Comparing learners' performance in writing formulae of compounds and balancing of equations in grade 11 at a selected school in Oshana region, Namibia

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Abstract
Writing formulae and balancing equations are among the most complex topics in Chemistry. Teachers find it difficult to teach while learners find it challenging to understand. The focus of this study was to compare the Grade 11 learners' performance in writing formulae of compounds and balancing equations. Examiners have reported major mistakes on writing formulae of compounds and balancing of equations. It was also reported that many learners lack confidence in writing chemical symbols and formulae. Therefore, this study sought to find the correlation between writing formulae (WF) and balancing equations (BE) to help learners and teachers link the two concepts and overcome the difficulties of writing formulae and balancing equations, this thus triggered this study. This study addressed two research questions: How do learners' performance WF as compared to BE? and What is the correlation between learners' performance in WF and BE? The data were collected at a selected school in Oshana region in Namibia. The mixed method was used to collect and analyze the data; whereby qualitative and quantitative methods were utilized to draw data from the participants. The quantitative design was used by collecting the number of marks that each learner scored from both WF and BE. The findings indicated that learners performed better in WF compared to BE. A sample of 20 learners was randomly selected to participate in WF and the other on BE writing formulae and the other for balancing equations were used to collect data, one for writing formulae and one for balancing equations. The study revealed that learners performed relatively lower in WF and BE. The findings have also shown a strong positive correlation between learners' performance in WF and BE. The conclusion that a better understanding of writing formulae of compounds could facilitate a better understanding of balancing chemical equations was made. The study recommends a better teaching of WF to facilitate a better academic performance of BE.

Keywords: *formulae of compounds, balancing equations, stoichiometry*

Background

The subsequent examination reports in Chemistry in Namibia (DNEA, 2020; 2021; 2022) noted with concern that the performance of learners in Chemistry has been diminishing over the past years making Chemistry one of the low performed subjects. The greatest problem among the topics that were underperformed was stoichiometry, particularly there were lots of mistakes on writing formulae of compounds and balancing of equations, unbalanced/partially balanced/incorrect equations were also given by many candidates. The foregoing is somehow retarded the performance of the learners in Chemistry (DNEA, 2021; 2022). DNEA (2022) particularly further reports that most of the candidates lacked confidence in writing chemical symbols and formulae. DNEA (2021, 2022) indicated that some candidates wrote incorrect formulae of compounds such as $Mn(SO_4)_2$ instead of $MnSO_4$, $Cr(SO_4)_3$ instead of $Cr_2(SO_4)_3$ and Fe_2SO_4 instead of $Fe(SO_4)_3$. There is thus a need to inquire into what can be done to improve our learners' overall performance particularly on the topic of Stoichiometry. Moreover, it is not clear as to how the learners can be assisted to perform better in this topic of stoichiometry still remain fold, hence a need to carry out a study on how to draw closer to a better understanding of the topic among the learners.

Statement of the problem

Poor academic performance in Chemistry as indicated by DNEA (2020; 2021; 2022) has attracted attention among concerned individuals in Namibia. For instance, in 2020, 66.6% of the candidates performed poorly in the questions that had to do with stoichiometry as opposed to the 64% candidates in 2021 (DNEA, 2021; 2022). Additionally, the percentage of students scoring quality grades (A*-D) in Chemistry Examination over the

past three years reduced from the 54.3 to 44.7 % in 2022. It is therefore sensible to note that there is poor performance in this topic and this is alarming. Among the causes of poor performance in stoichiometry are poor skills in writing formulae of compounds and writing of balanced equations, attitudes of learners towards the topic, lack of teaching experience and lack of appropriate teaching methods (DNEA, 2021). It is therefore evident that if this poor grasp of the concepts in Stoichiometry is not alleviated, this poor performance will remain in Chemistry as a school subject and continue to affect the choices of learners' scientific careers negatively. Against the foregoing background, this study compared the performance of learners in writing formulae of compounds and balancing of equations, the study also sought to identify the relationship between learners' performance in writing formulae and balancing equations.

Questions of the study

The study sought answers to the following questions:

1. How does the performance of the Grade 11 learners at a selected school in Oshana region in writing formulae compare with balancing equations?
2. What is the relationship in performance of the Grade 11 learners at a selected school in Oshana region in writing formulae and balancing equations?

