Impact of Problem-Based Learning on Learner Achievement and Problem-Solving Skills on Environmental Non-Metal Pollution

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Abstract: **This study investigated the impact of Problem -Based Learning (PBL) on learner achievement and their problem solving skills on environmental non-metal pollution. Learners' attitude towards environmental non-metal pollution was also evaluated. The study implemented a quasi-experimental design involving the pre-test, post-test control group design. The research sample consisted of two grade 12 classes (total of 95 learners) studying Chemistry 5124 at Kenneth Kaunda Secondary School in Chinsali District of Muchinga Province. Learners in the experimental group were instructed via PBL, while the lecture and discussion methods were used in the control group. Achievement test, problem solving skills test and attitude questionnaire were used to assess three parameters, namely; understanding of the topic, problem-solving skills on the topic and learners' attitude towards the topic. An independent samples t-test was used to compare achievement of the two groups at 95% confidence level. Problem-solving skills data were analysed descriptively by computing frequencies while attitude data were analysed using descriptive (mean) and inferential statistics (Mann-Whitney U–test). The study findings indicated a significant difference between the experimental and control group ($t_{(df=93)} = 3.554$, $p = 0.001 < \alpha = 0.05$ two tailed). Problem solving skills assessment results reflected that learners' problem solving skills of the experimental group (75.6%) increased more than that of the control group (42.0%). The attitude results indicated that learners' liking, interest and motivation towards the topic increased more in the experimental group compared to the control group with attitude mean of 4.11 (SD = 1.059) and 3.42 (SD =1.346), respectively. The value of U= 557.000, Exact. Sig (2-tailed) = 0.00. Based on the findings, it is recommended that PBL instruction be used in teaching environmental pollution arising from non-metals as it showed a positive impact in concept learning, problem-solving skills and learners' attitude towards learning.**

***Keywords*: Problem-Based Learning, Achievement, Problem-Solving Skills, Environmental Pollution, Non-Metals**.

I. INTRODUCTION

1.1 Background and Literature review

The students' academic performance in any subject is an important index for measuring the effectiveness of teaching and learning and the extent to which the intended objectives of the subjects are being achieved Okunloye & Awowale (2011). The relevance of science to national goals, aspirations and economy dictates, to a large extent, the huge commitment and support which nations make and give to science and technology advancement. As such, the teacher of science and technology is the means through which the skills and knowledge get to the learners (Agogo & Onda, 2014).

Chemistry is a scientific subject whose relevance is seen in almost every aspect of society. For example the use of disinfectants, soap and detergents in homes help in carrying out daily activities such as laundry and therefore, the knowledge behind these cleaning agents is based on chemical reactions. The relevance is also seen in agriculture as crop enhancing agricultural chemicals such as fertilizers are used in fields and gardens to ensure a constant and viable food supply. Every science learner should master Chemistry knowledge and skills that are relevant and applicable in the environment (Datta & Osaka, 2005; Meyer, 2005) as cited by Makoni (2014). It is widely acknowledged that chemistry is one of the most difficult subjects in secondary science as it contains aspects of chemical reactions that need to be understood in order to solve chemistry related problems Osman & Nur (2013).

Therefore, because of this reason, it should be emphasised in terms of its teaching and learning as it plays a very important role in unifying other science subjects (Agogo & Onda, 2014).

Thus, in this realistic educational chaos, environmental chemistry is perhaps the branch of chemistry that has more links to the daily aspects of chemical reactions than any other component (Jardim, 1998). As such, the chemistry of it needs to be understood clearly by learners in order to improve their performance.

The specific Chemistry of the environment, in this study was Chemistry of non-metals and their compounds. The ecological effects of excessive non-metal compounds on the environment are easy to see and this makes their study an authentic topic whose different concepts require learners to master Chemistry from various perspectives.

Society and technology are changing regularly. That is why we need people who have the ability to make decisions and give logical solutions to real life problems. Zambia is undergoing rapid socio-economic development and the education sector is no exception. Education is an agent of change. Therefore, one of the purposes of teaching Science is to equip learners with knowledge and skills to live effectively in this modern age of Science and Technology and to enable the learner to contribute to social and economic development of the nation. It is to this end that Science is taught at all levels of education in Zambia (ECZ, 2014 & CDC, 2013).

Science and technology enhanced national social and economic development, can only be achieved by improving the performance and problem solving skills of learners through the use of teaching approaches that would enable the learner to see the relationship between content taught in class and the experiences in their local environment. However, efforts that have been made so far to equip learners with knowledge and skills have not improved performance of learners at Grade 12 in School Certificate Examinations in some topics of Chemistry. For instance one such topic is non-metals in Science 5124 and Chemistry 5070, where a lot of learners still have challenges understanding some concepts as pointed out in the 2016 and 2017 Examination Council of Zambia examiners report (ECZ, 2016, 2017). The reports specifically said that learners faced challenges on the topic of non-metals in Science 5124 and Chemistry 5070 - the topic is not well understood and learners have limited knowledge on the topic. One, among other reasons pointed out, was that some teachers rush through the topic or fail to cover it. As a result, candidates' knowledge of the topic tends to be scanty.

This problem seem to recur each year as evidenced by the results (%) published by the Examination Council of Zambia reports over the period 2013 to 2017 as 17.76% in 2013, 29.37% in 2014, 17.65% in 2015, 32.83 % in 2016 and 35.28% in 2017 in Science 5124. The problem of poor performance in Science by learners is also evident at Kenneth Kaunda Secondary School whose recorded quality pass percentages were 22% in 2014, 35% in 2015, 54% in 2016, 54% in 2017 and 50% in 2018.

Various researchers have identified specific challenges faced by learners with regard to the topic of non-metals. Among the issues identified include understanding concepts on environmental pollution caused by non-metals and non-metal compounds which are deemed to be abstract concepts that are taught partially in primary education. Learners have challenges understanding these concepts, hence it is important that sources and mechanisms be stressed at secondary school (Marinopoulos & Stavridous, 2001; Godoy & Valeiras, 2007).

