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The Differential Effects of the Algorithm and Proportional Reasoning Approaches on Senior High School Students' Understanding of Titrimetric Analysis

Solomon Boachie[1] Kennedy Ameyaw Baah[2] Francis Quansah[3] Joan Danquah[4]

Abstract
This study evaluated The Differential Effects of Algorithm and Proportional Reasoning Approaches on Senior High School Students' Understanding of Titrimetric Analysis in Berekum Presbyterian Senior High School in the Brong Ahafo Region. The target population was the science students in the school. The accessible population consisted of science one and science two final year elective chemistry students. Quasi-experimental design was used for this study. In this design the researcher used a questionnaire and test to solicit information on students' understanding on the Effects of Proportional and Algorithm Reasoning Approaches. Purposive sampling technique was used to select 30 students for the research. Science A students formed the experimental group and were taught using algorithm approach while the science B students comprised the control group and were taught using the proportional reasoning approach. There was no interaction between the control group and the experimental group. Difference in performance in pre-test and post-test, the analysis of the study imply that students exposed to algorithm instructional approach to the teaching and learning in titrimetric analysis performed statistically better at significant level (p-value = 0.000 at α=0.05). Students in the experimental group (algorithm approach) performance were better in post-test than the post-test of students in the control group (proportional reasoning). The Hake Gain was then used to calculate for students understanding in titrimetric analysis using algorithm instructional approach in teaching and learning of titrimetric analysis. The gain 0.46 (SD = 0.132) achieved fell within the range i.e. $0.36 < \langle g \rangle < 0.68$ meaning that students understood the titrimetric analysis after they were exposed to algorithm instructional approach. The results of the study imply that students exposed to algorithm instructional approach to the teaching and learning in titrimetric analysis performed significantly better than proportional instructional approach

Key Words: *Abstract Concepts in Chemistry: algorithm approach, stoichiometry, proportional instructional approach, titration.*

Introduction

The declining trends in high science school enrolment present science educators with the need to make informed policy decisions regarding the effectiveness and appropriateness of current instructional approaches. Science education is considered to be in crisis not only in Nigeria and Ghana but globally. The cause of this is identified as the fall in the number of students taking the physical sciences especially physics and chemistry, because while the numbers taking physics and/or chemistry are falling at higher levels of education, numbers taking biology are higher and fairly steady (Taale, 2010a). One of the goals of science education is to develop learners' ability to acquire knowledge in specific subject areas and to improve their conceptual understanding. Scientific literacy refers to understanding science and the ways in which it can be applied to society (Dani, Wan, & Henning, 2010).

A study of chief examiners' reports on the Senior Secondary School Certificate Examination (SSSCE) in 2008 chemistry practical results revealed that some of the candidates could not use the mole concept to solve problems posed in quantitative analysis. This affected their results in chemistry and their inability to pursue further studies. According to the report a number of them also could not quote the correct units for the titre value, molar masses and concentrations of the solutions used. SSCE examination results in recent times show that even though some students in senior high schools within Berekum Municipality in Ghana have been scoring passes that enabled them to pursue the study of science and science related fields in the universities, the quality of passes obtained is rather low.

Akinola (2006) believed that the causes of the mass failure of students in senior high chemistry included the teachers' methodology, structuring of the curriculum, and the concentration of examination questions on few topics and the inability of students to prepare enough before their examinations.

Although several instructional approaches been by experts, this study however concerned itself with the differential effects of two approaches namely: algorithm approach and proportional reasoning approach. The researcher is of the view that when these approaches are used to teach titration calculation in chemistry to Senior high school students of varied cognitive abilities their performance will improve.

Many students solve chemistry problems using algorithmic strategies and do not understand the chemical concept behind their algorithmic manipulation; they have less trouble with the algorithmic part of the problem than they do with conceptual part (Cracolice et al…, 2008). Identifying this concern is problematic because teachers may accept a correct numerical answer without examining students' conceptual understanding dealing with related concepts (Dahsah & Coll, 2007, 2008).

