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Impact of the BSCS 5Es Model on Zambian Grade 11 Learners' Comprehension and Attitudes on Acid-Base Concepts in Chemistry 5070

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The study explored the impact of the Biological Science Curriculum Study 5Es model on grade 11 students' comprehension and attitudes toward acid base concepts in Chemistry 5070. The study involved 40 students in grade 11 at Roan Antelope Secondary School, a government school in Luanshya district on the Copperbelt Province of Zambia. They were studying acids and bases by engaging in activities and projects in which students explored concepts and their application in real world context. The teacher guided students through the 5Es of the BSCS model of instruction. Results from a 30 item acid-base concept test revealed a modest gain from pre-test (mean = 13.02) to post-test (mean = 15.44 (t= 1.901 p = 0.066). Acid-base concept maps and reports on group experiments and projects showed that students had gained in ability to link the acid-base concepts together with examples from real-life. They successfully completed group experiments and projects and reached valid conclusions in testing for acid and bases in materials and substances taken from the environment (milk, soils, water, and fruits). Basing on response to an attitude questionnaire, the students' attitudes towards teaching and learning approach, towards the topic "acids and bases", and towards household and industrial applications, and impacts on the environment were positive, overall. The 5Es model implemented via practical inquiry activities in which materials and substances drawn from the local environment modestly improved learning of and attitudes and awareness towards chemistry concepts associated with acids and bases and their household and environmental applications and environmental impacts.

Keywords: 5Es model, real-world context, chemistry 5070, acid-base concepts, achievement, attitudes, high school

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INTRODUCTION

Learning chemistry among secondary students around the world is not an easy process for reasons associated with poor instructional methods, the complexity of chemistry concepts and explanatory models, and the lack of reference and connection of chemistry concepts to real world contexts (Shumba, 2012; Bradley & Mosimerge, 1998; Demircioğlu, Ayas, & Demircioğlu, 2005; Özmen & Yildirim, 2005). The difficulties in learning chemistry concepts such as those associated with acids and bases, we conjecture, can be eased when students are engaged in exploring materials and substrates from the local environment. Students will find it easier to acquire understanding of concepts anchoring this on experiences evident in their local environments. Learning becomes contextualized as necessary for learner motivation and interest that would most likely lead to enhanced achievement as suggested by constructivist learning theory. This theory supports contexualisation and personalisation of meaning whereby the real world and local environments serve as sources of learning. For deep understanding and for personalising meaning learners ought to make a connection between their mental constructions and reality of materials and substances in their households and environments. Instructional models based in constructivism are relevant for this kind of connected learning in chemistry.

One example of an instructional model is the 5E model developed in the context of the Biological Sciences Curriculum Study (BSCS) (Bybee & Taylor, 2006). The BSCS model entails the 5Es (i) Engaging learners via a question, a demonstration, posing a problem, or via a discrepant event, (ii) Exploring phenomena, (iii) Explaining phenomena, (iv) Elaborating scientific concepts and abilities, and (v) Evaluating Learners and providing feedback (Bybee & Taylor, 2006; Singer & Moscovici, 2008). It has drawn interest of science and practitioners to test its efficacy in various cultural settings and science subjects other than biological sciences. The 5E model has been shown to be effective in chemistry topics e.g., gases, physical and chemical changes, and acids and bases (Mustafa & Dermircioglu, 2012; Akar, 2005; Kolomuc, Ozmen, Metin, & Acisli, 2012). Would the 5Es model implemented in the context of exploring materials and substances in the local environment have the same efficacy on Zambian secondary school students studying chemistry?

PURPOSE OF THE STUDY

This action research entailed implemented a series of inquiry lessons designed on the basis of the BSCS 5Es instructional model. The purpose was to assess the impact on Grade 11 students' comprehension and attitudes towards acid base concepts carried in Chemistry 5070 in Zambia. The action research was guided by need to provide answers to two research questions.

1. What is the impact of BSCS 5Es instructional model on student comprehension of chemistry 5070 acid-base concepts?
2. What is the impact of BSCS 5Es model on students' attitudes towards chemistry 5070acid-base concepts taught in real life context?