Learners' attitude toward learning Chemistry is a factor that has long attracted the attention of researchers. It has been observed that a lot of learners are losing interest in chemistry and this is alarming because the future generation needs future communities who are good in chemistry. Understanding learner's attitude is essential in supporting their achievement and interest toward a particular subject (Ogembo, Otanga &Yaki, 2015, Yunus & Ali, 2012). Leaners' academic performance in Chemistry is a function of their attitude (Bassey, Umoren & Udida, 2008). Learners' attitude towards Chemistry is essential and crucial in discussing factors in Chemistry achievement. Attitude and academic achievement are important outcomes of science education in secondary schools (Najdi, 2013). Most learners have a negative attitude towards Chemistry, hence low attitude towards problem – solving in Chemistry. They lack interest in the subject and do not grasp the concepts of Chemistry (Delmang & Gongden, 2016).Therefore, there is need to find the basis for enhancing positive attitude of learners. One way this can be done is by teaching concepts by making the learners aware of the problems they face in their local environment as a starting point. That is, learning through solving an ill structured problem as this would enable them see the connection between the chemistry learnt in class and their environment.

Therefore improving performance of learners and enhancing positive attitude requires the use of a more engaging approach and one among them is the problem-based learning approach.

Problem Based Learning (PBL) is an approach where learners are in the focus of the learning process. In this approach, learners work in groups to cooperate on the ways to solve a given problem. They retrieve their prior knowledge and discuss as a group. Hence this strategy is learner centered and learners research and cooperate to find meaningful solutions to real life problems (Torp & Sage, 2002) .Further, PBL instruction is constructed on the ill structured problems. These problems allow free inquiry and allows learners to engage in self-directed learning and work in collaborative groups to work through the process of solving the problem. They take active roles in planning, monitoring and evaluating the learning process. Hence this self-directed learning results in learners who can think for themselves more independently (Hmelo-Silver, 2004, Savery, 2006).

PBL is grounded in the fact that learners are self-dependent learners who can construct their own knowledge if proper guidance is given by the teacher (Abanikannda, 2016).The starting point of PBL is always a problem situation, and learners work with the problem in a way that allows them to reason and apply knowledge.

Different Researchers highlight the impact of PBL on learner achievement, problem-solving and attitude. For example, Aidoo, Boateng, Kissi & Ofor (2016) in their study on the effect of PBL on learner achievement in chemistry showed a statistically significant difference in the achievement mean scores in favour of the experimental group. The results proved PBL as an effective way to teach chemistry in order to improve learners' critical thinking and problem solving skills. In another study done by Basri, Zain, Jaafar, Basri & Suja (2011) on students understanding of basic engineering and science of environmental pollution, via application of a PBL approach, showed students gain in problem-solving skills and ability in identifying the sources of pollution and its impact on the environment and the controlling method.

Further, a study done by Ayyildiz and Tarhan (2017) on the effect of PBL in teaching of chemistry lessons, enthalpy changes in systems, showed that learners taught via problem-based instruction performed better than their counter parts taught via traditional teaching methods and had fewer alternative conceptions, conceptual difficulties, and lack of knowledge than did the control group. In addition, Ferreira & Trudel (2012) in their study on the Impact of PBL on Student Attitudes toward Science, Problem-Solving Skills, and perception of learner's environment indicated a significant increase in student attitudes towards science, problem-solving skills and positive views of the learning environment. The use of PBL facilitated the development of a sense of community in the classroom.

Further, by allowing learners to become involved in real world meaningful problems, problem-based learning help learners to develop problem-solving skills through active learning rather than rote learning. For instance, the local stream is covered with algae when people wash near the river and have gardens near the river, due to excess nutrients such as Nitrogen and Phosphorous (non-metals) in water. The water becomes polluted and unusable and this in turn affects the aquatic organism in the water due to depleted oxygen when algae dies. Drinking such water may also affect the well-being of the people around the area. Learners need to state and explain sources of the problem, effects and come up with solutions to the problem. If such authentic problems are used as a starting point to teach concepts of environmental pollution caused by non-metals and their compounds, learners would see the interrelationship between the concepts they learn in classroom and their real world problems and this would enhance their motivation in understanding the concepts of effects of non-metallic pollutants in water and they can develop good problem-solving skills which they can put into use to solve their immediate problems even after secondary school.

This study therefore attempted to find out the impact of problem-based learning on learner achievement and problem-solving skills on environmental non-metal pollution. After thorough literature review, evidence still showed poor results being attained at national and local examinations. Despite having these poor results, not much has been done in terms of the material delivery to the learners in addressing the problem. Therefore it was in this interest to do a study so as to help learners see the unfamiliar chemistry a friendly subject and in turn improve their performance and problem solving skills.

1.2 Research Questions

I. What is the impact of PBL on learner achievement on environmental nonmetal pollution?
II. What is the impact of PBL on learner problem solving skills on environmental nonmetal pollution.
III. What is the impact of PBL on learner attitude towards environmental nonmetal pollution?

II. METHODOLOGY

2.1 Research Design

Research designs are ''plans and procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis'' (Creswell, 2009).The study employed a quasi-experimental research design which involved the pretest, posttest experimental and control group design. Two intact Grade 12 classes were used in the study. The use of intact classes made it possible for the researcher to administer a treatment to one class while the other class was the control group.

The two learners' groups, consisting of 45 learners in the experimental group and 50 learners in the control group ,were both pre-tested in order to determine whether their level of understanding the concepts, problem-solving skills and attitude towards learning environmental non-metal pollution were equivalent. The difference in performance, problem-solving skills and attitude that might have occurred were determined and attributed to the intervention.

In the experimental group learners were taught concepts of pollution caused by non-metallic compounds on environmental media of Chemistry 5124 syllabus using PBL approach. Before the intervention, an orientation was given to the learners (experimental group) about PBL process, rules of working in cooperative groups, the role of learners in the scenarios to be given were clearly explained and the assessment strategies. The teacher acted as a facilitator to guide learners learning through the PBL process, during the learning process, the learners in the experimental group were presented with problem scenarios and the role of learners were clearly stated. For example, the first, second and third scenarios targeted the effects of excessive nitrogen and phosphorous containing compounds in water, soil and air. The second and third scenarios covered concepts on the effects of carbon containing compounds (CO_2 and CO) in air .Learners analysed the problem by identifying the relevant facts from the problem. As learners understood the problem better, they were required to find solutions to the ill structured problem and identify the concepts they needed in order to solve the problem, labelling those concepts as learning issues by considering the leading questions directed by the teacher. In the control group learners were taught the same concepts of pollution caused by non-metallic compounds on environmental media using the lecture and class discussions. Learners were asked to present the results of their group discussions.

