Journal of Education and Practice www.iiste.org
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online) DOI: 10.7176/JEP
Vol.10, No.23, 2019

Effect of using Algebraic Method on Secondary School Students' Performance in Balancing Chemical Equations in Chemistry

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Abstract
The study was undertaken to establish the effect of Algebraic Method on Secondary School Students' performance in balancing chemical equations. The sample of the study consisted of 81 Grade 11 students from two intact classes which were purposively selected but randomly assigned to experimental and control groups. The design of the study was pre-test post-test control group quasi-experimental design. The study subjects in the experimental group were taught using Algebraic method, while the control group was taught using the conventional Inspection method over a period of four weeks. Balancing Chemical Equation Performance Test (BCEPT) was used to determine the performance of the two groups after treatment. An independent samples t-test at an alpha level (α) = .05 was conducted to compare the performance of the groups during both the pre-test and post-test. The results of pre-test revealed that there was no significant difference in the performance of both groups. This result implied that the experimental and control groups were equivalent in terms of performance before treatment was administered to the experimental group. However, during post-test there was a statistically significant difference in the mean performance scores of experimental (*M = 62.2, SD = 21.8*) group and control (*M =49.7*, *SD = 18.0*) group t (*79) = 2.817, p = .006*. The implicature was that students taught balancing chemical equations using Algebraic method performed better than those taught using Inspection method.
Keywords: Algebraic method, Balancing chemical equations, Inspection method, Performance
DOI: 10.7176/JEP/10-23-08
Publication date: August 31st 2019

1. Introduction

Chemistry is one of the principal science subjects taught at senior secondary school. It is one of the basic subjects that students are required to pass at credit or better level in order to qualify for admission into university to study science based programmes. Despite the important position of Chemistry among other science disciplines, performance of students at Senior Secondary School Certificate Examinations has consistently been unsatisfactory (Njoku, 2005). One of the contributions to undesirable performance of students in Chemistry is inappropriate teaching methods (Ayogu, 2001). The West African Examination Council (WAEC) Chief Examiners' Report (2009) reported poor performance in Chemistry. Similarly, in Zambia for example, in 2017 the national percentage pass in Science was 35.28% and in 2016 was 32.83% (ECZ chief Examiners' Report, 2017) and in 2014 the percentage pass in Science was 17.76% whereas in 2013 it was 29.37% (ECZ chief Examiners' Report, 2014). A similar observation was made at Mkushi Coppermine Secondary School where the current study was carried out (Table 1.)

Table 1: Performance of Students in Chemistry and Science at Mkushi Coppermine Secondary School from 2015 to 2017

Subject	Mean Raw Scores (%)		
	2017	2016	2015
Chemistry	35	36	37
Science	42	16	22

Source: Mkushi Coppermine Secondary School Guidance Office (2018)

Table 1 reveals that the performance of students in Chemistry and Science is below national average performance. This is contrary to current pronouncements by the Ministry of General Education (MOGE) where it has been emphasised that schools attain 100 per cent pass rate countrywide. This envisaged goal may prove a pipedream to attain by schools like Mkushi Coppermine Secondary School due to poor performance recorded since 2015 unless educators and other education stakeholders address the cause of unsatisfactory performance in chemistry, such as, failure to balance chemical equations.

Balancing of chemical equations is one of the fundamental chemical concepts (Ababio, 2004). The concept is cardinal because it cuts across many topics in Chemistry. Therefore, students who do not fully comprehend how to balance chemical equations, experience difficulties in understanding of the subsequent topics. Suffice to say that understanding of balancing of chemical equations is the prerequisite to comprehension of chemical equilibrium, Electrochemistry and Organic chemistry topics (Anthony, 2009). However, balancing of chemical equations has been a difficult concept in Chemistry for both students and teachers. For example, WAEC (2012)

reported that balancing of equations constitute parts of Chemistry concepts that teachers find difficult to teach their students and in addition, students find it difficult to understand. In the same vein, Cambridge Ordinary Level 5070 Chemistry Principal Examiner's report for Teachers (2016) found out that students' performance in balancing chemical equations was low. Johnstone (cited by Ekere, 2014) reported that one of the problem areas in Chemistry which persisted into college and university education was balancing chemical equations. For instance, it has been found elsewhere that some university students were unable to balance chemical equations satisfactorily (Marais and Combrink, 2009).