METHODS AND PROCEDURES

Study setting and the participants

The research was conducted at Roan Antelope Secondary School in Luanshya district of the Copperbelt province of Zambia. Figure 1 shows the map of Zambia with an inset to show the districts of the Copperbelt province. This province is the epicenter of the mining of heavy metals including copper, cobalt, and manganese. The soils are acidic Oxisols. Luanshya district is itself a major copper mining town.

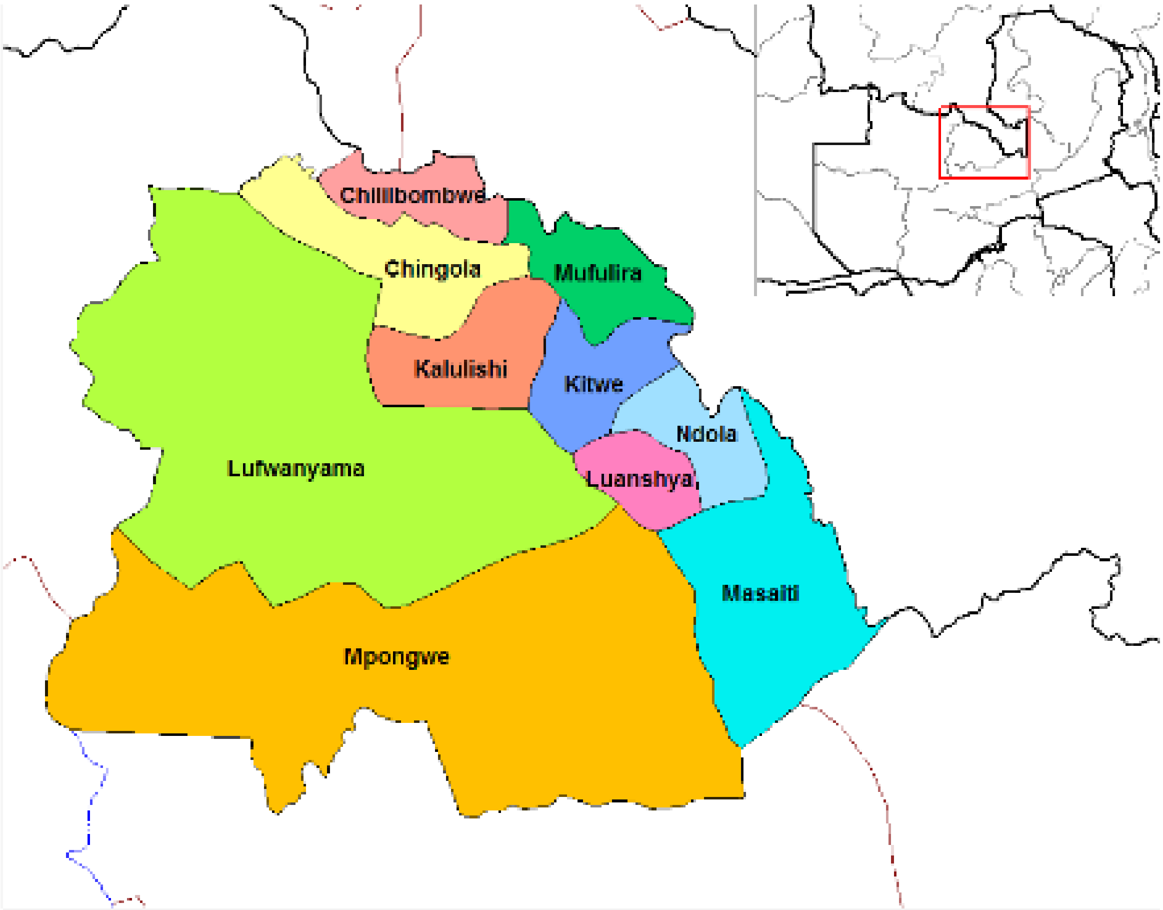

Figure 1. Map of Zambia showing the districts of the Copperbelt Province.
Source: https://en.wikipedia.org/wiki/Districts_of_Zambia, accessed November 18, 2015

Roan Antelope Secondary School is a large co-educational government school with a total enrolment of 1500 pupils (boys and girls). The researchers purposively selected one of the two Grade 11 classes that were following the Chemistry 5070 syllabus. The selected class was taught by one of the researchers (Chola, 2013), a chemistry teacher. The number of students in the purposively selected Chemistry 5070 class is 42. This class was engaged with inquiry activities following the BSCS 5Es model for five weeks.