2.2 Study Site

The research project was done in Chinsali District in Muchinga Province of Zambia at Kenneth Kaunda Secondary School. The school is situated 8km from the town's Main Post Office.

2.3 Sample and sampling procedure

Six (6) Grade 12 classes exist at Kenneth Kaunda Secondary School as intact classes. The school was chosen for the study because it is one among other schools in the district that has been recording fewer learners obtaining a credit or better (grades 1-6) in science 5124 in General certificate examinations. Purposive sampling technique was employed to obtain four classes based on the fact that they take 5124 science syllabus. This was done because the other two classes take 5070 science syllabus which is regarded as ‘‘pure Science’’ and they are considered to be more intelligent than their counter parts in the other four classes. If the two classes were made part of the study, it would not have given a true picture of the situation. The two classes that participated in the study were selected using simple random sampling with replacement. A number representing a class was written on each piece of card (numbers from 1 to 4).The cards were folded and placed in a box. The box was shaken and a card was picked from the box, the first card to be picked represented a class to be in the sample. It was placed back and the box was shaken again, the second card was picked and it represented the second class to be part of the sample. The two intact classes were randomly assigned to either the experimental or the control group by toss of a coin.The sample comprised 45 learners in the experimental group and 50 learners in the control group.

2.4 Development of instruments

Chemistry Achievement Test (CAT)

In preparing the Chemistry Achievement Test (CAT), questions on achievement were derived from the ECZ past papers while taking into consideration the 2013 Science 5124 syllabus and the recommended Chemistry textbooks for grades 11&12 for proper guidance.

Reliability of the CAT instrument was determined using Test-Retest method with a two weeks interval. The test scores obtained from the first and second administration were correlated using Pearson product moment correlation coefficient. With high index obtained of 0.84 the instrument was declared reliable.

Face and content validity for CAT were done by qualified Chemistry teachers at Kenneth Kaunda Secondary School. This was done to help check if the content was appropriate and measured what it intended to measure. Further, the instrument was pilot tested on one grade 12 class at the adjacent school (Lubwa Secondary School).

The following were sample questions for the CAT

1. Phosphate containing fertilizers causes water pollution. Addition of such compounds in water bodies causes __________

   A. .Enhance growth of algae
   B. Increase in amount of dissolved oxygen in water.
   C. Deposition of calcium phosphate.
   D. Increase in fish population.

2. Minimizing air pollution is essential for health and for the environment.
   Explain why it is dangerous to use a charcoal brazier in a poorly ventilated room?

3. The table shows pollutants and their possible effects.

Which statement is not correct? STATEMENT	POLLUTANT	EFFECT
A	CFCs	Causes destruction of ozone layer
B	CH_4	Forms basic rains.
C	CO	Poisonous to humans.
D	NO_2	Forms acid rain.

Match the pollutants given in Column I with their effects given in Column II. Column I Column II.

(i) Phosphate fertilizers in water (a) oxygen demand in water increases

(ii) Methane in air (b) Acid rain

(iii) Synthetic detergents in water (c) Global warming

(iv) Nitrogen oxides in air (d) Eutrophication

Problem Solving Skills Test (PSST)

Real life problems related to learner’s experiences were used in creating problem scenarios. The PSST developed assessed the four main skills proposed by Polya (1957) as a basis for a great deal for research in solving problems namely (i) Understanding the problem- Learners Identify the problem, interpret information in the problem scenario given and comes up with list known as list of facts about the problem. (ii) Planning - Leaners find the connection between the data (known) and the unknown. This involves logical and critical thinking and learners consider different ways (methods) of solving the problem given. In doing this learners need to choose/propose appropriate procedure and materials (iii) Implementation - Learners carry out the plan or explain their plan, checking that each step is correct and (iv) Reflection (evaluation)- learners ask themselves if results make sense for example did we/i answer the question(s) as required? Are there errors in the data set? Can i pinpoint how my data supports the claim? What could be possible sources of errors in my solutions? Can i check the argument? Can i use the results or the method, for some other related problem?

Reliability of PSST instrument was determined using Test-Retest method with a two weeks interval. The test scores obtained from the first and second administration were correlated using Pearson product moment correlation coefficient. With high index obtained of 0.75 the instrument was declared reliable.

Face and content validity for PSST were done by qualified Chemistry teachers at Kenneth Kaunda Secondary School. This was done to help check if the content was appropriate and measured what it intended to measure. Further, the instruments were pilot tested on one grade 12 class at the adjacent school (Lubwa Secondary School).

PSST sample Scenario and questions.

Scenario
Humankind's increasing use of reactive non-metals such as nitrogen in fertilisers and plastics among many other products is one area that has seen the importance of non-metals in the agriculture and manufacturing industries.You are a chemical analyst consultant working for Ministry of Agriculture in Chinsali District of Muchinga Province. There is a report from Mpyana Bwalya ward area counsellor that in the 2014/2015 farming season despite receiving enough rainfall and application of chemical fertilizer (Compound D and Urea), there has been stunted growth of crops and vegetables leading to poor harvesting. The records from the area counsellor shows that they have been applying chemical fertilizers for the past three years and they have been having a bumper harvest each year.
The Beaker labelled B contains soil samples collected from different fields in the community area. Carry out an investigation and suggest the solution to the problem.

1. From the problem scenario given above

a) List two (2) facts or pieces of information that are known.
b) What appropriate materials are needed to help investigate/solve this problem?
c) With the help of a well labelled diagram ,outline the procedure you would follow in your investigation (experiment)
d) Based on your observation, state the colour of the indicator.
e) What does the colour of the indicator tell you about the soil sample?
f) What can be done to the soil to help solve the problem?

2 (i) Mention one related problem where the method you have proposed can be applied to?

(ii) Identify one possible source of error in the experiment.

Attitude Questionnaire

The researcher developed Attitude Questionnaires based on a 5 point Likert- Scale ranging from (1) strongly disagree to (5) strongly agree. These were administered to collect data on learners' attitude towards environmental pollution. The questionnaires composed of 12 items that were used to find out the attitude of learners towards environmental pollution arising from non-metals. In order to avoid response bias, some statements on the questionnaire were negatively phrased and they were reversed coded accordingly.