Based on a study of Analysis and Classification of Student's Learning Difficulties in the balancing of chemical equations candidates lose marks because of their inability to balance chemical equations (Ekere, 2014). Similarly, the Caribbean Examination Council (2013) reported that less than 50% of the students wrote the correct balanced chemical equation for the combustion of ethane in the examination. Further, it has been found that balancing chemical equations of combustion reactions involving hydrocarbons is problematic among high school elective science students (Baah and Amphiah, 2012). Moreover, WAEC chief examiner's report (2010, 2011) reported that most Chemistry students performed poorly in Chemistry because of their inability to balance chemical equations correctly. This is consistent with Kenya National Examination Council (2005) that reported that in Chemistry, balancing chemical equations was a challenge to most students. The 1994 Chief Examiner's report available through the WAEC also showed that most candidates were unable to write balanced chemical equations for the Senior Secondary School Certificate Examination (SSSCE) chemistry paper. It can not be over-emphasized that chemistry students often have great difficulties in both acquiring and using the skills required to balance chemical equations (Savoy, 1988; Hines, 1990).

Zambia, like other African and Caribbean countries are facing the problem of students' poor performance in balancing chemical equations. For example, the ECZ Examinations Performance Chief Examiners' Report (2016, 2017) reported that most candidates lost at least a mark for the question on balancing chemical equations. It was further found that students' performance was low in balancing chemical equations. However, over the years teachers of chemistry have been using a popular method known as Inspection method to teach balancing chemical equations (Guo & Toth, 1997). Balancing of chemical equations is important in the learning of Chemistry, and if students are lacking the skill of balancing chemical equations their overall performance in their final examination would be poor. In order to enhance students' performance in balancing of chemical equations there is a need to explore and adopt more effective pedagogies. Algebraic method is reportedly one such a method that may be used to balance chemical equations with easy (Zabadi & Rammiz, 2017). It is a method that cuts down the number of steps in many solutions given in books and brings down the stress that students experience while balancing chemical equations (Subramanya, 2012). Algebraic method involves putting unknown coefficients in front of each molecular species in the equation and solving for the unknowns (Tuckerman, 2011). Therefore, there is need to incorporate Algebraic method in order to improve students' performance in balancing chemical equations.

1.1 Statement of the problem

In Chemistry, the balancing of chemical equations is one the major aspect taught to students in order for them to understand the greater part of the discipline. Balancing chemical equations is therefore a critical component not only to student's understanding of the subject but also to obtaining desired results by both the learners and the schools themselves. Balancing Chemical reactions is an excellent demonstrative and instructive example of the inter-connectedness between Linear Algebra and Stoichiometric principles (Gabriel & Onwuka, 2015). The findings are also in accord with Sanger (2005) and Nyachwaya et al. (2014) who reported that if students had difficulties in balancing chemical equations they would not be able to understand and solve stoichiometry problems properly. In fact, balancing of chemical equations is so fundamental that without mastery of it, students find every other aspect of Chemistry difficult (Johnstone, 2000). It has been observed that students are currently having difficulties in this area of the subject with negative impact in terms of the results at the level of certification especially at Senior Secondary School Certificate Examination (Antony 2009). It has been observed that if the aspect of balancing chemical equations is not tackled with the urgency it deserves, it is likely going to be a major issue regarding student's comprehension of chemical equilibrium, Electrochemistry and Organic Chemistry (Anthony, 2009).

After careful literature survey, there did not seem to be any study conducted on the impact of Algebraic method on students' performance in balancing chemical equation in Zambia. Therefore, it would be worthwhile to carry out a study on the impact of Algebraic method on students' performance in balancing chemical equations in Chemistry in Zambia particularly at Mkushi Coppermine Secondary School in Luano District.

1.2 Research objective

The purpose of the study was to determine the impact of Algebraic method on the performance of Grade 11 secondary school students in balancing chemical equations.

1.3 Research question
What is the impact of Algebraic method on performance of Grade 11 students in balancing chemical equations?

1.4 Hypothesis
Ho: There is no statistically significant difference in performance in balancing chemical equations between Grade 11 students who are taught balancing chemical equation using Algebraic method and those who are taught using Inspection method.