Acid-base concepts Chemistry 5070 and real life issues

The action research had multiple procedures to analyse and understand the Chemistry 5070 coverage of acid-base concepts the basis of which was used to devise the scheme of work and lessons that incorporated inquiry activities implemented following the 5Es model. The analysis of the syllabus revealed that it carried a lot of acid-base concepts across the 13 units. Figure 1 shows number of concepts in each unit of Chemistry 5070. The majority (n = 18) of the concepts were concentrated in Unit 6 "Acids, Bases and Salts".

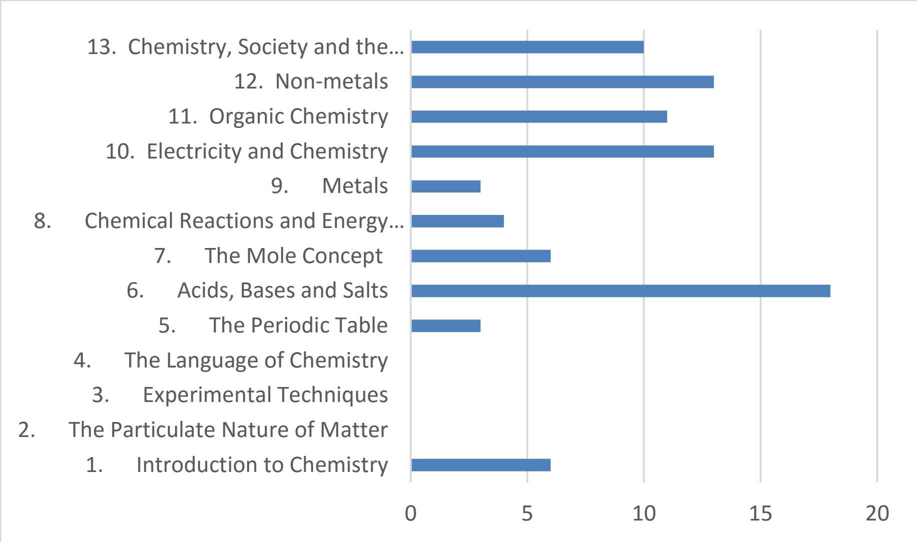

Figure 2. Number of Acid-Base Concepts in Units of Chemistry 5070

Many of the concepts easily linked to real world issues, e.g., acid rain, corrosion of infrastructure, electrolytic mineral processing, food and beverages industry, and manufacture of products the researchers identified the issues that would be the focus in the 5Es action research. Some of the real world issues could be located in the syllabus and others were identified in the manner proposed by Dejong (2006) to cover the personal, social and society, and professional practice domains. All these domains aid to contextualize learning. These criteria were interpreted to suggest inclusion of issues arising from everyday lives of the students in their community, in this case Roan Township in Luanshya mining town. Real world issues focused on (i) nutrition, e.g., pH of anti-acid medicine, fruits and milk products, (ii) environmental effects, e.g., sulphur oxides and acid rain, acid soils, and corrosion of infrastructure, (iii) food security and agriculture, e.g., fertliser manufacture, pH and liming of soils, (iv) industrial application, e.g., lead accumulators, detergents and cleaners, and (v) chemistry for sustainable development, e.g., green chemistry, and safe disposal of chemicals. The real world issues were later incorporated in a 5E instructional cycle scheme of work of five weeks duration. Box 1 shows an extract of learning activities from the scheme of work.

Box 1. Illustrative extract from week 3 scheme of work

Acid-Base Concepts: The pH scale: definition. Measurement of pH of different solutions that are alkaline and acidic. Use of pH color scale.

Real life issues: Importance of pH in agriculture. Determination of soil pH. Importance of knowledge of pH of foods substances in preventing acidosis. Testing household chemicals using litmus paper made from red cabbage and white paper. Determination of soil pH in Roan Township. Exploring pH as milk goes sour.

5Es Activities

Engagement- explain importance of pH to farmers, industries, and in nutrition.

Exploration- completion of lab activity based on determination of pH of different household chemicals.

Explanation- explanation of concepts such as pH.