The response scale was translated as follows: 5 = Strongly agree, 4 = Agree, 3 = Neutral (Undecided), 2 = Disagree, 1 = Strongly disagree.

A mean score above 3 showed a positive attitude towards learning, a mean score of 3 showed neutral (undecided) and a mean score below 3 showed a negative attitude.

Internal consistency of the attitude questionnaire was tested using Cronbach's alpha. Cronbach's alpha showed the questionnaire to reach acceptable reliability, $\alpha = 0.89$. Most items appeared to be worthy of retention, resulting in a decrease in the alpha if deleted. With $\alpha = 0.89$ obtained, the instrument was declared reliable.

Face and content validity of Attitude Questionnaire was done by experts. This was done to help check if the content was appropriate and measured what it intended to measure. The instrument was pilot tested on one grade 12 class at the adjacent school (Lubwa Secondary School).

2.5 Data analysis

The data collected on achievement and problem solving skills was analysed using statistical package for social sciences (SPSS) version 23(descriptive-(frequencies and percentages) and inferential statistics (independent samples t-test). Data collected on attitude was analyzed using descriptive statistics (mean) and inferential (Mann –Whitney U test). Results were presented in form of tables for easy description of trends in the data set.

III. RESULTS OF THE STUDY

3.1 What is the impact of PBL on learner achievement on environmental nonmetal pollution?

The pretest was given to assess if the two groups were equivalent in knowledge before the intervention. The achievement mean scores between the experimental and control groups were compared.

3.1.1 Pre-test results.

The following hypotheses were tested at (α) –level =0.05

i. $H_{O:}$ There is no statistically significant difference in Knowledge on environmental non-metal pollution between the experimental and control group.
ii. H_1: There is a statistically significant difference in Knowledge on environmental non-metal pollution between the experimental and control group.

Table I. Independent samples t-test with equal variances assumed.

Group	N		Test	Mean	Mean. Diff	SD	t	df	Sig(2-tailed)
Experimental Control	45 50		Pre-test Pre-test	32.67 31.78	0.887 0.887	10.340 9.105	0.444	93	0.658

Table I shows the pre-test mean scores of the experimental and control group as 32.67(SD = 10.340) and 31.78(SD = 9.105) respectively. The $t_{(93)}$ =0.44, p-value = 0.658, $p > 0.05$. The p-value is greater than the set alpha (α) –level = 0.05.Therefore, the null hypothesis is not rejected. This means that there is no statistically significant difference in the knowledge on environmental non-metal pollution between the experimental and control group based on the pre-test results. This shows that the control and the experimental groups were statistically equivalent in terms of the knowledge on environmental pollution and thus were at an appropriate stage to learn concepts of environmental pollution arising from nonmetals.

3.1.2 Post-test achievement results.

In answering the research question 1(what is the impact of PBL on learner achievement on environmental non-metal pollution).The post test was given to assess whether there was going to be an impact of PBL instruction on learner achievement on environmental nonmetal pollution.

The following hypotheses were tested at (α) –level =0.05

H_{AO} : There is no statistically significant difference between the experimental and control group in the Post-test achievement.

H_{A1} : There is a statistically significant difference between the experimental and control group in the Post- test achievement.

Table II. .Independent samples t-test with equal variances assumed.

Group	N	Test	Mean	Mean. diff	SD	t	df	Sig(2-tailed)
Experimental Control	45 50	Post-test Post-test	61.58 53.74	7.838 7.838	9.787 11.517	3.554	93	0.001

Table II shows the post-test mean scores of the experimental and control group as 61.58(SD = 7.838) and 53.74(SD = 7.838) respectively. The $t_{(93)}$ =3.554, p-value = 0.001, $p < 0.05$. The p-value is less than the set alpha (α) –level = 0.05.Therefore, the null hypothesis was rejected. This means that there was a statistically significant difference in the achievement mean scores in the post-test between the experimental and control group. This shows that the control and the experimental groups were statistically different in their understanding of concepts on environmental pollution caused by non-metals. The results suggest that PBL had a greater positive impact compared to lecture and discussion method on enhancing the understanding of concepts on environmental non-metal pollution.

3.2 What is the impact of PBL on learner problem solving skills on environmental nonmetal pollution?

3.2.1 Pre-test results.

Problem solving skills pre-test was administered before treatment to assess initial learner's skills. The frequencies of learners' responses in answering questions assessing the four main problem solving skills are tabulated in Table III below.

Table III. Pre-test comparison of frequencies (%) between experimental and control group in the four main problem-solving skills (N=95).

	Experimental (n = 45)	Control (n = 50)
Demand of Question	Total frequency of learners who gave correct responses	Total frequency of learners who gave correct responses.
understanding the problem	13(28.9%)	13(26.0%)
Problem planning	08(17.8%)	09(18.0%)
Implementation	11(24.4%)	08(16.0%)
Reflection	01(2.2%)	01(2.0%)
Average	08(17.8%)	08(16.0%)

Table III compares the pre-test frequencies and percentages of learners in the four main problem solving skills' area, namely; understanding, planning, implementation and reflection. The four main problem-solving skills when analysed gave an average learner frequency percentage of 17.8% in the experimental group and 16.0% in the control group. Therefore, based on the average frequencies and percentages of learners obtained in the pre-test results, it can be concluded that the two groups (experimental and control) were comparable in terms of the four main problem-solving skills since frequencies (percentages) of both groups of learners were comparable in all the four skills.

3.2.2 Post-test results.

Problem solving skills post-test was administered after treatment to assess if there was any impact of the intervention on learner's acquisition of these skills. The frequencies of learners' responses in answering questions assessing the four main problem solving skills were tabulated as

Presented in Table IV.

Table IV. Post-test comparison of frequencies (%) between experimental and control group in the four main problem solving skills

	Experimental (n = 45)	Control (n = 50)
Demand of Question	Total frequency of learners who gave correct responses	Total frequency of learners who gave correct responses.
understanding the problem	39(86.7%)	27(54.0%)
Problem planning	32(71.1%)	24(48.0%)
Implementation	32(71.1%)	21(42.0%)
Reflection	31(68.9%)	13(26.0%)
Average	34(75.6%)	21(42.0%)

Table IV compares the frequencies and percentage of the experimental group and the control groups in four main Problem -Solving Skills in Chemistry Post-test. Results show that there was improvement in percentages of learners who were able to give correct responses from understanding the problem to reflection of the problem in both groups but the improvement was more in the experimental group than in the control group as evident from the average percentages obtained in the post-test results of the two groups at 75.6% experimental post-test compared to 17.8% experimental pre-test and 42.0% control post- test compared to 16.0% control pre-test

Further, higher numbers of learners in understanding the problem to reflection of the problem in the experimental group indicates that learners' problem-solving skills were positively impacted on by PBL in that it enhanced learner's problem-solving skills. Hence PBL enhanced learner's problem solving skills by 57.8% in the experimental group compared to 26.0% obtained in the control group.