Significance of the study

The aim of the study was to investigate the factors that cause learners' poor performance in writing formulae of compounds and balancing equations. The outcome of the study could be beneficial to both the teachers and the learners taking Chemistry as a school subject. Learners might benefit in that if a positive correlation is established, learners might link the two concepts together and hopefully their performance might improve. Furthermore, teachers might also benefit from the study since it might lead to finding the solutions to overcome learners' difficulties in Writing Formulae (WF) and Balancing Equations (BE). Finally, chances for further poor performance in Chemistry Grade 11 could be minimized.

Literature review

This section presents the review of literature related to the writing of formulae of compounds under the following sub-topics: understanding how to balance equations, comparison of learners' performance in WF and BE, the relationship between Writing Formulae (WF) and Balancing Equations (BE).

Understanding how to balance equations

In balancing equations, it is important to understand the difference between a coefficient of a formula and a subscript in a formula (Savoy, 2017). For instance, in the formula $3H_2O$, 3 and 2 are the coefficient and subscript of the formula respectively. Savoy further explained that the coefficients in a balanced chemical equation can be interpreted both as the relative number of molecules, moles or formula units involved in the reaction. However, subscripts on the other hand indicate the relative number of atoms in a chemical formula. Thus, it is clear that teachers need to sensitize the learners to be aware of all these concepts to facilitate and cement the understanding of concepts. It is thus also worth noting therefore that the subscripts should never be changed when balancing equations.

Teachers also need to draw the learners' attention to the fact that changing subscripts changes the identity of the substance in contrast. Sharing the same sentiments is Suderji (2010), who notes that changing a coefficient in a formula changes only the amount and not the identity of the substance and hence can be manipulated in balancing chemical equations. Suderji further stresses that, changing a coefficient in a formula gives the formula of the reactants and products thus showing the relative number of particles of each of the reactants and the products. It is thus important for teachers to make learners recognize that in a chemical reaction atoms are neither created nor destroyed (Lythcott, 1990). Against the foregoing background, the literature suggests that the teachers have a duty to guide the learners to discover that the same number of each type of atom on the product side and on the reactant side of the arrow are equal.

Comparison of learners' performance in WF and BE

Literature holds the view that learners perceive Chemistry to be a difficult subject (Johnstone, 2016). In support of the foregoing Savoy (2017) asserts that the difficulties in stoichiometry may lie in the capabilities of human learning as well as in the intrinsic nature of the subject. Steenberg (2006) on the

other hand documents that, learners' performance in writing formulae is generally poor compared to their performance in balancing equations. However, in the Namibian context this relationship between learners' performance in writing formulae and balancing equations seems to be fold, hence a need to inquire deep into this subject.

Yarroch (2009) also points out that, most learners experience difficulties in both acquiring and using the skills required to balance the chemical equations; as such they lack confidence about writing chemical equations and balancing them. It can thus be deduced that the writing of formulae (WF) forms the basis for balancing equations and as such if learners lack the understanding of the purpose of coefficients and subscripts in formulae, they will ultimately not grasp a better understanding of balancing equations. Mahaffy (2004) reveals that approximately two thirds of the learners who took part in his study indicated that the topics WF and BE were either difficult to grasp or never grasped. Thus, it appears that there is a need to carry out intervention studies in order to alleviate this poor grasp of these two concepts in an endeavor to harmonise the teaching and learning of Stoichiometry and ultimately improve the performance of the learners.

The relationship between Writing Formulae (WF) and Balancing Equations (BE)

It is of great importance for the relationship to be understood between writing formulae and balancing equations to aid both teachers and learners to link these two concepts together to enhance the teaching and learning of Stoichiometry since the two concepts form the basis for the teaching of Stoichiometry. Literature by Anamuah and Apafo (2004) revealed that learners' persistent difficulties in solving stoichiometric problems were partly associated with their inability to represent chemical equations correctly. Therefore, an understanding of WF will make it easier for learners to balance equations. Anamuah and Apafo further noted that, if WF was well understood then BE will be easier to manipulate. It is therefore a necessary condition that teachers foster an understanding of WF to facilitate the grasp of BE.