2. Methodology
2.1 Research Design
According to Christiansen *et al* (2010), research designs are ways of doing research. In different words, research design is the structure of research which shows how all the main parts of the research project will be conducted in order to address the research questions (Kombo & Tromp, 2010). In order to determine the effect of Algebraic method on students' performance in balancing chemical equations, a pre-test post-test control group quasi-experimental design was used. Two grade 11 intact classes were purposively selected and then randomly assigned to experimental and control groups. The use of intact classes was premised on the fact that normal school routine was not to be disturbed. This is in line with Best and Kahn (2006) who consider students to be naturally organised in groups as classes within schools and are considered to share similar characteristics. Students had no previous experience in balancing chemical equations. Therefore, a pre-test using Balancing Chemical Equations Performance Test (BCEPT) was the correct way to assess whether the groups were equivalent in balancing chemical equations before treatment. A pre-test allows the assessment of whether the groups are equivalent on the dependent measure before the treatment is given to the experimental group (Sherri, 2009). In addition, pre-testing allows for the analysis of differences that might initially exist between control and experiment groups which in turn would allow for the adjustment for such differences (Green, Camilli & Elmore, 2016). Post-test measures for the two groups were compared in order to assess the changes that might have occurred after admitting the treatment. Therefore, performance between the two groups on both pre-test and post-test measures was compared.

Structure of the quasi-experimental design that was used in the study

The experimental group was taught balancing chemical equations content of the Science 5124 syllabus using Algebraic method while the control group was taught the same content using Inspection method. The following was the structure of the pre-test post-test control group quasi experimental design that was used in this study.

O_1	X	O_2
O_1	–	O_2

Where:

$O1$ were the observations made during the pre-test measures. Both the experimental and control groups were given BCEPT as pre-test measure.

X was the treatment employed in order to assess its effect on students' performance in balancing chemical equations.

$O2$ were the observations made during the post-test measures. Both the experimental and control groups were given BCEPT as post-test measures. Comparisons were made between post-test performances between groups. If there was a significant difference in performance in balancing chemical equations between the two groups, then it was deduced that the treatment was the cause of such change.

2.2 Population
Mkushi Coppermine Secondary school had a population of 450. A population is a group of individuals who have the same characteristics (Creswell, 2008). The school is a boarding providing education to both girls and boys. The study targeted the Grade11 classes and studied Science 5124 syllabus as an integrated course of study.

2.3 Study sample and Sampling techniques
Mkushi Coppermine Secondary School had two streams of senior classes per Grade. The study sample and sampling techniques were based on the Grade 11 classes who by then were schemed to learn balancing chemical equations. The Grade 11 classes therefore, were purposively selected as research participants and were then randomly assigned to control and experimental groups respectively using simple random sampling. The two classes had a total population of 81 students. Grade 11A class had 41 students and Grade 11B class had 40 students.

2.4 Research instrument
The Balancing of Chemical Equations Performance Test (BCEPT) questions were adopted from past examinations of Examinations Council of Zambia (ECZ) from the year 2013 to 2017 and Chemistry text books approved by Ministry of General Education (MOGE). The test was then pilot-tested on a random sample of 16 grade 12 students

from Mkushi Coppermine Secondary School who were not participants in the main study but had already learnt the topic. The sample size of 16 students for the pilot is supported by Baker (1994) who found that a sample size of 10-20% of the sample size for actual study is a reasonable number to consider enrolling in a pilot. Pilot testing was done in order to establish validity of the test.

2.5 Data collection

Identical Balancing Chemical Equations Performance Test (BCEPT) was used to test the performance of students of experimental and control groups. Both the pre and post tests had printed 30 complete but unbalanced chemical equations. Each BCEPT comprised of three parts and the total marks of 60. BCEPT was administered as a pre-test to 81 Grade 11 students for 1 hour 25 minutes to determine the comparability of experimental and control groups' ability level in balancing chemical equations before treatment. The treatment was administered over a period of four (4) weeks. Each of the intact grade 11 class was taught "Balancing of Chemical Equations" for 160 minutes per week, in four separate 40 minutes lessons. The experimental group was taught using Algebraic method while the control group was taught using Inspection method, the method prescribed by Curriculum Development Centre (2013). Two days after the end of the treatment, BCEPT was administered as post-test to experimental and control groups under similar conditions as were available for pre-test.

2.6 Normality testing

In statistics it is vital to test for normality in order to decide whether to use parametric or non-parametric tests. For this reason, it was vital to test the assumption of normality before any statistical analysis of data was done when comparing the means of two or more groups because the validity of the results depend on the test of normality. In order to test for normality, it is imperative to test whether a sample of observations comes from a normal distribution (Henry, 2002). The assumption of normality can be checked using either Kolmogorov-Smirnov test or Shapiro-Wilks test (Pallant, 2017). The former works best if the sample size is more than 50 while the latter is used to test for normality of the data if the sample size is less than 50. To know the normality for pre-test and post-test data, the Shapiro-Wilk test was used on SPSS version 21.0 because the sample size for each group was less than 50.