A comparison between the experimental and control group in the four main problem-solving skills in the pre-test and post-test was summarised using the bar chart as shown in Figure 1.

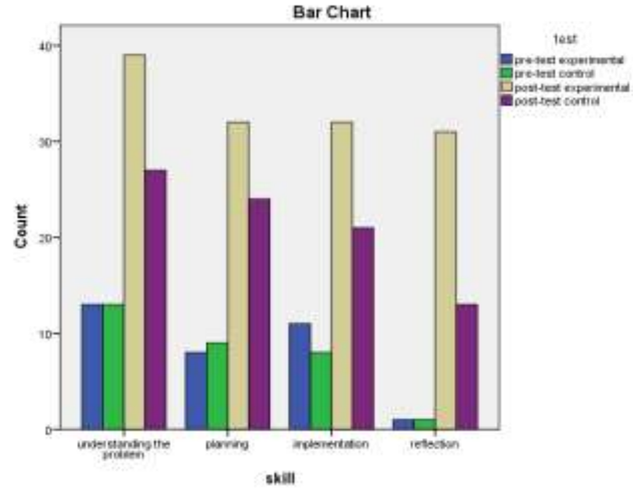

Figure1.Comparison of frequencies of learners between experimental and control group in the pre and post-test problem solving skills.

The bar graph shows that more learners in the experimental group had developed better problem-solving skills after treatment compared to their counterparts in the control group as evident in the frequencies represented by the bars. Hence, learners' problem-solving skills were positively impacted on by PBL in that it enhanced learner's problem-solving skills.

3.3 What is the impact of PBL on learner attitude towards environmental nonmetal pollution?

3.3.1 Learner attitude before treatment.

The attitude questionnaire was administered before treatment in order to assess initial learners' attitude towards environmental pollution concepts in the two groups (experimental and control).

The pre-test questionnaire responses were analysed and outcome summarised in the following tables. The attitude mean and standard deviation were calculated in order to show the attitude mean on the five point Likert scale.

Table V. Comparison of pre-test attitude mean responses between the experimental and Control group (n=95)

(Column heading codes: AM–Attitude Mean, STD –Standard Deviation EG: Experimental Group, CG –Contro Group)

Item #	Statement	EG (n=45)		CG (n=50)	
		AM	STD	AM	STD
Q1	I am interested in learning about Non-Metallic pollutants and their effects on water because I have seen how dirty water is in nearby streams and wells.	3.16	1.086	3.26	1.103
Q2	I feel knowledge of water purification can help me solve my immediate water problems and help me study chemistry further.	3.62	1.154	3.70	1.374
Q3	I am disinterested to learn about water pollution caused by fertilizers because it is not my responsibility to solve water problems in my area but the people who work for water reticulation.(reversed responses)	1.80	1.099	2.26	1.275
Q4	When I come across concepts on water pollutants that I don't understand, I still try to learn them because I find this topic interesting	1.98	1.500	1.98	1.317
Q5	I would like to learn about ways of reducing pollution caused by vehicles even after secondary school because I find this topic useful in my daily life.	3.00	1.225	3.10	1.329
Q6	To be honest I find Air Pollution concepts exciting because am encouraged to know more about solutions to global warming and climate change	2.44	1.179	2.54	1.182

Item #	Statement	EG (n=45)		CG (n=50)	
Q7	I am interested to know more about effects of charcoal burning on the environment because I find this topic interesting	2.89	1.071	2.64	1.025
Q8	I am curious and encouraged to interact and share concepts on possible solutions to acidic soils with other students	2.96	1.296	2.34	1.222
Q9	I am confident in my ability to participate in land pollution lessons because if given a chance with much knowledge I want to solve problems related to plastic burning	2.93	1.136	3.34	1.222
Q10	I would like to have more lessons on preventive measures on land pollution because I find this topic exciting	3.09	1.345	2.82	1.320
Q11	I am excited and keen to learn about sources of land pollutants and their effects on the environment because I find this topic motivating	3.47	1.517	3.40	1.498
Q12	I feel learning about land pollution caused by Nitrogen is challenging because I don't see how it can help me solve my immediate problems in my area(reversed responses)	2.64	1.448	2.22	1.217
	Average	2.83	1.255	2.80	1.257

On the Likert Scale, agree and strongly agree indicate positive responses while disagree and strongly disagree indicate negative responses, neutral indicated undecided. All items in the questionnaire were analysed as a whole by comparing attitude mean responses between the two groups. Therefore, the results of the study established from Table V show that the two groups (experimental and control) had varying attitude towards each questionnaire item with overall attitude mean responses at 2.83Experimental and 2.80 Control respectively. The respondents' attitude mean responses of 2.83Experimental and 2.80 Control on the five point Likert scale meant that both groups had negative attitude towards each questionnaire item and hence towards the topic and thus were comparable in their attitude towards environmental pollution concepts.

In order to be certain if the two groups were equivalent or not in terms of the attitude they had towards non-metals and the pollution they cause on environment media, the total attitude scores for each respondent (experimental and control) were calculated. This involved adding up all scores from the twelve (12) items on the questionnaire for each respondent knowing that the questionnaire had 12 items measured on a five (5) point Likert scale ranging from strongly disagree (1) to strongly agree (5) and the total obtained was considered an overall score for each respondent. Since there were twelve items on the questionnaire, the minimum score was 12 and maximum 60(Pallant, 2005).Negative statements were reverse coded. The scores were subjected to a statistical test to check if there was going to be any difference in the attitude mean ranked scores between the two groups. Mann-Whitney U-test was used since the data was approximately not normally distributed.

The following hypotheses were tested at an α level of 0.05

H_{BO}: There is no statistically significant difference in the pre-test attitude mean ranked scores between the experimental and control groups.

