The Effect Of Numeracy On Attitude And Conceptual Understanding Of Mole Concept By Grade 11 Students.

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Abstract: The achievement of students in chemistry and in mole concept in particular in Zambia's secondary schools has remained low. One of the reasons contributing to the low achievement is the failure by the students to deal with the mathematical aspect of the mole concept. This study therefore, sought to investigate the effect of mathematical aspect of the mole concept on the achievement of the learners. In addition, the study sought to determine learners' attitude towards the mathematical aspect of the chemistry subject. The study further sought to determine whether the effect of numeracy on achievement differ by gender. The study used a Pre-Post-test quasi experimental research design. The target population was 100 grade eleven pupils at a Secondary School in Zambia. Simple random sampling was used to select and assign two classes to be used as the experimental and control groups. The data collection instruments were Chemistry Performance Assessment Test (CPA) and a Likert scale Chemistry Related Attitude Questionnaire (CAQ).Data was presented descriptively using frequency tables and analysed using means and percentages while hypotheses were tested using the independent sample t-test. The results show that incorporating the teaching of basic mathematics concepts in the teaching and learning of the mole concept has a positive effect on student's achievement. When incorporated, the understanding of the concept is enhanced and this results in high achievement. The results also show that positive attitude towards the mathematical aspect of chemistry subject fosters high achievement. However, the results showed that numeracy skills has no effect on achievement in mole concept depending on one's gender. These results have an implication to teaching and learning of mole concept.

Key Words: Chemistry education, Effect, Mole concept, Numeracy

1.0 Introduction

In Zambian secondary schools, chemistry is taught as a subject under natural sciences. Banda, Mumba and Chabalengula [1], noted that every science discipline is well embedded in five cluster goals of science education, these are; scientific knowledge, scientific methods, personal needs, societal issues and career awareness. Starver (as cited in Banda et al.,[1]) condensed the goals of science education into three broad goals, which are: prepare students to enter the work force, prepare students to study science at higher level of education, pursue occupation and take up careers and prepare students to become more scientifically literate citizens. The teaching of chemistry should therefore be done such that students understand and like it. However, research shows that chemistry is generally a difficult subject to students at all levels [23]. For instance, the 2014 Examinations'-Performance Report (EPR) of the Examinations Council of Zambia (ECZ) show a general poor performance in both Chemistry 5070 and 5124 examinations. [7]. In Zambia, 5070 Chemistry is the pure chemistry paper comprising only chemistry concepts while 5124 is the combined science paper comprising chemistry and physics concepts. The low performance has also been reported by the ECZ in the 2013, 2015 and 2017 Examination Performance Reports. [7]. Poor performance of pupils in Chemistry could be ascribed to learner'-s' attitude and conception towards the subject in addition to many other factors [2, 6]. Pupils may have negative tendencies and pessimism towards chemistry due to the bad experiences that they have had with the subject [15]. Chemistry is also perceived by many students to be a difficulty subject. As it is in every area of science, there are some concepts in chemistry that many students find difficult to grasp. A lack of understanding of key concepts of a discipline can limit a student's ability to grasp and apply fundamental principles of that discipline. Such concepts are referred to as 'Threshold concepts' [18]. The mole concept shows characteristics of being such a concept [32].As noted by Moss and Pabari [20], School Chemistry often includes two very different types of learning experiences: one involves pouring of liquids and collecting gases, and using equipment' such as test tubes, balances and Bunsen burners; the other comprises mole calculation, balancing equations or learning atomic and molecular structures. For many secondary or high school level students, the first type of chemistry is fun; the second type is difficult, confusing and boring. However, several interventions can be put in place to ensure that pupils' attitudes and performance in Chemistry are improved. One of such interventions is to teach the subject beginning from what the student already knows, which should be integrated with new ideas. This allows students to construct their own knowledge through experience and bring about meaningful learning. Studies done on this topic also show that many students have problems dealing with the mathematical aspect of the mole concept and chemistry as a whole. For example Bridges [2] reported that most of the teachers believe that students are not ready mathematically to be successful in chemistry. She further reports that according to the teacher'-s' comments, boys have a tendency to learn stoichiometry more easily than the girls. Charles, Arokoya and Amadi [4] in Nigeria investigated the effect of mathematics knowledge on chemistry students' academic performance in gas laws. Their findings showed that mathematical knowledge had a

greater impact on the achievement of the learners. The findings further revealed that there was a significant difference between the mean performances of mathematics between the high and low achievers in chemistry.