According to studies by Schmidt and Jigneus (2003) Swedish students exhibited such weaknesses also but solved their problems by employing logical reasoning, the mole method and proportionality to interpret sentence problems into mathematical equations, which often resulted in the formation of paraconceptions. Interestingly, Dahsah and Coll (2008) found in studies in Bangkok that both teachers and students used formulae to solve similar stoichiometric problems instead of using a more pro-active learner-centred or the constructivist approach

Statement of the Problem

In a series of theoretical and pre-tests conducted by the researcher to find out the strengths and weaknesses of students in order to devise remedial interventions, it came to light that a large number of the students did not understand the application of the mole concept to computational problem-solving in titrimetry. This made it difficult for them to know and understand the concept underlying the practical work they were doing. It was also found that some students lacked the manipulative skills required for the appropriate handling of the actual titration equipment. Therefore, students' understanding of the mole concept affects more than just one component of their overall studies in chemistry. Their success in titrimetric analysis particularly in problem - solving will be limited if proper foundation of the mole and its related concepts are not laid. Stoichiometry is a concept that involves problem-solving skills and retention of prior knowledge (Okanlawon, 2010). Comprehensive and diverse instructional strategies are needed to improve student learning of stoichiometry (Kazembe, 2010). For this reason, the researcher investigated the students' ability in the application of the mole concept through computational problem-solving in titrimetry.

Theoretical Framework of the Study

The conceptual framework of the study was based upon constructivist theory, particularly in regard to the constructivist paradigm for conducting research and constructivist pedagogy. Past researchers have focused on student learning of stoichiometry from the students' point of view rather than from a theoretical framework introduced by the teacher (Agung & Schwartz, 2007; Dahsah & Coll, 2007). Researchers can use constructivist theory to analyze the quantitative data collected from the test item and questionnaire. Constructivism is a view of knowing or understanding. The theory is based upon the notion that constructivism can help to explain how people learn (Taskin-Can, 2011). In this study, constructivism refers to the ability of the students to develop new learning (i.e., an understanding of stoichiometry) based upon previous knowledge (i.e., writing a compound, writing a balanced equation, and comprehending the concept of a mole). Constructivist-based research suggests that an informal science experience lays the critical foundations for deep conceptual understanding (Jones & Rua, 2000). As such, constructivists hold the view that learners' understanding of school science, to a large extent, is conditioned by their present common sense experiences and the application of the mole concept through computational problem-solving in titrimetry.

The Purpose of the Study

The study was designed to enhance students' ability in the application of the mole concept through computational problem in titrimetry. The activities were targeted at developing the cognitive skills (the mind) the psychomotor skills (the manipulative skills) the affective skills (the interest or motivation) and the computational skills (calculation) of students in titrimetry. The study may also serves as a source of information for further research in titrimetry.

Research Questions

The following research questions were addressed in the study:

1. What is the effect of proportional reasoning instructional approaches on the students' understanding of titrimetric analysis?
2. What is the effect of algorithm instructional approach on the students' understanding of titrimetric analysis?

Methodology

The research design used in this study was the quasi- experimental design. The focus of the study was on chemistry students at Berekum Presbyterian Senior High School in the Brong Ahafo Region in Ghana. The target population was the science students in the school. To be precise, the population was the 2016/2017 Berekum Presbyterian Senior High School science students was used.
Purposive sampling technique was used to select the sample for the study. The target sample in the study consisted of thirty chemistry final year students of 2014 / 2015 academic year from Presbyterian Senior High School – Berekum in the Brong Ahafo Region. The participants comprised ten (10) females and twenty (20) males. Questionnaire, titrimetric practical knowledge test (TPKT) were designed for the study. The TPKT was selected from the practical test question for WASSCE 2014. The test consisted of one essay practical questions with sub questions a,b and c with the c having four sub questions (ci, cii, cii and civ). These questions were critically reviewed by an assessment and evaluation officer, and a subject area expert. A five-item questionnaire was developed from the research questions stated. The respondents were to place a tick (√) in a box of their choice was used to collect the qualitative data. The Statistical Package for Social Sciences (SPSS) version 20 for windows 2007was used for the analysis.