H_{B1}: There is a statistically significant difference in the pre-test attitude mean ranked scores between the experimental and control group.

Table VI. Mann-Whitney U-test.

	Pre-test
Mann-Whitney U	1072.500
Wilcoxon W	2347.500
Z	-0.392
Exact. Sig. (2-tailed)	0.697

From Table VI, the U-value was 1072.500, p-value = 0.697 sig (2-tailed). The p-value is greater than the set alpha (α) – level = (0.05).Therefore, the null hypothesis is not rejected and conclude that there is no statistically significant difference in the pre-test attitude mean ranked scores between the experimental and control groups. Thus this showed also that the control and the experimental groups were equivalent in terms of the attitude they had towards learning environmental pollution before treatment.

3.3.2 Learner attitude after treatment.

The attitude questionnaire was administered after treatment in order to assess whether there was any change in learners' attitude towards learning environmental pollution caused by non-metals in the two groups (experimental and control). The post-test questionnaire responses were analysed and outcome summarised in the following tables showing the post-test attitude mean responses. The average attitude mean and standard deviation were calculated in order to show the attitude mean on the five point Likert scale.

Table VII. Comparison of post-test attitude mean responses between the experimental and control groups (n = 95).
(Column heading codes: AM – Attitude Mean, STD – Standard Deviation, EG – Experimental Group, CG – Control Group)

Item #	Statement	EG (n=45)		CG (n=50)	
		AM	STD	AM	STD
Q1	I am interested in learning about Non-Metallic pollutants and their effects on water because I have seen how dirty water is in nearby streams and wells.	4.09	0.949	3.74	1.065
Q2	I feel knowledge of water purification of can help me solve my immediate water problems and help me study chemistry further.	4.16	0.928	3.84	1.346
Q3	I am disinterested to learn about water pollution caused by fertilizers because it is not my responsibility to solve water problems in my area but the people who work for water reticulation.(reversed responses)	4.15	1.224	2.92	1.509
Q4	When I come across concepts on water pollutants that I don't understand, I still try to learn them because I find this topic interesting	3.96	1.065	3.14	1.525
Q5	I would like to learn about ways of reducing pollution caused by vehicles even after secondary school because I find this topic useful in my daily life.	4.24	0.957	3.60	1.340
Q6	To be honest I find Air Pollution concepts exciting because am encouraged to know more about solutions to global warming and climate change	3.82	1.173	3.20	1.400
Q7	I am interested to know more about effects of charcoal burning on the environment because I find this topic interesting	4.11	1.049	3.32	1.269
Q8	I am curious and encouraged to interact and share concepts on possible solutions to acidic soils with other students	3.80	1.140	3.14	1.443
Q9	I am confident in my ability to participate in land pollution lessons because if given a chance with much knowledge I want to solve problems related to plastic burning	3.91	0.996	3.76	1.153
Q10	I would like to have more lessons on preventive measures on land pollution because I find this topic exciting	3.98	1.055	3.12	1.223
Q11	I am excited and keen to learn about sources of land pollutants and their effects on the environment because I find this topic motivating	4.13	1.014	3.90	1.313
Q12	I feel learning about land pollution caused by Nitrogen is challenging because I don't see how it can help me solve my immediate problems in my area(reversed responses)	3.82	1.154	3.32	1.571
	Average	4.015	1.059	3.42	1.346

The results of the study established from Table VII show that in both groups (experimental and control) ,learners' responses to attitude questionnaire changed from the pre-test to the post-test. This is evident in the higher percentages of respondents' attitude mean responses of 4.11 (SD = 1.059) for the experimental group and 3.42 (SD =1.346) for the control group. The respondents' attitude mean of 4.11 for experimental showed positive attitude on the Likert scale and 3.42 for control showed also positive attitude on the Likert scale. This therefore, show that both groups developed positive attitudes after the intervention. However, the high rise in attitude mean for the experimental group (4.11) compared to the control group (3.42) is reflective enough to show that learners in the experimental group were more positively enhanced in attitude compared to their counter parts in the control group.

In order to be certain if there was any significant difference in the levels of attitude developed towards non-metals and the pollution they cause on the environment, the total attitude scores for each respondent (experimental and control) after treatment were calculated. This involved adding up all scores from the twelve (12) items on the questionnaire for each respondent knowing that the questionnaire had 12 items measured on a five (5) point Likert scale ranging from strongly disagree (1) to strongly agree (5) and the total obtained was considered an overall score for each respondent. Since there were twelve items on the questionnaire, the minimum score was 12 and maximum 60 (Pallant, 2005). Negative statements were reverse coded. The scores were subjected to a statistical test using Man-Whitney U-test to check if there was going to be any difference in the attitude mean ranked responses between the two groups.

The following hypotheses were tested at an α level of 0.05

H_{CO}: There is no statistically significant difference in the post-test attitude mean ranked scores between the experimental and control groups.

H_{C1}: There is a statistically significant difference in the post-test attitude mean ranked scores between the experimental and control group.

Table VIII. Mann-Whitney U-test

Post-test	
Mann-Whitney U	557.000
Wilcoxon W	1832.00
Z	-4.250
Exact.Sig. (2-tailed)	0.00

From Table VIII the U-value was 557.000, p-value = 0.00 sig (2-tailed), $p < 0.05$. The p-value is less than the set alpha (α) – level = (0.05).Therefore the null hypothesis is rejected and conclude that there is a statistically significant difference in the post-test attitude mean ranked scores between the experimental and control groups. This shows that the control and the experimental groups were different in terms of the levels of positive attitude they had developed after treatment with the mean ranks in favour of the experimental group. Hence PBL had a more positive impact in enhancing learners' attitude towards environmental pollution caused by non-metallic compounds in the environment than the lecture and discussion methods.