The understanding of valency, application of concepts of polyatomic ions and molecules and ultimately the production of correct chemical formulae will depend on learners' knowledge of bonding (Barke & Engida, 2001). It therefore, follows that learners should be given solid background knowledge of chemical bonding in order for them to have a better understanding of WF. Yitbarek (2009) concurs with the foregoing and opines that, the difficulty of lack of Chemistry language skills can be solved by maximizing exposure to chemical language. Therefore, teachers should not assume that learners are familiar with chemical terms; rather they should introduce the terms carefully (Sawrey, 2000).

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 quantitative design was used because of its characteristic that it deals with numerical values as opposed to utilizing non-numerical data as outlined by Ansari (2013). The comparison between the learners' performance in writing formulae and balancing equations was done by using descriptive statistics, which was merely numerical. Despite the fact that this is a mixed methods approach, the quantitative part of this study was classifies a correlation study as defined by Al-Shammakhi1 and Al-Humaidi (2015), that a correlation study assesses the relationship between and amongst variables. In addition, the mere fact that this study attempted to establish the relationship between the performances of learners in writing formulae versus balancing equation implies that the study was of a quantitative nature.

The population of this study was all Grade 11 learners studying Chemistry at School X in the Oshana region, thus the total population for this study was 61 participants. This study used two tests in which Test A was on WF and Test B was on BE. The tests consisted of multiple-choice questions and structured questions. Additionally, the qualitative data was drawn from the snapshots of the responses (written answers to both the WF and BE) of the learners to the test items. This was done to understand the reasons that caused them to respond the way they did.

Findings

Biographical information of participants

This section presents the biographical information of participants. The section commences by presenting the percentages that males and females constituted to the sample. Figure 1 shows the male and female

percentage compositions.

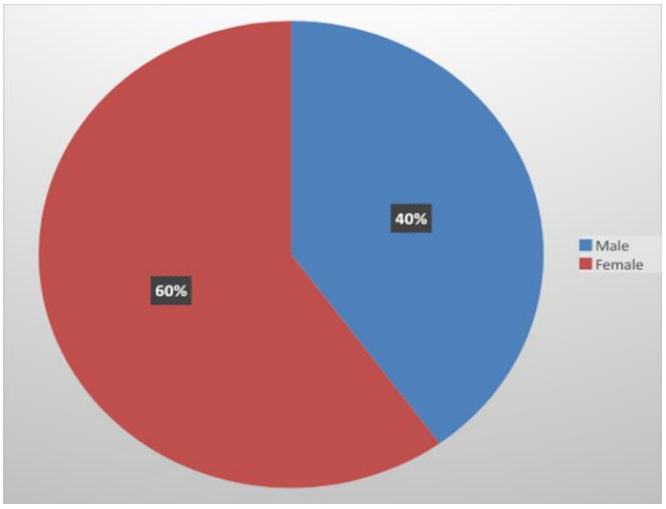

Figure 1: The percentage composition of participants according to their gender

The study drew data from 20 participants of which 8 (40%) were males and 12 (60%) were females. This shows that there were more females than males in the study. This reflects the composition of the general Namibian population which has more females than males.

The data regarding the comparison of learners' performance in WF and BE

This section presents the data regarding the comparison of learners' performance in WF and BE. In presenting this data the section is divided into two subsections, one section consists of quantitative data regarding the comparison of learners' performance in WF and BE and the second section consists of the analysis of qualitative data regarding the comparison of learners' performance in WF and BE. The aim of this section was to give the response to the first research question of this study (i.e., How does the performance of the Grade 11 learners at a selected school in Oshana region in writing formulae compare with balancing equations?).

Table 1: Comparison of the mean scores of the learners in the WF and BE tests

Mean mark of WF	Mean mark of BE
21.55 (20 learners)	18.25 (20 learners)

The mean score of WF was 21.55 (20 learners) while the mean score for BE was 18.25 (20 learners). This seems to suggest that learners performed slightly better in WF than in BE. The results seem to agree with Sirhan's (2007) results who found that most of the learners in his study were successful in matching the chemical symbols and their words written on a flip chart but still difficulties in balancing chemical equations for most of the learners. However, there some learners performed well in BE but did not pay attention to the subscript of the elements. They ended up balancing the equation wrongly and this made them lose marks. Therefore, learners seemed to understand and wrote formulae but were still struggling to balance the equations.