Results/Discussion

Research Question One: What is the effect of the proportional reasoning instructional approach on the students understanding of titrimetric analysis?

This research question focused on the effect of proportional reasoning on students understanding of titrimetric analysis. The performance of the students was analysed with a paired t-test analysis whiles students understanding of titrimetric analyses was analysed using the Hake Gain. The results are summarised in Table 1

Table 1 Mean Scores of Control Group

Test	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	48.93	15	4.061	1.049
Post-test	53.07	15	4.832	1.248

Table 1 shows the mean scores of both pre-and post-test of the control group. From the table, the mean score of the post-test was 53.07 (SD=4.832) compared to that of the pre-test which was 48.93 (SD=4.061) suggesting that although the students in the control group performed well in the post- test than the pre-test the effect of proportional reasoning instructional approach was not felt in a way that the understanding of the

concepts in titrimetric analyses were really grasped. This was further analysed with the paired t-test analyses.
The results are summarised in Table 2

Table 2 Paired Sample t-test of Control Group

	Mean	Std. Deviation	Std. Error Mean	T	Df	Sig. (2-tailed)
Pre-test - Post-test	-4.133	5.317	1.373	-3.011	14	.009

Table 2 shows a paired t-test analysis in relation to the effects of proportional reasoning instructional approach on students understanding in titrimetric analyses. From the table, the p-value gave 0.009 which suggested that there was statistically significant difference in the pre-and post-test of the students in the control group. To check the effect of proportional reasoning on students understanding, the Hake Gain was used to analyse students' pre-and post-test. This intervention was experienced by the control group. The results are summarised in Table 3

Table 3 Hake Gain of Control Group

	N	Mean Pre-test (SD)	Mean Post-test (SD)	Hake Gain (SD)
Pre-test	15	48.933 (4.061)	53.066 (4.382)	0.077 (0.099)

* N = Number of Students * SD = Standard Deviation *All the scores were converted to percentages

Table 4 indicates the Hake gain for the pre- and post-tests for control group. Questions on the titrimetric analysis were designed to elicit students' preconceptions about the course. Students' pre and post-test scores were used to calculate Hake gain, $\langle g \rangle$ on the level of proportional reasoning approach teaching approach used in the teaching. A substantial use of proportional reasoning approach teaching approach in the teaching should give a gain$\langle g \rangle$ between 0.36 and 0.68, i.e. $0.36< \langle g \rangle <0.68$. In comparison, the Hake gain for the control group gave 0.077 (SD = 0.099), which expresses the lack of effectiveness of proportional reasoning approach to improve students' understanding because it falls below the Hake gain interval. This means that students could not understand the course i.e. titrimetric analysis when proportional reasoning approach was used in a form of intervention to teach them. To prove this argument, a paired sample t-test was used to analyse the pre-and post-test of the control group.

Research Question Two: What is the effect of the algorithm instructional approach on the students' understanding of titrimetric analysis?
The research question three was set to find out the effect of algorithm approach on students' understanding on titrimetric analysis. Before analysing the understanding of the students, the means scores of their pre-and post-tests were analysed to find the difference in academic performance and if algorithm teaching approach influenced the academic performance of the students. The results are summarised in Table 4

Table 4 Mean Scores of Experimental Group

	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	50.53	15	5.579	1.440
Post-test	73.07	15	8.242	2.128

Table 4 indicates the mean scores of the experimental group in both pre-and post-tests. In the pre-test the mean score was 50.53 (SD=5.579) and that of the post-test was 73.07 (SD=8.242). from these mean analyses, students performed better in their post-test than in the pre-test suggesting that there was an effect of the intervention (algorithm approach of teaching) on students' academic performance in the experimental group. To buttress this claim, a paired sample t-test was used to if actually there has been a difference in performance. The results are summarised in Table 5

Table 5 Paired Sample t-test of Experimental Group

	Mean	Std. Deviation	Std. Error Mean	T	Df	Sig. (2-tailed)
Pre-test - Post-test	-22.533	4.984	1.287	-17.511	14	.000

Table 5 shows the comparison of the mean scores of the students' pre-and post-tests in the experimental group thus a paired T-test analysis of the mean scores. From the table the mean score was -22.533 (SD=4.984). The p-value (sig. [2-tailed]) was 0.000 at significance level of 0.05 (α=0.05) means that there was statistically significant difference between students pre-and post-tests. Also such statistics suggests that there was a significant difference in students' academic performance and that the use of algorithm instructional approach impacted on the academic performance of the students.