2.0 Statement of the Problem

The 2013, 2014, 2016 and 2017 Examination council of Zambia performance reports reveal a poor performance in chemistry as a whole, and in mole concept in particular [7].The poor performance on the mole concept in this reports was mainly attributed to lack of good mathematical skills to workout questions that require numerical answers. The 2016 Examination council of Zambia performance report further reveal that candidates with low performance had difficulties in attempting questions involving calculations. [7].

Table 1. *Comparison of performance in chemistry (5070) and science (5124) in %.*

	2017	2016	2015	2014	2013	2012
Chemistry 5070	50.05	48.21	49.82	49.12	47.99	48.17
Science 5124	35.28	32.83	17.65	17.76	33.94	29.37

As it can be seen from Table 1, the percentage pass rate for the two subjects has been below 50% for a number of years, indicating that more than 50% of the learners who had sat for examinations in these years failed in chemistry and science. Poor performance was however so notable in topics that involved some mathematical concepts. The sampled scripts showed that most candidates had challenges that are related to the mastery of the concepts, mathematical manipulation and the interpretation of practical observation and skills in drawing graphs. Wrong units on numerical values, lack of accuracy in terms of significant figures, number of decimal places and premature rounding off were some of the factors that led to loss of marks by candidates. Generally, there is lack of good mathematical skills to workout questions that require numerical answers. This research therefore, sought to ascertain the extent of the effect of numeracy on learners' conceptual understanding of Mole concept.

3.0 Purpose of the study and Objectives

The purpose of this study was to determine the effect of numeracy (the mathematical aspect) on the conceptual understanding of learners of the mole concept. It also sought to establish the attitude of learners towards the mathematics aspect of the mole concept. By extension, the study also sought to find out whether gender has a role to play in achievement of the learners. The objectives of this study were to:

(i) Determine the effect of numeracy on the conceptual understanding of learners on Mole concept.
(ii) Determine if there is a relationship between mathematical skills and achievement in mole concept.
(iii) Establish the learners' attitude towards the mathematical aspect of the chemistry subject.
(iv) Establish whether the effect of numeracy on the conceptual achievement on mole concept differ by gender.

In order to find out the effect of numeracy on conceptual understanding of secondary school learners on Mole concept and their attitude towards the mathematical aspect of chemistry, the following research questions guided the study:

1. What is the effect of Numeracy on the conceptual Achievement on the Mole concept by grade eleven learners?
2. Is there a relationship between the mathematical skills and achievement in mole concept?
3. What is the learner's attitude towards the mathematical aspect of the chemistry subject?
4. Does the effect of numeracy on the conceptual Achievement on the mole concept differ by gender?

4.0 Literature Review

The Mole concept

Silberberg defines the mole as the SI base unit for amount of a substance. The amount that contains a number of objects equal to the number of atoms in exactly 12g of carbon-12 (which is 6.022 $X10^{23}$) [26]. Termed the chemist's counting unit, the mole is more than a unit of measurement. Unlike the gram, or cubic centimetre, the mole is enveloped within a concept, an accepted way of comprehending the mole [31].Staver and Lumpe [28, 29] explains that the mole is an example of a theoretical concept, based upon the definition proposed by Lawson, Abraham and Renner (1989): "a pattern of regularity named by a term" stemming from perceived relations of imperceptible attributes. Thus, the theoretical abstract nature of the mole anticipates the difficulty of its understanding, especially by high school students. In the chemistry curriculum, students must master the important concept of stoichiometry, a mathematical chemistry concept that is used to determine how much product will be produced or formed from a given quantity of reactants [36]. Reactants are substances that are mixed to form a product (eg, sodium hydroxide and hydrochloric acid are mixed to produce sodium chloride and water).Stoichiometry is the foundation of chemistry, as such, if students cannot understand stoichiometry and the mole concept, they cannot understand chemistry [26].Therefore, the mole concept is and remains important to understanding the part of chemistry that involves problem solving [4].Chemistry is said to be a difficult branch of science to learn [34].Understanding the mole concept is an important part of learning chemistry, but students' understanding of this concept is low, with many students demonstrating surface learning only [4].Therefore, improving students understanding of chemistry could increase the number of students entering fields of study that involve chemistry [18].