Table 2: Test for normality for pre- and post-test scores for experimental and control groups

	Group	Shapiro-Wilk		
		Statistic	Df	Sig.
Performance	Experimental group pre-test	.949	41	.064
	Control group pre-test	.950	40	.078
	Experimental group post-test	.965	41	.231
	Control group post-test	.963	40	.215

From Table 2, the Sig. for experimental group pre-test was .064 whereas for control group .078. Both Sig. were greater than .05. Therefore, the data of pre-test were normally distributed. The Sig. for experimental group post-test was .231 but for control group it was .215. Both Sig. were greater than .05. Therefore, the data of post-test were also normally distributed.

2.7 Data analysis

The data generated from BCEPT were analysed using independent samples t-test with the significant level (α-level) set at .05.

3. Results of the study

3.1 Pre-test performance Results

The pre-test results were analysed using independent samples t-test. Table 3 shows the results of analysis.

Table 3: Pre-test t-test Analysis of the Difference in performance in balancing chemical equations by students of the Experimental and Control groups

Group	N	$\overline{X}$	SD	$\overline{t}$	P
Experimental group pre-test Performance	41	39.37	24.368	.062	.951
Control group pre-test	40	39.03	25.141		

Table 3 shows that the means for the experimental group and control group were 39.37 and 39.03 respectively. The standard deviations for Experimental group and Control group were 24.368 and 25.147 respectively. There was no significant difference in mean scores of the groups. In addition, Table 3 shows that p – value of .951 is greater than .05 level of significance. This confirms that the difference in mean scores was not statistically significant. This means that the two groups had equivalent ability in balancing chemical equations before treatment. Therefore, if any significant difference is observed in post mean scores of the two groups, then such difference would not be attributed to chance but to the impact of the Algebraic method.

3.2 Post-test performance Results

The post-test results were analysed using independent samples t-test. Table 4 shows the results of analysis.

Table 4: Post-test independent samples t-test Analysis of the Difference in performance in balancing chemical equations by students of the Experimental and Control groups

Group	N	$\overline{X}$	SD	t	P
Experimental group post–test Performance	41	62.2	21.767	2.817	. 006
Control group post –test	40	49.68	18.005		

Table 4 shows that the means for the Experimental and Control group were 62.2 and 49.68, and the standard deviations were 21.767 and 18.005 respectively. There was a significant difference in mean performance scores of the groups. In addition, Table 4 shows that p – value of .006 is less than .05 level of significance. This confirms that the difference in mean performance scores was statistically significant. It implies that students taught balancing chemical equations using Algebraic method performed significantly better than those taught using Inspection method. Relying on statistical significance testing alone to interpret quantitative research results is only one-half of the coin (Fan, 2001). Therefore, measures of effect size, confidence interval reporting should be used in collaboration with significance testing to interpret the findings.

Effect Size

Effect size is the standardized difference between means (Olejnik & Algina, 2000; Vacha-Haase, 2001). It quantifies the size of the difference between experimental and control groups and it may be said to be a true measure of the significance of the difference. In other words, it is used to assess the importance of the findings of the study. Kirk (2001) indicates that effect size assists to decide whether results are practically significant. Effect size is manually computed by calculating eta squared because SPSS does not provide eta squared values for t-tests. The following was the formula used for calculating the effect size.

Eta squared = $\frac{t^2}{t^2+(N1+N2-2)}$

The appropriate values from the post-test independent samples t-test output where substituted.

Eta squared = $\frac{2.817^2}{2.817^2+(41+40-2)} = 0.09$

According to Cohen (1988) Eta squared values are interpreted as: .01=small effect, .06=moderate effect, .14=large effect. The effect size was between moderate effect and large effect. An independent samples t-test was conducted to compare performance between the experimental group in which Algebraic method was used in balancing chemical equation, and the control group in which the Inspection method was used. There was a statistically significant difference in the post-test performance scores for experimental (*M = 62.2, SD = 21.8)* and control (*M = 49.7, SD = 18.0*) groups; *t (79) = 2.817, p = 0.006*. The magnitude of the difference in the means was moderate (eta squared = .09).