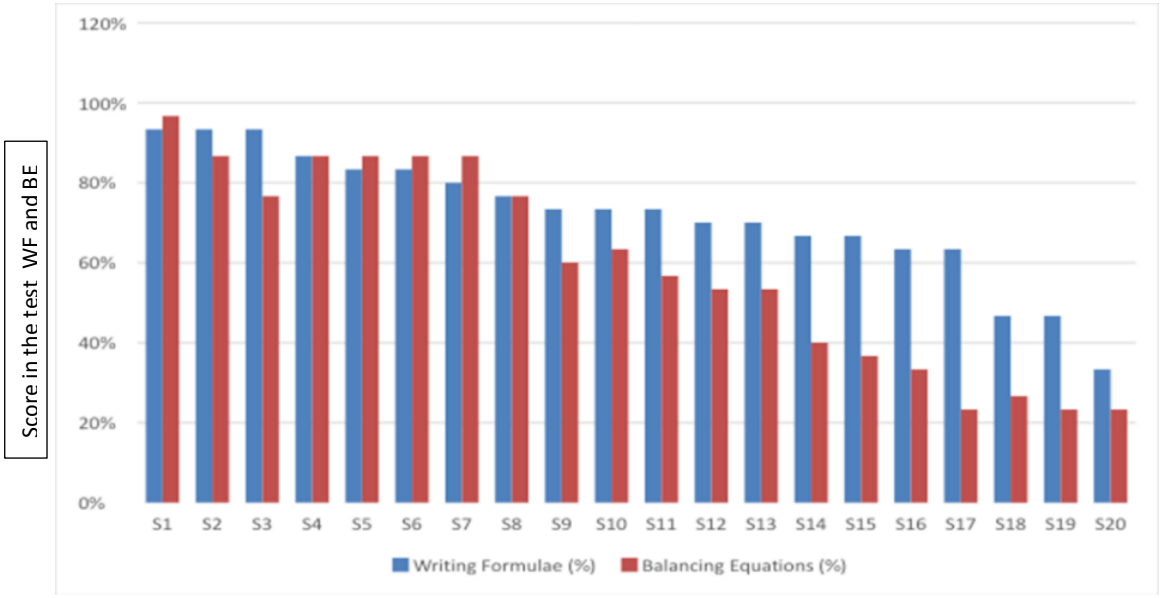

Figure 2: Comparison of learners' scores in WF and BE

From Figure 2, 17 (85%) of the learners performed better in WF compared to 13 (65%) of learners in BE; this shows that more percentages were obtained in WF compared to BE. However, Figure 2 shows that 7 (35%) learners have performed poorly in BE compared to 3 (15%) of learners in WF, in terms of percentage of this shows that less percentages were obtained in WF compared to BE. Therefore, in terms of comparison of how many learners obtained a higher score in which test, it appears that the results point to better performance in WF. In addition, to the comparisons of the number of learners who passed each test, Figure 3 shows a comparison of the five-point summaries for the WF and BE tests.