To pattern the understanding of the students, the Hake Gain was used to analyse the pre-and post-tests of the students. The results are summarised in Table 6

Table 6 Hake Gain of Experimental Group

	N	Mean Pre-test (SD)	Mean Post-test (SD)	Hake Gain (SD)
Post-test	15	50.53 (5.579)	73.07 (8.242)	0.46 (0.132)

Table 6 gives the Hake Gain analysis of students' pre-and post-tests of the experimental group. Questions on the titrimetric analysis were designed to elicit students' preconceptions about the course. Students' pre and post-test scores were used to calculate Hake gain, $\langle g \rangle$ on the level of algorithm instructional approach used in the teaching. A substantial use of algorithm instructional approach in the teaching should give a gain$\langle g \rangle$ between 0.36 and 0.68, i.e. 0.36< $\langle g \rangle$ <0.68. In comparison, the Hake gain for the experimental group was 0.46 (SD = 0.132), which expressed the effectiveness of algorithm instructional approach to improve students' understanding because it fells between the Hake gain interval. This meant that students understood the course i.e. titrimetric analysis when algorithm instructional approach was used in a form of intervention to teach them.

Discussion of the Results

The study basically focused on the use of appropriate instructional approaches (proportional reasoning and algorithm instructional approaches) in the teaching of titrimetric analyses in Presbyterian Senior High School, Berekum in the Brong Ahafo Region in Ghana. The study was guided by research questions which were analysed in this chapter. This section presents into details the discussions of the analyses of the research questions guiding this study. In the earlier part of this chapter, findings were mainly presented and analysed based on the specific research questions with only brief comments on them. In this part however, the findings have been discussed in detail under the research questions set to guide the study.

Findings with respect to research question one, suggested that proportional reasoning instructional approach could not impact well on the understanding of the students in the teaching and learning of titrimetric analyses. The students in the control group who were exposed to proportional reasoning instructional approach improved on their performance of the post-test but could not improve well in their understanding of the concepts behind titrimetric analyses. The pre-test gave a mean score of 48.93(SD=4.061) and that of the post-test was 53.07 (SD=4.832) thus increase in academic performance of students in the control group. The paired t-test analysis done on students means scores gave a p-value of 0.009 at significance of 0.05 (α=0.05), suggesting that there is a significant difference between the pre-and post-tests of the control group. Hake Gain was used to analyse students' pre-and post-test to check their understanding in titrimetric analysis. The gain (0.077) achieved fell below the range i.e. 0.36< $\langle g \rangle$ <0.68

meaning that students did not understand the titrimetric analysis after they were exposed to proportional reasoning.
According to studies by Schmidt and Jigneus (2003) Swedish students exhibited such weaknesses also but solved their problems by employing logical reasoning, the mole method and proportionality to interpret sentence problems into mathematical equations, which often resulted in the formation of paraconceptions