Mathematics Ability

For students experiencing maths anxiety and low reasoning ability, the difficulty of understanding the mole is apparent. Tobias [33] defines maths anxiety as feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of ordinary life and academic situations. Spicer [27] describes it as an emotion that blocks a person's reasoning ability when confronted with a mathematical situation. Gabel and Sherwood [8] used an

aptitude-by-treatment interaction design to study the effectiveness of instructional strategies in teaching problem solving to high school chemistry students. They concluded that the lack of understanding of basic mathematical principles is a "real impediment to solving mole problems correctly using reasoning methods and should be considered by chemistry teachers when presenting students with problems to solve" (p 850). Success in Mole concept problem solving is directly related to a student's masterly of mathematical concepts such as Scientific notation, two-step problem, and division problems. As reported by Moss and Pabari [20], the Higher Education Academy Physical Sciences Centre carried out research on chemistry undergraduates in England and Scotland to explore the difficulties university staff experience when teaching undergraduates. The largest problem was said to be the level of mathematical skills that students have. Students who have the potential to learn chemistry but are hindered by poor backgrounds in mathematics will panic when faced with problems. When students were asked what they were worried about before starting a chemistry course, the response of one of the students was, "Maths- absolutely petrified of the maths and the conversions."(p 78). Larson [16] found that students experiencing maths anxiety and low reasoning ability do have difficulty in understanding the mole concept. The same study revealed that five areas were prominent in the general failure of students to construct meaningful understanding of the mole concept and these included:

- inconsistency between the instructional approaches of the textbook and teacher
- Confusing mole concept vocabulary
- Students mathematical anxiety and proportional reasoning ability
- Learners cognitive levels, and
- lack of practice in problem solving.

Attitudes of Students towards Mathematical aspect of Chemistry

A business Dictionary defines attitude as a predisposition or a tendency to respond positively or negatively towards a certain idea, object, person, or situation. Attitude influences an individual's choice of action, and responses to challenges, incentives, and rewards. (Business Dictionary, 2019). It is a social orientation – an underlying inclination to respond to something either favourably or unfavourably. Attitudes towards science were defined as liking-disliking science or negative-positive feelings towards science [15]. There is a great agreement among science theorists and practitioners on the importance of students' attitudes toward chemistry lessons in school. Steiner [30] pointed out that there was a relationship between students' perceptions and attitudes towards chemistry course and their course achievements. Accordingly, they expressed that more successful students defined their approaches towards the lesson like that "relevant", "coordinate", "have confidence", "enthusiastic", and it was also common among these students that chemistry was useful and opens new prospects. Research shows that the attitudes of learners towards Chemistry is generally low. According to Johnstone (cited in O'dwyer,[22]), much of the negativity and pessimism that surrounds Chemistry as a subject is related to bad experiences pupils have had with the subject. The combination of abstraction, symbolism and practical work has turned many pupils off the subject. Learner's motivation to learn is important but does not necessarily determine whether they employ a deep or a surface approach. Aspects of learners' motivation to learn can be classified as either intrinsic (e.g. wanting to know) or extrinsic (e.g. wanting to learn in order to pass examinations). Reid [24] found that; for many learners, difficult tasks are more enjoyable than easier tasks. Therefore, it is important when discussing the attitudes of learners to realise that learners don't simply have a negative attitude to difficult material and a positive attitude to easy material. The most important thing to note is that enjoyment comes when the learner is successful in their effort to gain understanding. If a true understanding of a chemical concept is not possible due to the learner's intellectual inability, learner satisfaction decreases and their attitudes towards Chemistry deteriorate [22]. Enhancement of students' positive attitudes to chemistry is very important considering two main reasons. First of all, research on the link between attitudes and academic achievements discovered that these variables were closely related to each other. The second reason that makes attitudes important is that attitudes predict behaviours [15]. Researchers typically assume that students' belief in their ability to succeed in chemistry tasks, courses, or activities, or their positive attitude, has a powerful impact on their choices of science-related activities, and at the same time on the effort they expend on those activities, the perseverance they show when encountering difficulties, and the ultimate success they experience [15]. Students who have a strong belief that they can succeed in chemistry-related tasks and activities will be more likely to select such tasks and activities, and work hard to complete them successfully [3]. As a matter of choice, students who do not believe that they can succeed in chemistry-related activities will avoid them if they can and will put forth minimal effort if they cannot. When confronted with the typical challenges that science involves, they will be more likely to give up and to experience the stresses and anxieties that help ensure the erosion of their efforts [3]. Thus, students' belief in their ability is proposed to be an important factor influencing attitudes toward chemistry and chemistry anxiety.