IV. DISCUSSION OF RESULTS

4.1 Impact of problem-based learning on learner achievement.

The findings from the study revealed after treatment, there was a statistically significant difference in the achievement mean scores of learners in the experimental group that were taught using PBL when compared to learners in the control group that were taught using the lecture and discussion methods ($t_{(df = 93)} = 3.554$, $p = 0.001$(sig. two-tailed)). Since the p-value < 0.05, this rise in difference is because the application of PBL facilitated and enabled the learners in the experimental group to find it easier to understand concepts because problem scenarios used to teach were part of their local environment and that made it fascinating and easier to grasp the concepts. In addition, these results clearly indicate that understanding of concepts is easier when learners are able to relate the concepts they learn in classroom to something they experience every day. Thus these results show that by allowing learners to actively participate in finding solutions to problems, the concepts are understood better. Therefore the results show that PBL had a significant effect on the achievement of learners on environmental pollution caused by non-metals and non-metal compounds in environment media. These findings are in support of the research done by Ayyildiz and Tarhan (2017) who found a statistically significant difference between two groups in favour of students treated with PBL in teaching chemistry, enthalpy changes in systems. Further, these results also support the studies by Arwila, Salagi & Suyanti (2019), Tarhan & Sesen (2013), Tarhan, Kayali, Ureka & Acar (2008), Tandogan & Akinoglu (2007) who found in their studies that the implementation of problem based learning positively impacted learner's academic achievement. Learner's conceptual development were positively impacted on and PBL enabled learners to have few misconceptions of concepts. The results of this study and five (5) of these studies seem to support each other, therefore it shows that if PBL is well implemented, it can enable learners to perform very well in the topic there by reducing poor performance.

4.2 Impact of problem-based learning on learner problem-solving skills.

The findings on impact of PBL on learner problem-solving skills showed that there was a significant impact of PBL to the learner's problem solving skills as evident in the post-test results of the two groups at $75.6\%_{\text{Experimental post-test}}$ compared to $17.8\%_{\text{Experimental pre-test}}$ and $42.0\%_{\text{Control post- test}}$ compared to $16.0_{\text{Control pre-test}}$. Therefore based on these findings, PBL enhanced learners problem-solving skills by 57.8% in the experimental group compared to 26.0% in the control group. This means that a very good number of learners from the experimental group had developed problem-solving skills (understanding/defining the problem, planning, implementing the plan of action and reflection) following the intervention, these findings show that learners in experimental group improved and developed more in terms of problem-solving skills as compared to those in the control group. The improvement in the development of the problem solving skills is due to the fact that the use of problem scenarios reflecting their local problems allowed learners in the experimental group to think of ways to solve the problem. This helped the learners plan and arrive at the conclusion in a manner that helped them retrieve their prior knowledge. These results support Basri, Zain, Jaafar, Basri & Suja (2011) who found that students who were taught using PBL which constituted 30% of the total course assessment developed problem solving skills and actively participated in the classroom meetings. Learners gained the ability in identifying the sources of pollution and its impact on the environment and the controlling method. These results also support Aidoo, Boateng, Kissi & Ofor (2016) who found that students in the experimental group taught with PBL performed much better than the control group taught with conventional methods and they further added that the student's problem solving skills and thinking abilities had improved when the PBL instructional method was used in teaching Chemistry. In respect of the findings of this study and other studies done by different scholars, PBL was found to be more influential than traditional and discussion methods in enhancing learners' problem-solving skills.

4.3 Impact of problem-based learning on learner attitude.

The findings on impact of PBL on learner attitude showed that there was a significant impact of PBL on the learner's attitude towards learning environmental pollution caused by non-metals as evident in the post-test overall attitude means of 4.11 for experimental group and 3.42 for the control group. $U = 557.000$, Exact.Sig (2-tailed) = 0.00, $p < 0.05$. In light of the findings, these results imply that the use of real life scenarios in teaching the experimental group facilitated and made it easier to find concepts on environmental nonmetal pollution as being part of their life and thus was influential regarding learners developing more positive attitude towards learning. In addition the use of daily life pictures of scenarios utilized in the experimental group allowed learners interest and motivation to be pulled to the class activities. On the other hand, the positive attitude developed by learners in the control group (Mean =3.42) was as a result of the group discussions done during in class activities that helped learners' interest and motivation to be enhanced. The Overall results from the analysis however, show that PBL had a more positive impact on the attitude of learners towards environmental nonmetal pollution concepts compared to the lecture and discussion methods. Therefore, the high rise in enhanced positive attitude for learners in the experimental group suggest that by starting with meaningful problems related to learners' local environment as a basis for teaching, learners' interest and motivation can be enhanced. These results are in accord with the study which was done by Ferreira & Trudel (2012) who found a significant increase in learners' positive attitudes towards science, problem-solving skills and positive views of the learning environment when taught using problem-based learning approach. They further stated that the use of PBL facilitated the development of a sense of community in the classroom. These results are also in support of the study done by Festus & Ekpete (2012) who found that learners' positive attitude towards chemistry and performance were more enhanced through problem-based learning techniques compared to the traditional methods.

V. CONCLUSION

The results of the study have provided evidence that PBL has a positive impact on learners' achievement and problem-solving skills when learning the topic of environmental pollution caused by no-metals and non-metal compounds. The results have also shown that PBL instruction is more effective compared to lecture and discussion methods in enhancing learners' positive attitude towards the teaching of concepts of environmental pollution in the topic of non-metals.

The learners who learnt environmental pollution concepts in the topic of non-metals using PBL approach had improved more in academic achievement, problem solving skills and developed more enhanced positive attitudes compared to their counter parts taught using the lecture and discussion methods.

VI. RECOMMENDATIONS.

Based on the major findings of this study, the following recommendations are made:

1. Since use of PBL in teaching and learning of environmental pollution caused by non-metallic compounds in the topic of non-metals has proved to be effective, this research should also be carried out in other topics to see if the same results can be realized.
2. Teachers should be encouraged on the importance of PBL approach to teaching and learning of topics in Chemistry.
3. Teachers of chemistry should embrace PBL approach in schools if we are to solve the problem of learners performing poorly in internal and external examinations.
4. The use of PBL should be emphasised during continuing professional development meetings in schools so that teachers can be familiar on the use of this teaching approach.

Recommendation for Further Research

Further research should be undertaken on the impact of project-based learning on learner achievement and problem-solving skills on environmental pollution caused by non-metals to monitor if learners are able to come up with projects that can practically help in solving their immediate problems in their local environment.

ACKNOWLEDGEMENT

The author's wishes to acknowledge the Copperbelt University and Kenneth Kaunda Secondary School management, staff and learners for support and assistance in making this research a success.