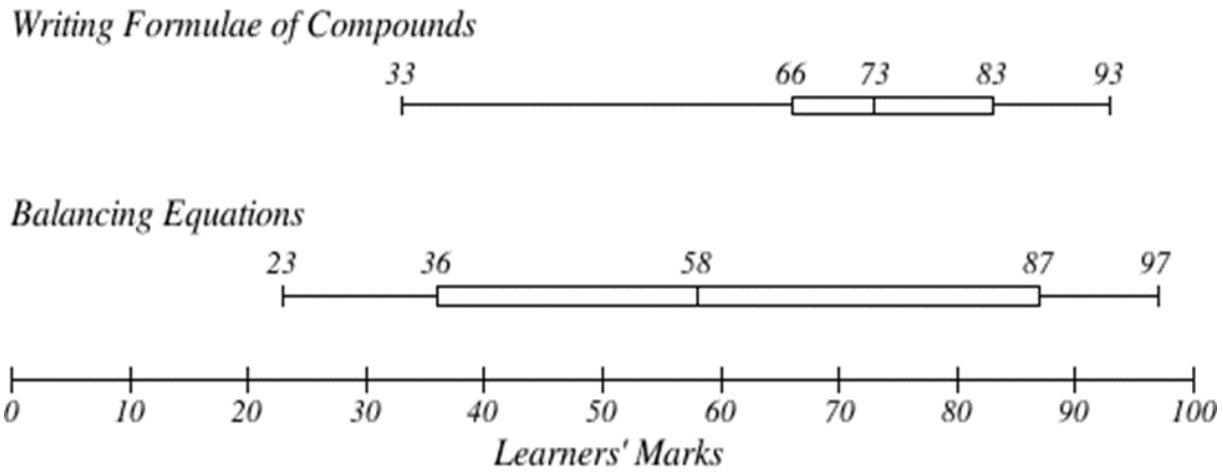

Figure 3: A comparison of the five-point summaries for the WF and BE tests

As indicated in Figure 3, the five-point summary of the WF appears to show that the scores were concentrated more on the right while the five-point summary of the BE were concentrated more on the left. For the BE the lowest score was 23%, while for WF the lowest score was 33%, this seems to suggest that in terms of lowest scores the learners performed better in WF compared to BE. The lower quartile for BE was 36% as opposed to 66% in the WF. This appears to point to the view that learners performed better in WF compared to BE. Furthermore, the median of BE was 58% while that of WF was 73%, this implies a better performance in WF compared to BE. Moreover, the upper quartile of the BE was 87% while that of WF was 83% this suggests a better performance in BE compared to WF. In terms of the highest score, the highest score of the WF was 93% while that of BE was 97%, revealing a better performance in BE compared to WF. Compared to literature,

Steenberg (2002) also documented that, learners' performance in writing formulae was poor compared to their performance in balancing equations.

All in all, Figure 3 shows that for BE the scores are distributed on the right drawing closer to a negative skewness whereas the scores of the WF are more concentrated on the left suggesting a positive skewness. This shows that WF have scored high marks compared to BE, drawing closer to the point that learners have performed better in WF compared to BE. Also, to sum up this section overall, the quantitative data presented in this section, (Figures 2 and 3) indicate that learners have performed well in WF as compared to BE. This contradicts the literature findings by Steenberg (2002) which shows that the learners find it difficult to write formulae than balancing equations.

The qualitative data regarding the performance of the learners' in WF and BE

This section presents the quantitative data regarding the learners' performance in BE and WF using the Mean scores. To start with, Figure 3 presents the comparison of the answers produced by a learner on the question assessing the same concept for both the BE and WF tests.

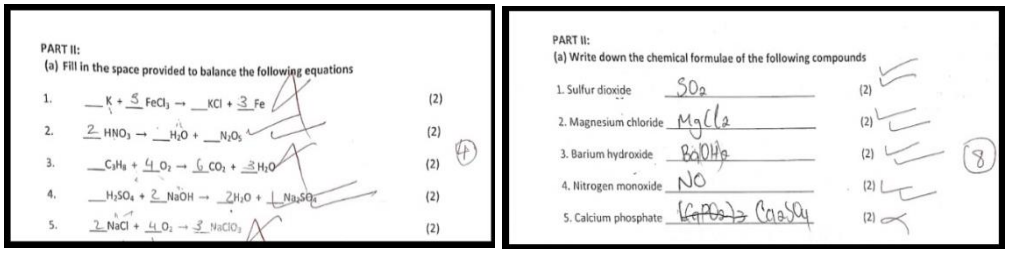

Figure 4: Comparison of answers by S1 in both the BE and WF tests

As seen from Figure 4, S1 answers to Part II of both BE and WF were different, despite the fact that they were asking almost the same concept. Also, Figure 4 appears to point to the fact that S1 wrote the formulae of the compound successfully and scored almost all the marks correctly, but this particular learner could not balance the equation. For this particular learner, it appears that there was a lack of the mathematical calculations to enable him/her to balance the required equation that would ultimately yield the desired answers. This is why this learner ended up not scoring anything because there was no equation balanced to get all the marks. This therefore suggests that the learner was not competent in BE despite the fluency illustrated in WF. In addition, Figure 5 compares the answers for S2, on the different task of WF and BE.