Summary

The literature review showed that many students have difficulty learning chemistry and in particular the mole concept. This is because they lack the skills necessary to complete the course successfully. These skills include, but are not limited to, mathematical skills, critical and analytical thinking skills and study skills. Students with limited mathematical skills find it a challenge to be successful in mole concept. In addition, lack of positive attitudes towards the mathematical aspect of the mole concept and chemistry as a subject, could have a negative impact on the student's achievement and success in understanding the mole concept.

5.0 Methodology

5.1 Research design

The research design used was a pre – post-test quasi experimental design due to the inability of the researcher to randomly assign participants to groups but instead intact classes were used. Both groups were pre-tested on the basic concepts in mole concept mathematics and mole concept content to establish the equivalence of the two groups. Both groups were taught fundamental concepts of mole concept by the same teacher and were later post-tested. The mole concept achievement test scores were tested for statistical significant differences in means using an independent samples t-test. This was not a true experimental design, because participants were not randomly selected. However, the pre-test allowed to assess whether the groups were equivalent on the dependent measure, that is, attitudes towards mathematical aspect of Chemistry, basic mathematics concepts and mole concept content before the treatment was given to the experimental group. This is consistent with Sherri [25], (p 323) who wrote: "a pre-test allows us to assess whether the groups are equivalent on the dependent measure before the treatment is given to the experimental group". In addition, the researcher was able to assess any changes that may have occurred in each group after treatment by comparing the pre-test measures for each group with their post-test measures. The following was the structure of the pre-test post-test quasi experimental design that was used in this study.

O_1	X	O_2
O_1	–	O_2

Where:

O_1 Was the observations that was made during the pre-test measures. Both the experimental and control groups were given first the basic mathematics concepts test, the mole concept test and then the Chemistry Attitudes Questionnaire (CAQ) as pre-test measures.

X was the treatment that was employed in order to assess its effects on students' performance in the Mole concept test. In this case it was the teaching of the mathematical concepts found in the Mole concept.

O_2 Was the observations made during the post-test. Both the experimental and control groups was given first the Mole concept test, and then the Chemistry Attitudes Questionnaire (CAQ) as post-test measures. Then comparisons were made between pre-test and post-test attitudes and performance within groups and between groups.

5.2 Sample and Sampling Procedure

There were four grade 11 classes studying Chemistry 5124 syllabus at the school where data were collected. Therefore, two classes were randomly selected to be the research subjects. One class was randomly assigned to be the experimental group, and the other class was the control group. Both classes consisted of 50 students each. The subjects of the study were not randomized into experimental and control groups but were left as intact classes. This was to avoid the disruption of the school programmes.

5.3 Research Instruments

The Chemistry performance Assessment test (CPA) composed of test items drawn from prescribed text books and national examination papers on mole concept topic and were used to establish the students understanding of the key ideas. The test items were drawn across the mole concept topic so as to show the linkage of ideas and how one idea is used to solve the next problem. Interest was on seeing how leaners were able to see and use the relationship in ideas or concepts. A mathematics performance assessment pre-test was also administered to both groups at the beginning of the research to establish the equivalence of the two groups in their understanding of basic mathematics used in the mole concept. A mathematics performance assessment post-test was administered to the experimental group whose results were correlated with the chemistry performance results to see if there was a relationship. The items in this tests were drawn from prescribed mathematics text books and topics included: scientific notation, number divisions, ratios, two step problems and decimal fractions. The Chemistry Related attitude Questionnaire (CAQ) sought to ascertain the attitudes of learners towards the mathematical aspect of the chemistry subject. The items tried to reflect the learner's feelings as much as possible. The feelings were distributed in range of strongly agree to strongly disagree and in between to show the extent to which an individual feels towards a particular item.

5.4 Data Analysis

Data were analysed using the Statistical Package for Social Scientists (SPSS) software. Both dependent variables, that is, students' attitudes towards Chemistry, and students' achievement in the Mole concept test were separately analysed. The statistical test used to determine if there was a statistically significant difference in means of the two groups, that is, experimental and control groups, on both attitude and achievement was independent sample t-test. This was the best statistical test to test the hypothesis because data for achievement was quantitative data, and comparisons was made between two groups [25]. Furthermore, data for attitudes of pupils in mathematical aspect of Chemistry was quantitative as well because of the items in the questionnaire being ranked on a five point Likert Scale (i.e., Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree). In each case, the significance level (α-level) was set at 0.05.