Elaboration - additional experiments on pH of different foods and discussion on the use of pH in industries and research.

Projects: (i) pH determination of household chemicals using litmus paper made from red cabbage and white paper. (ii) Determination of soil pH in Roan Township. (iii) Exploring milk pH as it goes sour.

Evaluation- assessment and feedback based on their explanation and elaboration.

Resources: Food packages showing food contents e.g., milk packet displays mineral ions present. Different chemicals found both in the lab, homes, and industries for testing the pH.

Implementing the 5E learning cycle

The 5E activities included inquiry activities and group projects to help students discover and connect knowledge of acids and bases to their real life contexts. In a lesson period of 60 minutes each week students were engaged in four different activities which included (i) laboratory experiment, (ii) discussions of effects of acids on the environment, (iii) concept map construction, and (iv) carrying out research projects. The experiments were done by the students in order to engage students in the lesson and for them to explore, explain, elaborate, and evaluate acid-base concepts. Experiments involved use of real world substances such as battery acids, lemons, oranges and household products apart from the usual laboratory chemicals for teaching acids and bases. Students individually constructed concept maps as part of evaluating their understanding of acid-base concepts. Students to show their understanding of the following: (i) definition of acids and bases, (ii) classification of acids and bases, (iii) recognition of properties of acids and bases, and (iv) identification of examples from real-life. The number of concepts and relations were taken as indicators of the students' knowledge. Six group projects were undertaken and reported on by students to help them expand, elaborate and evaluate on acid-base concepts as follows:

(i) Determining acidity and alkalinity of household chemicals using phenolphthalein. In this project students were required to measure the acidity and alkalinity of household chemicals. Chemicals included, baking soda, shampoo, spirit of salt (toilet cleaner), tea, coca cola, Coffee, and distilled water.
(ii) Studying effects of acids and bases on browning of apples.
(iii) Determination of soil acidity and alkalinity in Roan Township.
(iv) Investigation of milk pH as it goes sour over a period of 4 days
(v) Making and testing indicators from red cabbage and white paper.
(vi) Titration analysis to determine the amount of magnesium hydroxide present in milk of magnesia (anti-acid tablets) using hydrochloric acid.

Data collection procedures

The action research utilized multiple data collection procedures to gain insights into the 5E processes and activities that involved exploring and studying samples and substrates from the local environment. The research utilized the following instruments to collect the data: (i) a researcher developed acid-base concept test, (ii) a researcher constructed attitudes questionnaire, and (iii) researcher developed criteria to assess group project reports and individual constructed acid-base concept maps. For the projects, students were required to write and present full reports highlighting the aims, procedures, results, and conclusions. The concept maps were analysed and scored for their correct representation of concepts and their linkages.

Both the test and the attitudes questionnaire were administered as pre-test and posttest, respectively, at the start and end of the five week implantation cycle. The test contained 30 multiple choice question. Each question had one correct answer and three distractors. The duration of the test was 40 minutes. The test consisted of items requiring knowledge and understanding of the acid base concepts, applications in real life contexts, and environmental awareness relating to impact of acids and bases. The test also attempted to cover the range of learning outcomes covered in Bloom's taxonomy of learning in the cognitive domain. Box 2 contains samples of the three types of items.

Box 2. The three types of acid base concept test items.

Knowledge of acids and bases

Q1. Which of the following best describes what happens when an acid mixes with a base?

A. new acid and a salt are formed. B. a new base and a salt are formed. C. no reaction occurs. D. a salt and water are formed.

Connecting to real life

Q17. Which of the following can be good content for anti-acid tablets? A. $Mg(NO_3)_2$. B. $MgSO_4$ C. $Mg(OH)_2$ D. Mg_3N_2)

Environmental awareness

Q28. Which one of the following is not the harmful effect of acid rain?

A. Corrosion of roofs. B. Wearing of buildings made of marble. C. Makes the soil acidic. D. Makes the soil alkaline.

The attitudes questionnaire was a forty item 5-point Likert scale response scale developed by the researchers. The questionnaire consisted of four sections A-D each comprised of ten items each to which indicated the strength of agreement on the scale: 1= strongly disagree 2= agree 3 = neutral 4= agree 5= strongly agree. Section A assessed students' attitudes towards the teaching approach incorporating 5E activities, section B assessed their attitudes towards the topic acids, bases, and salts, section C assessed attitudes towards uses of acids and bases in society, and section D explored student's attitudes towards impact of acids and bases in the environment. Section E was open ended for students to comment on anything they would like to say about the teaching and learning of acids and bases and the way it was taught to them. All students completed it within 20 minutes.