4. Discussion of the findings

4.1 Effect of Algebraic method on students' performance in balancing chemical equations

The Algebraic and Inspection methods were compared in the learning of balancing chemical equations by students. The concern was not about substituting one method for the other but about the merit of diversity which seeks to enrich performance in balancing chemical equations. Students' performance in balancing chemical equations was established from the pre-test which was administered to the experimental and control groups. Therefore, any significant difference in performance between the two groups after treatment should be attributed to Algebraic method that was used in the experimental group. The pre-test results have shown that there was no statistically significant difference between the performance of experimental and control groups. This implies that the students in the two groups were equivalent on the ability in balancing chemical equations before treatment.

After treatment, a post-test was administered to experimental and control groups. The result of the study in Table 3 compared with results in Table 4 indicates that both the experimental and control groups had improved in performance from pre-test to post-test. Although different methods were used, there were improvements in both groups because teaching on the topic "balancing chemical equations" took place. However, there was higher gain score from pre-test to post-test scores in experimental than in control group. The higher improvement in performance in balancing chemical equations in experimental group was because of Algebraic method that was used. The novelty of application makes it an effective, teaching and learning method.

The results therefore, suggest that when Algebraic method is used in teaching and learning balancing chemical equations, students' performance improves significantly. It should be noted that Algebraic method cuts down the number of steps in many solutions given in books and brings down the stress that the students' experience while balancing chemical equations (Subramanian, 2012). The results presented in Table 4 indicate that students in experimental group had higher post-test mean performance scores than those in control group. The implication is

that students taught balancing chemical question using Algebraic method performed better than those students taught the same topic using Inspection method. The difference in performance scores could not occur by chance because in the pre-test scores analysed in Table 3 both groups had mean performance scores that were nearly equal. In different words, the difference in mean performance was not statistically significant. Therefore, difference in mean performance of students in balancing chemical equations is attributed to the Algebraic method as a significant factor rather than chance. Similar studies have been carried out elsewhere and yielded similar findings (Charnock, 2016; Zabadi & Ramiz (2017) Similarly, Bhattacharjee (2015) had found that Algebraic method leads to satisfactory answer to the fundamental fact that the balanced form of a chemical equation is not always unique. Other studies (Gabriel & Onwuka, 2015) reveal that Algebraic method is important in the learning of balancing of chemical equations because it helps average students and below average students to experience success in balancing, and hence avoiding frustration and failure which might contribute to students' loss of interest in balancing chemical equations.

Further, result of the current study agrees with the proposition that Algebraic approach lends well to both simple and advanced chemical equations that can be reduced to a set of equations which then can be logically and systematically resolved (Olson, 1997; Risteski, 2012). Moreover, Algebraic approach makes it much easier to balance chemical equations than by inspection method (Schmidt and Jignéus, 2003). The results also agree with a previous study (Kolb, 1978) that found that Algebraic method is more general and robust than others in balancing chemical equations. On the contrary, the findings of this study disagree with Ozmen and Ayas (2013) who reported that Algebraic method was problematic and persistently troublesome for high school chemistry. Similarly, Fox (2015) reported that the Algebraic method for balancing chemical equations is traditionally less popular than alternative methods because corresponding sets of linear equations are often tedious to equate.

The null hypothesis (H_O) was tested in order to verify whether there is no statistically significant difference between students taught balancing chemical equations using Algebraic method and those taught using Inspection method. The study results presented in Table 4 indicates that students in experimental group had higher mean performance scores than those in control group. This implies that there is a mean difference in performance between the two groups. Analysis of the results in the same table indicates that the difference in performance scores is statistically significant. The research hypothesis is thus supported and the null hypothesis is rejected on the basis of the result of the independent samples t-test. The implicature is that Algebraic method is significantly superior to Inspection method in enhancing performance in balancing chemical equations. The results agree with Burns and VanDerHeyden (2005) who reported that the Algebraic approach that is applied to balancing both simple and advanced chemical reactions is typically encountered in the secondary chemistry classroom and is superior to that of the Inspection method in improving students' performance.

4.2 Conclusion

The purpose of this study was to determine the effect of Algebraic method on students' performance in balancing chemical equations. Results show that students taught balancing chemical equations using Algebraic method had higher mean performance score than their counterpart taught the same content using the conventional Inspection method. The study has proven that incorporating Algebraic method in teaching balancing chemical equation does have a significant effect at improving students' performance in balancing chemical equations. Therefore, Algebraic method is viable and has potential of enhancing students' performance in balancing chemical equations in Chemistry.

Acknowledgements

The authors are thankful to both Mkushi Coppermine Secondary School in Luano District of Central Zambia, and to The Copperbelt University for the assistance rendered in carrying out this research.

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