6.0 FINDINGS

6.1 Effect of numeracy on achievement of the learners

The first question of the study was: What is the effect of Numeracy on the conceptual Achievement on the Mole concept by the learners? To answer this question, we look at the performance of both the control and the experimental groups.

Table 2: *Group Statistics, Mole concept Post-test*

Group	N	Mean	SD	t	df	p
Experimental	50	36.7	16.2	2.6	98	0.010
Control	50	28.9	13.4			

An independent-samples t-test was conducted to compare performance between the experimental group in which teaching of basic mathematics concepts were incorporated in teaching the mole concept, and the control group in which this approach was not used. There was a significant difference in the scores for experimental (M=36.7, SD=16.2) and control (M=28.9, SD=13.4) groups; t (98) =2.6, p = 0.010. These results suggest that incorporating teaching of basic mathematics concepts in teaching of mole concept does have an effect on secondary school student's achievement. Specifically, results show that teaching of basic mathematics concepts before teaching the mole concept enhances learners understanding of the mole concept leading to better understanding and achievement. . Learners with good mathematical skills had better understanding of the mole concept and this resulted in high achievement.

6.2 Relationship between mathematical skills and performance

The second question of the study was: Is there a relationship between the mathematical skills and achievement in mole concept? A correlation test was run to determine whether there is a relationship between performance in basic mathematical concepts and performance in mole concept.

Table 3: *Pearson correlation*

		CHEMISTRY	MATHS
CHEMISTRY	Pearson Correlation	1	.809**
	Sig. (2-tailed)		.003
	N	50	50
MATHS	Pearson Correlation	.809**	1
	Sig. (2-tailed)	.003	
	N	50	50
**. Correlation is significant at the 0.01 level (2-tailed).			

A Pearson product-moment correlation was run to determine the relationship between performance in basic mathematical concepts and performance in mole concept. There was a strong, positive correlation between performance in basic mathematical concepts and performance in mole concept which was statistically significant. (r= .809, n= 50, p= .003).

6.3 Learner's attitude towards the mathematical aspect of chemistry subject

The third question of this study was: What is the learner's attitude towards the mathematical aspect of the chemistry subject?

Table 4: Group Statistics, Attitudes Pre-test

GROUP	*N*	*Mean*	*Std. Deviation*	*Std. Error Mean*
EXPERIMENTAL	*37*	*71.4*	*17.1*	*2.8*
CONTROL	*46*	*79.2*	*14.7*	*2.2*

We can see that there is a statistically significant difference between the mean achievement of the experimental group (M=71.4) and a control group (M=79.2) in their chemistry related attitudes. This means that the control group had a more positive attitudes towards chemistry than the experimental group before the treatment was administered to the experimental group. After the administration of the treatment, the Chemistry Related Attitudes was again administered to both the control and experimental groups. The following are the group's statistics:

Table 5: *Group Statistics, Attitudes Post-test*

GROUP	N	Mean	Std. Deviation	Std. Error Mean
EXPERIMENTAL	42	86.4	16.5	2.5
CONTROL	48	78.7	15.2	2.2

We can see that there is a statistically significant difference between the mean achievement of the experimental group (M=86.4) and a control group (M=78.7) in their chemistry related attitudes. This means that the experimental group had a more positive attitudes towards chemistry than the control group after the treatment was administered to the experimental group. Before the treatment was administered, we saw that the experimental group had a low attitude toward mathematical aspect of the chemistry subject. This results shows that the change in the attitude of the learners towards the mathematical aspect of the mole concept in the experimental group can be attributed to the teaching of the basic mathematics concept before the learners learning of the mole concept topic.

6.4 Effect of numeracy on conceptual achievement of mole concept by gender

The fourth question of this study was: Does the effect of numeracy on the conceptual Achievement of the mole concept differ by gender?

Table 6: *Group Statistics, Mole Concept Post-test by Gender*

Group	N	Mean	SD	t	df	p
Experimental	53	33.8	15.3	0.675	98	0.502
Control	47	31.8	15.3			

Since the p value (0.502) is greater than alpha level (0.05) the researcher can conclude that there is no statistically significant difference between the two groups. This means that the differences between groups means is likely due to chance and not due to the independent variable manipulation. Therefore, the results show that numeracy skills has no effect on the achievement depending on whether one is a boy or a girl.