RESULTS AND FINDINGS

Learners' achievement

Students performance on the 30-item acid-base test showed a small gain from the pre-test ($\bar{x}$ = 13.02; s = 5.29) to post-test ($\bar{x}$ = 15.44; s = 5.68). The gain was not statistically significant (t= 1.901 df = 35 p = 0.066 α = .05). The practical relevance of the modest gain was assessed via item analysis. Sample illustrative questions from the acid-base test are shown in Box 3. The analysis showed that the frequency of correct responses had remained constant or regressed as much as 2% on items requiring molar computation (Q2), conceptual or theoretical comprehension (Q3), or interpreting ionic equations (Q10 & 12). However, gains of up to 20% in the number of pupils obtaining correct responses was realized for questions that required knowledge of chemical properties of acids and bases, and of the chemical reactions between acid and bases and identification of products (Q7, 8, 21, & 23). In questions that required awareness of uses and applications and environmental impact of acids and bases, the number of pupils making correct choice of answers improved by up to 17% (Q5, Q13, Q15, Q27).

Box 3: Illustrative test items.

Molar computation

Q2. Determine how much acid is needed to prepare calcium chloride in using 2M HCl and 200ml of 0.5M $Ca(OH)_2$.

Conceptual or theoretical comprehension

Q3. Aluminum hydroxide is classified as a weak base. How would you describe the ionic character of aluminum hydroxide?

Interpreting ionic equations

Q12. The reaction between iron and hydrochloric acid can be best represented by the following ionic equation …

Knowledge of chemical properties of acids and bases, of the chemical reactions between acid and bases, and knowledge of identification of products

21. Dolomite contains an unknown compound X. Carbonic acid, formed when carbon dioxide dissolves in water, filtered through can dissolve the dolomite layer forming affecting its shape due to wearing. Compound X is likely to be...

Awareness of uses and applications and environmental impact of acids and bases

Q15. Lime is widely used by farmers. What could be the reasons?

Anecdotal evidence of the positive impact of the 5E approach was evident in student constructed concept maps as illustrated in Figure 4. Three quarters of the students successfully constructed concept maps showing the relationships, branching cross links and examples of acids and bases and their connection to applications in industry or to the environment impact.

