study. Figure 6 shows a Scatter Plot showing the learners' performance on the DAE and WPE.

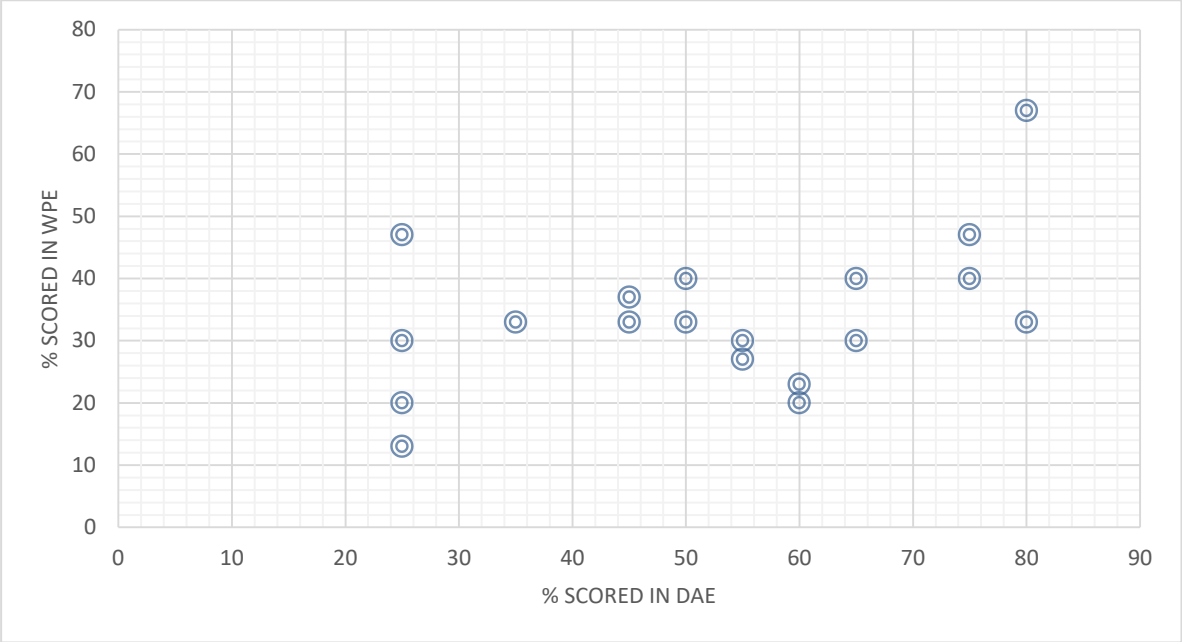

Figure 6 A scatter plot of the relationship between the learners' performance in DAE and WPE

Fig 6 shows that there is a weak positive correlation between learners' performance on the DAE and the WPE. This implies that for the learners who had higher scores in DAE had a very slight chance of scoring higher in WPE.

In order to find out the strength of the relationship between the learners' performance on the two tests Pearson's Correlation Coefficient and the Coefficient of Determination were calculated and these are presented in Table 3.

Table 3: Pearson's Correlation Coefficient and the Coefficient of Determination

Statistical value	**Value**
r	0.446
CoD (r^2)	19.9%

Table 3 shows the correlation coefficient (r) of0.446. This implies a weak positive correlation between learners' performance in DAE and WPE. That is, there is a slight chance that learners whose scores were high in DAE were not likely to score high scores in WPE. Also, for the learners whose scores were low in DAE were also not likely to score low on the WPE.

It is obvious that the performance of learners in WPE depends on other variables. The coefficient of determination of 19.9% (see Table 3) implies that if all the variables that have an impact on the performance of learners in WPE were to be kept constant, the performance of learners in WPE can be explained by their performance in DAE up to only 19.9%. About 80.1% is due to other parameters other than DAE.

On the basis of the foregoing data (see Figure 6 and Table 3), and to answer Question 2 of this study (What is the correlation between the learners performance in WPE and DAE?) the study found a weak positive correlation of 0.446 between the learners' performance in WPE and DAE.

Both the quantitative and qualitative data show that the learners' performance in DAE was better as compared to their performance on the WPE. Teachers should therefore teach problem-based algebra in order to strengthen learners' understanding of word problems in the Algebra part of the syllabus. The fact that the WPE solving abilities were weaker, implies the need for mathematics teachers to place more emphasis on the teaching of wordy problems to direct algebraic equations. There is also need to explain in detail the concepts of WPE and how to approach these in teaching in order to mitigate the poor problem-solving abilities found in this study.

Further, there is a need for strengthening the teaching of DAE to facilitate learners' understanding of WPE. Moreover, there is a need for teachers to stimulate the learners' interest in word algebraic problems and direct algebraic problems thereby harmonizing the two sections of Algebra and the learners' performance in DAE and WPE. That is the Namibia Senior Secondary Certificate (NSSC) Mathematics teachers need to align their teaching methods to the competencies of the DAE because this algebraic part seems to have a little significant impact on the learners' performance in another part of Algebra which is WPE.

Conclusion

This study found a weak positive correlation (r) of 0.446 between grade 12 learners' performance on WPE and the DEA. The learners' limited fluency in translating the mathematical problems stated in words into direct equations seems to have contributed to their low performance on the WPE. In this study only 19.9% of the total variance could be accounted for by the interaction of the performance in the WPE and the DAE.

Recommendations

Based on this study, the use of activities that enhance learners' understanding in DAE must be boosted in order to be able to aid their performance in WPE. When assessing learners' Algebra, both the DAE and WPE questions must be balanced to avoid disadvantaging learners' performance in Algebra this means there is a need to strike a balance between the two kinds of activities. Further research should be carried out on identifying other factors influencing learners' performance on WPE.

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