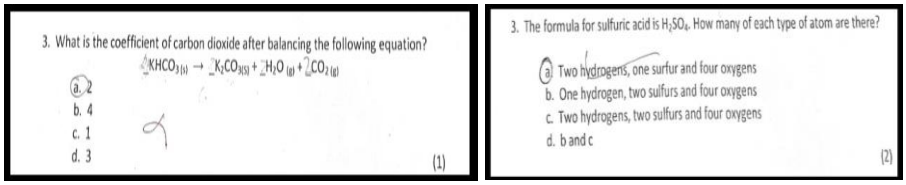

Figure 5: Comparison of answers by S2 **in both the BE and WF tests**

As illustrated in Figure 5, S2 answered well in WF but could not answer the balancing equation question despite the fact that it was a multiple-choice question where guessing could have even aided this. Thus, according to the answers provided, S2 seemed to lack the skills of balancing chemical equations but managed to answer the question that had to do with writing the formula of compounds. This suggests a weak BE grasp as compared to WF. It appears that the learners were performing relatively weaker in BE compared to WF. Also Figure 5illustrates a comparison of S3's response to both the WF and BE asking a different task.

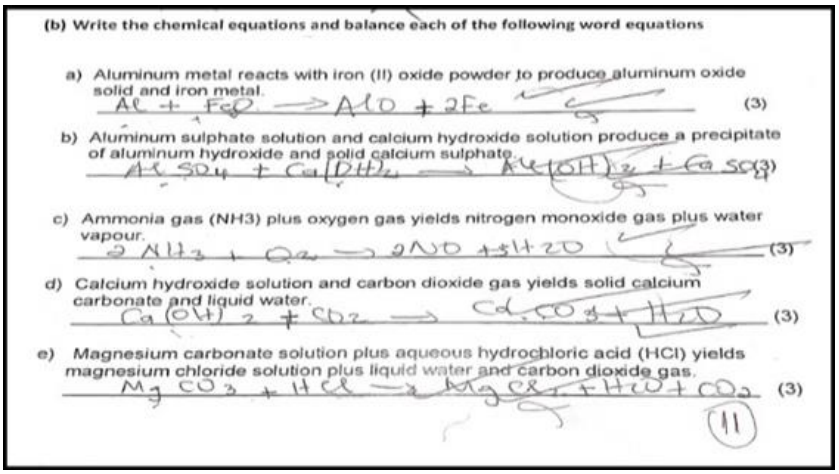

Figure 6: Comparison of S3's response in WF and BE on a different task

Figure 6 above that S3's could write the correct formula compounds and successfully came up with the equation but the same learner could not balance the equation, due to the failure of balancing the equations, this learner lost marks. The response of S still appeared to suggest a poor grasp of BE compared to WF. In agreement with Figures 4, 5 and 6, Krishna (2017) indicates that balancing equations is among the most complex topics in Chemistry in which teachers find it difficult to teach while learners find it challenging to understand. To sum up this section, on the basis of both the quantitative and qualitative information gathered, the data revealed that learners performed relatively better in WF compared to BE. Therefore, on the basis of both the quantitative and qualitative data presented, the data revealed that the learners' performance in WF was better as compared to BE. Therefore, to answer the Research Question Number One of this study (How does the performance of the learners in writing formulae compare with performance of learners in balancing equations)? Both the quantitative and qualitative data revealed that the performance of learners in WF was better than in BE.

The data regarding the relationship between the learners' performance in WF and BE

This section presents and discusses data regarding the relationship between the performance of learners in WF and BE. This was done in order to respond to the Research Question 2 (What is the relationship in performance of the Grade 11 learners at a selected school in Oshana region in writing formulae and balancing equations?). This relationship was therefore established by using correlational statistics such as the Scatter Plot, Pearson's Correlation Coefficient and the Coefficient of Determination. Figure 6 shows a Scatter Plot that shows the relationship between learners' scores in WF and BE.

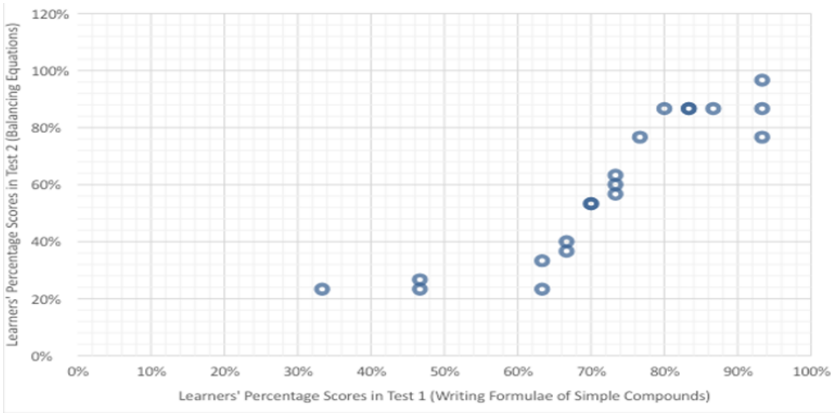

Figure 7: Scatter plot of the relationship between the learners' performance in WF and BE