REFERENCES

[1]. Abanikannda, M.O. (2016).Influence of problem-based learning in chemistry on academic achievement of high school students in Osun state. International Journal of Education, Learning and Development, 4 (3), 55-63.
[2]. Aidoo.B, Boateng, S.K, Kissi, P.S & Ofor, I. (2016).Effect of Problem-based learning on Students' achievement in chemistry, Journal of Education and Practice. 7(33), 103-108
[3]. Agogo, P. O & Onda,M.O. (2014).Identification of Students' Perceived Difficult Concepts in Senior Secondary School Chemistry in Oju Local Government Area of Benue State. Global Educational Research Journal. 2(4), 044-049.
[4]. Akinoglu, O & Tandogan, R.O.(2007).The effects of Problem-Based Active Learning in Science Education on Students' Academic Achievement, Attitude and Concept Learning. Eurasia Journal of Mathematics, Science & Technology Education, 3(1), 71-81
[5]. Arwila,T.M, Salagi,D and Suyanti,R.D (2019).The Effect of Problem-Based on Learning Models Using Macromedea Flash and Motivation Against Student Learning Outcomes on Environmental Pollution Materials, Budapest International Research and Critics Institute Journal, 2(4), 326-333.
[6]. Ayyildiz, Y and Tarhan, L (2017).Problem-based learning in teaching chemistry: enthalpy changes in systems, Research in Science & Technological Education, 36(1),35-54
[7]. Basri, N.E.A, Zain, S.M.D, Jaafar, O, Basri, H &Suja, H. (2011) .Introduction to Environmental Engineering: A problem-Based Learning Approach to Enhance Environmental Awareness among Civil Engineering Students, Procedia-Social and Behavioral Sciences 60(2012), 36-41
[8]. Bassey, S. W, Umoren, G & Udida, L. A. (2008). Cognitive Styles, Secondary School Students' Attitude and Academic Performance in Chemistry in Akwa Ibom State. Retrieved from https://www.longdom.org.
[9]. Curriculum Development Centre. (2013). Zambia Education Curriculum Framework, CDC, Lusaka.
[10]. Creswell, J. W, (2009).Research design, qualitative, quantitative, and mixed methods approaches (3rd ed.).Thousand Oaks, CA: Sage publication
[11]. Delmang, T.K., & Gongden, E.J. (2016).Ameliorating Students's Performance and Attitude towards Chemistry through Chemistry-Solving Techniques (CPST).International Journal of Scientific Research in Education, 9(2), 41-47.
[12]. Examination Council of Zambia (2014).Examination performance Review Booklet Natural Sciences, ECZ
[13]. Examination Council of Zambia (2016).Examination performance Review Booklet Natural Sciences, ECZ
[14]. Examination Council of Zambia (2017).Examination performance Review Booklet Natural Sciences, ECZ
[15]. Ferreira, M., & Trudel, A. (2012). The Impact of Problem-Based Learning (PBL) on Student Attitudes toward Science, Problem-Solving Skills, and Sense of Community in the Classroom. The Journal of Classroom Interaction, 47(1), 23-30.
[16]. Festus, C & Ekpete, O.A. (2012).Improving students' performance and attitude towards Chemistry through problem-based solving techniques. International Journal of Academic Research in progress Education and Development, 1(1), 167-174

[17]. Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235-266.
[18]. Jardim, W. F.(1998). New Challenges in Environmental Chemistry. Pure & Applied Chemistry, 70(12), 2259-2262
[19]. Makoni, R.D. (2014). Teaching Chemistry of water Purification in grade 11 using locally available material through the Scientific Inquiry Approach. Master's thesis, University of South Africa, Chemistry Department, Malamulele
[20]. Marinopoulos, D & Stavridou, H. (2001). Water and Air Pollution: Primary Students Conceptions about ITINERARIES and Interactions of substances, Science- Technology-Environment Society (STES), 2(1) 31-41
[21]. Najdi, S. (2013).Students Attitude toward Learning Chemistry. Journal of Al-Quds Open University for Education & Psychological Research & Studies, 1(1), 11-31
[22]. Ogembo, J.O, Otanga, H, & Yaki, R.N (2015) .Students and Teachers' Attitude and Performance in Chemistry in Secondary Schools in Kwale County, Global Journal of Interdisciplinary Social Sciences,4(3),39-43
[23]. Okunloye, R.W. & Awowale, A.A. (2011).Senior School students' perception of difficulty levels of Christian religious studies syllabus and associated factors in Ilon, Kwara State, International journal of Basic Education,2(1),119-127.
[24]. Osman, K. & Sukor, N.S. (2013).Conceptual Understanding in Secondary School Chemistry: A Discussion of the Difficulties Experienced by Students. American Journal of Applied Sciences, 10 (5), 433-441
[25]. Pallant,J.(2005).SPSS Survival Manual:A Step by Step Guide to Data Analysis Using SPSS for Windows (VER 12).Sydney:Allen & Unwin.
[26]. Polya, G. (1957).How to solve it: A new aspect of mathematical method. (2nd Ed.).Princeton, NJ: Princeton University Press.
[27]. Rivet, A. E., & Krajcik, J. S. (2008). Contextualizing instruction: Leveraging students' prior knowledge and experiences to foster understanding of middle school science. Journal of Research in Science Teaching, 45(1) 79–100.
[28]. Savery, J.R. (2006).Overview of Problem-based learning: Definitions and Distinctions, Interdisciplinary Journal of Problem-based learning, 1(1), 9-20.
[29]. Tarhan, L, Kayali, H.A, Urek, R.O & Acar, B. (2008). Problem-Based Learning in 9th Grade Chemistry Class: 'Intermolecular Forces' .Research in Science Education, 38(3), 285-300.
[30]. Tarhan, L & Sesen, A. (2013). Problem-Based Learning in Acids and Bases: Learning Achievements and Students' Beliefs. Journal of Baltic Science Education, 12(5) 565-578
[31]. Torp, L., and Sage, S. (2002). Problems as Possibilities: Problem-Based Learning for K–12 Education, 2nd edn. ASCD, Alexandria, VA: ASCD.
[32]. Valeiras, N and Godoy L.A (2007).Understanding Environmental Pollution Concepts: A case Study Using School Students in Argentina and Puerto Rico, International Journal of Environment and Pollution, 31(3/4), 342-358
[33]. Yunus, F.W & Ali, Z.M.(2012). Urban Students' Attitude towards Learning Chemistry. Procedia-Social and Behavioral Sciences. 68(2012), 295-304