In the research question two, the analysis was based on the academic performance and understanding of the experimental group students who were experienced in using algorithm instructional approaches in titrimetric analysis. From the findings the students' performance showed a significant improvement when comparing their pre-and post-tests. The mean scores for the pre-and post-test were 50.53 (SD=5.579) and 73.07 (8.242) respectively. This suggested that students performed very well in the post-test than the pre-test. The paired t-test used in analysing the means gave a p-value of 0.000 at α=0.05 meaning that there was a statistically significant difference between the pre and post-test of the experimental group i.e. the group exposed to algorithm instructional approach. The Hake Gain was then used to calculate for students understanding in titrimetric analysis using algorithm instructional approach in teaching and learning of titrimetric analysis. The gain 0.46 (SD = 0.132) achieved fell within the range i.e. $0.36< \langle g \rangle <0.68$ meaning that students understood the titrimetric analysis after they were exposed to algorithm instructional approach.
Findings of research question three is in line. Schmidt and Jigneus (2003) on students' strategies in solving algorithmic stoichiometry problems also support the claim of the research question three. In their report when solving chemistry problems many students tend to use algorithmic methods. Kusi (2013) in Hanson and Oppong (2014) asserted that learning of stoichiometry is basically through the use of algorithm in secondary schools in the Kumasi metropolis. This is especially true for students who have not sufficiently grasped the chemistry behind a problem. A difficult problem is preferably solved using algorithmic methods students have learned.

Contribution to the Teaching of Computational Problems in Titrimetry

The declining trends in high school science enrolment present science educators with the need to make informed policy decisions regarding the effectiveness and appropriateness of current instructional approaches. It was realised that the use of algorithm instructional approach when used in titration calculation enable students to perform better as compare to proportional reasoning approach as supported by Kusi (2013) in Hanson and Oppong (2014) asserted that learning of stoichiometry is basically through the use of algorithm in secondary schools in the Kumasi metropolis. This is especially true for students who have not sufficiently grasped the chemistry behind a problem. A difficult problem is preferably solved using algorithmic methods students have learned.

Conclusion

The causes of the mass failure of students in senior high chemistry included the teachers' methodology, structuring of the curriculum, and the concentration of examination questions on few topics and the inability of students to prepare enough before their examinations (Akinola, 2006). Ojo (2001) also identified the lack of qualified teachers and poor teaching methods as factors to be considered when it comes to students' performance in chemistry. It should be of particular interest to educators to find a way of making concepts easier to students to understand and allow students to select which one best suit them. The effective use of the algorithm instructional approach when used in teaching in teaching computational problems in titrimetric analysis in chemistry offer itself to science educators as one of the solution.

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Author Profile

Solomon Boachie had his undergraduate degree in Bachelor of Education (Hon) in Science Education (Chemistry) from University of Education Winneba, Ghana in 2008. He pursued a Master of Science Education (Chemistry) from the same University and graduated in 2015. He is a Chemistry tutor at St Ambrose College of Education, at Dormaa-Akwamu in Bono Region. He is currently pursuing Master of Philosophy in Science Education (Chemistry). He is a project work Coordinator at St Ambrose College of Education and a member of Ghana Association of Science Teachers in Ghana.

Kennedy Ameyaw Baah had his undergraduate degree in Bachelor of Education (Hons) in Science Education (Chemistry) from the University of Cape Coast, Ghana in 2006. He pursued a Master of Education in science education (Chemistry) from the University of Education, Winneba, Ghana and graduated in 2011. He pursued an Mphil in Chemistry from Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and graduated in 2017. He is a Chemistry tutor at the Wesley College of Education, Kumasi, Ghana. He has been promoted to the rank of Principal Tutor. He is currently a PhD Candidate at Kwame Nkrumah University of Science and Technology, pursuing chemistry. He is a member of the College Research Committee.

Francis Quansah is a tutor at Foso College of Education, Assin Foso in the Central Region of Ghana. He was a member of the academic board and the head of science department in the college from 2016 to 2019. He teaches Chemistry Education and Science Methodology. Mr. Quansah obtained his Bachelor of Education degree in Chemistry Education from the University of Education-Winneba, Ghana in 2002. In 2010, he obtained Master of Science Education degree in University of Education Winneba, Ghana and currently, he is pursuing a Master of Philosophy in Science Education at the University of Education-Winneba, Ghana. Presently, he serves at the counselling and advisory committee in the college.

Joan Danquah Degree: Bachelor of Education in Science (Chemistry) - U.C.C in 2008. Mphil in Environmental Science (University of Ghana, Legon in 2012). Chemistry tutor in SDA College of Education, Asokore - Koforidua in the Eastern Region of Ghana. PhD candidate in University of Ghana, Legon pursuing Chemistry.