Figure 7, shows that the nature of the correlation illustrated in Figure 7 a strong positive correlation in learners' performance in WF and BE exists. This implies that the learners who had higher scores in WF also had higher scores in BE and students who scored low in WF also tended to score low on the BE test. In addition to the information presented in

Figure 7 which shows the nature of the correlation that exist between WF and BE, the correlation coefficient t and the Coefficient of Determination (CD) were calculated and these are presented in Table 2.

Table 2: The values of Pearson's Correlation Coefficient and the Coefficient of determination

Statistical Value	Value
R	0.897
COD	80%

From Table 2, this value of correlation coefficient of 0.897 appears to be close to +1. This implies a strong positive correlation between learners' performance in WF and BE. That is, learners whose scores were good in WF are likely to score good scores in BE; also, learners whose scores were poor in WF are also likely to score poorly in BE. It is obvious that the performance of learners in BE depends on other variables, however it is imperative to determine the impact or influence of learners' performance in WF on BE. To this effect, the coefficient of determination was 80% as indicated in Table 2; this implies that if all the variables that have an impact on the performance of learners in BE were to be kept constant, the performance of learners in BE can be explained by their performance in WF up to only 80%, and about 20% would be due to other parameters other than WF.

On the basis of the foregoing data, presented in Figure 7 and Table 2, and to answer Research Question 2 of this study (What is the relationship in performance of the Grade 11 learners at a selected school in Oshana region in writing formulae and balancing equations?)?, the study found a strong positive correlation between the learners' performance in BE and WF. Both the quantitative and qualitative data presented draws closer to the idea that the learners' performance in WF was better as compared to BE. This implies that the learners had a better grasp of WF than BE, there is hence a need to help learners improve their grasp of BE. It therefore appears that teachers are challenged to include the teaching of mathematical calculation in order to strengthen more on the BE. The mere fact that the performance of learners in BE was weaker than in WF, implies the urge for teachers to stress more on the teaching of mathematical calculations in balancing equations by giving more activities or exercises on this part so that learners will put their understanding of BE to the level of WF. There is also a need to explain further and in detail the concepts of BE and how the learners can solve the BE activities in order to mitigate the weak in balancing equation abilities diagnosed, and ultimately help learners obtain better grades in Chemistry.

Taking into consideration a strong positive correlation between learners' performance in WF and BE, it can be deduced that there is a need for strengthening the teaching of WF to enhance learners' understanding of BE. Moreover, this need to help learners understand WF thoroughly in order to improve the learners' grasp of BE arouses a need for teachers to utilize the drill and practice teaching to stimulate the learners' interest in the two parts of writing formulae and balancing equations, thereby harmonizing the performance of learners in both WF and BE. The fact that this study discovered that learners' performance in WF is influenced by their performance in BE implies that the Chemistry learners who have a better grasp of WF will need to guide other learners to collaborate this and this might ultimately trickle down to an improved performance in BE for all learners.

Conclusion

Based on the results, there was a poor performance on BE compared to WF. Also, a strong positive correlation of 0.897 between WF and BE was concluded. From the foregoing data it could also be inferred that if all parameters that are involved in BE are kept constant, the learners' performance in BE could be explained by their performance in WF up to 80%, and the other 20% could be explained by other factors.

Recommendations

Based on the findings of this study the following recommendations were made. The teachers should:

- Ensure that students' exposure to chemical language is maximized.
- Not assume that students are familiar with chemical terms and these should be introduced carefully.

- Moreover, when teaching, students must be provided with a glossary of symbols of different elements and formulas of different compounds and made to learn them by rote with normal pacing to help students.
- Teach students clear rules and steps in solving BE activities and drill through these steps in the activities given to enhance learning and understanding of BE.
- Using new and innovative methods of teaching that stimulate learning on WF and balancing may be used to enhance the understanding of BE activities.

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