7.0 Discussions

7.1 Effect of numeracy on achievement of the learners

In this study, it has been found that incorporating the teaching of basic mathematics concepts in teaching of mole concept does have an effect on secondary school student's achievement in chemistry and specifically on this topic of the mole concept. Specifically, this results has shown that teaching of basic mathematics concepts before teaching the mole concept enhances learners understanding of the mole concept leading to better understanding and achievement. Therefore, these results imply that a better understanding of numeracy (basic mathematics concepts) have a positive effect on the achievement of the learners in this topic. Learners with good mathematical skills have better understanding of the concept and this resulted in high achievement. Results

from this study also show that there is a positive correlation between good mathematical skills and high achievement in mole concept. This is in line with what other researchers have also found in other studies. For instance, Charles Ogan et al., [4] looked at the effect of mathematics knowledge on chemistry students' Academic performance in Gas laws in Nigeria. They found that without some basic mathematical skills, calculations in chemistry are made extremely difficult especially with concepts and theories in chemistry. Odili [21] also stated that achievement in sciences is often contingent upon mathematical knowledge and the ability to perform mathematical operations, concepts and procedures that are used to solve problems in various fields and disciplines including chemistry.

7.2 Learner's attitude towards the mathematical aspect of chemistry subject

Results from this study shows that having a positive attitude towards the mathematical aspect of the mole concept results in high achievement. This is because, prior to the administration of the treatment, both groups of the study showed a low attitudes towards chemistry and a negative attitude towards the mathematical aspect of the chemistry subject. In fact, students had a strong feeling that chemistry would have been easy if it did not contain mathematical calculations. However, after integrating the teaching of basic mathematics concepts in learning and teaching of the mole concept for the experimental group, their attitudes and achievement increased compared to their colleagues in the control group where attitude and performance remained relatively low. This implies that positive attitude in chemistry fosters high achievement. This is consistent with what Michelli [19, 35] found out when she conducted a study to determine the relationship between attitudes and achievement in mathematics among fifth grade students. She found out that there was a correlation between attitude and achievement in mathematics among the fifth grade participants.

7.3 Effect of numeracy on conceptual achievement of mole concept by gender

Results from this study shows that numeracy skills has no effect on the achievement in mole concept depending on whether one is a boy or a girl. The findings are also in line with the findings of Charles Ogan et al. [4] who in their study established that there was no significant gender differences in the performance of students and so concluded that success in chemistry does not depend on the gender of the student. Therefore, both girls and boys should be encouraged by their teachers that they can do well in this topic and chemistry at large.

8.0 Conclusions

The following are the conclusions of this study:

i) Incorporating the teaching of basic mathematics concepts in teaching chemistry topics that involves calculations does have an effect on secondary school students' attitude towards chemistry. When the teaching of basic mathematics concepts are incorporated in teaching of the mole concept, secondary school students' attitude towards the mathematics in chemistry is enhanced and it generally becomes positive.

ii) Incorporating the teaching of basic mathematics concepts in teaching and learning of the mole concept have a positive effect on secondary school students' achievement. When the teaching of the basic mathematics concepts are incorporated in teaching of the mole concept, secondary school students understanding of the mole concept is enhanced and this leads to high achievement.

iii) Positive attitude towards the mathematical aspect of chemistry subject fosters high achievement. Positive attitude towards topics that involves calculations in chemistry can be fostered in students when the chemistry teachers incorporate the teaching or revision of the mathematics concepts needed for the learners to operate successfully in those topics.

iv) Numeracy skills (mathematical skills) has no effect on the achievement in mole concept depending on whether one is a boy or a girl. Success in chemistry does not depend on the gender of the student. Therefore, both girls and boys should be encouraged by their chemistry teachers that they can do well in this topic and chemistry at large.

9.0 Recommendations

Based on the findings of this study the following are the recommendations:

i) The Chemistry Curriculum for Senior Secondary Schools, should incorporate the revision of mathematical concepts as a technique to be used in teaching the mole concept and other chemistry topics heavily immersed in calculations by science teachers.

ii) Professional bodies such as Zambia Association of Science Educators (ZASE) should organize workshops and seminars to popularize and sensitize teachers of science and chemistry in particular on the integration of the teaching of basic mathematical concepts in teaching students science concepts that involves calculations than just assuming that learners have this skills from their mathematics lessons.

iii) Chemistry teachers and mathematics teachers should work together to ensure that learners have necessary mathematical skills needed to successfully operate in science topics that require calculations.

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