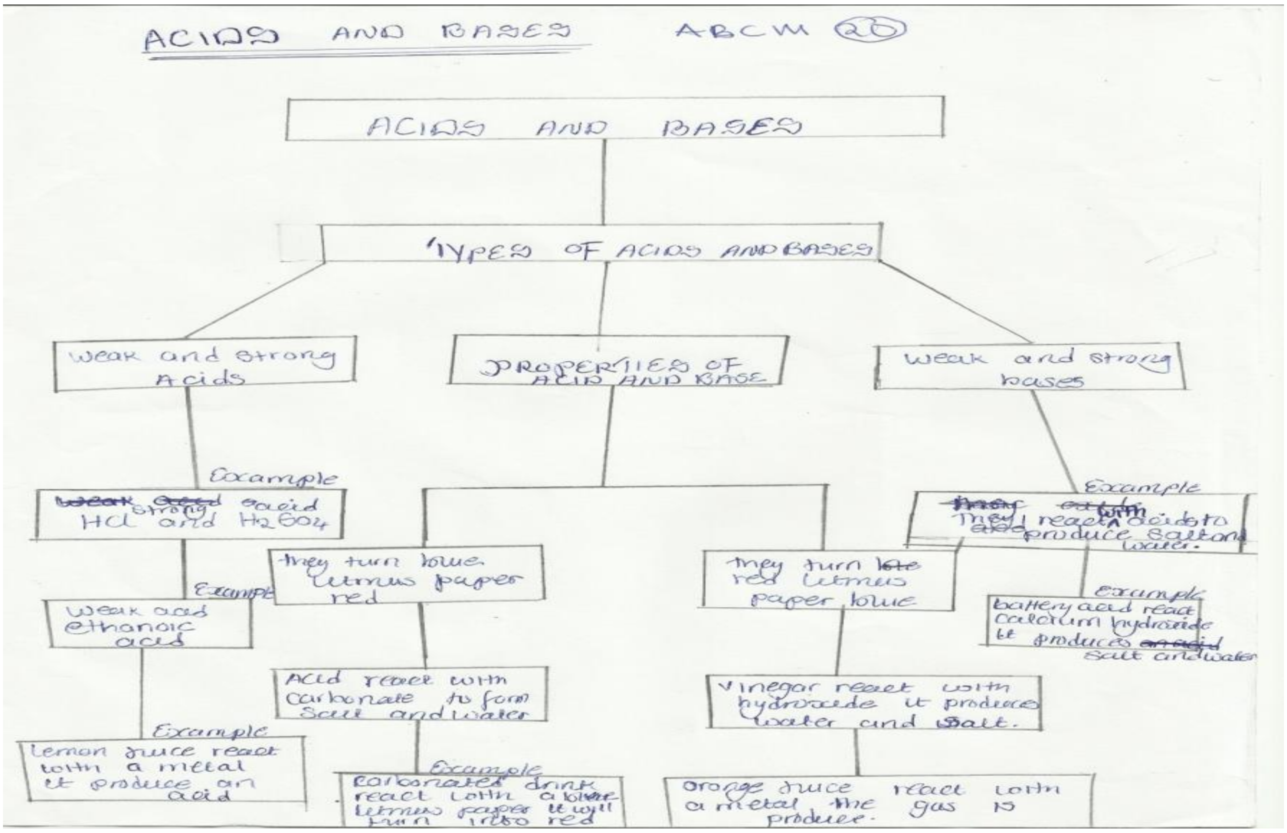

Figure 4. Sample acid-base concept map by students.

Learner attitudes

The construct of socioscientific issues (SSI) currently constitutes the most prominent approach regarding the integration of ethical aspects into science lessons.

Learner attitudes

The study also assessed the attitudes of students via a 40-item questionnaire structured in four sections with 10 items each (5 items positively stated and 5 equivalent items negatively stated to test consistency of the responses). The sections and items of the questionnaire assessed attitudes towards the teaching approach, attitudes towards the topic 'acids and bases', attitudes towards acids and bases in society, and attitudes towards environmental impacts of acids and bases. Table 3 shows the correlation matrix for four sections of the questionnaire. The students' perception of the teaching approach modelled around the 5E cycle did not relate significantly to attitudes towards the topic 'acids and bases' (r = .309; p = 385), attitudes towards acids and bases in society (r= .290, p = .217) and attitudes towards environmental impacts (r = .291; p = .414) in a two tailed test (α = .05). However, attitudes towards the topic 'acids and bases', attitudes towards acids and bases in society, and attitudes towards environmental impacts were positively correlated. These correlations were significantly correlated in a two tailed test (α = .05). This would suggest that a favorable disposition to the topic was significantly associated with positive disposition towards acid and bases in society and their awareness of both household and industrial applications and environmental impacts.

Table 3. Association among students' attitudes towards the teaching approach, attitudes towards the topic 'acids and bases', attitudes towards acids and bases in society, and attitudes towards environmental impacts (n = 36)

Attitudes Towards	A. Teaching and learning approach	B. Topic 'Acids and Bases'	C. Acids and Bases in Society	D. Environmental Impacts Awareness
Teaching and learning approach	1.00 (p = .00)			
Topic 'Acids and Bases'	.309 (p = .385)	1.00 (p = .00)		
Acids and Bases in Society	.290 (p = .217)	.939* (p = .00)	1.00 (p = .00)	
Environmental Impact Awareness	.291 (p = .414)	.617* (p = .05)	.679* (p = .031)	1.00 (p = .00)

*Correlation (r) significant at the .05 significance level in a two tailed test.

The students' responses to the attitude questionnaire had changed modestly from the pre-survey to the post-5E lessons' survey. A gain occurred in the proportion (%) expressing positive attitudes towards the teaching approach (7/10 items) and on attitudes towards environmental impacts of acids and bases (6/10 items). In both the pre- and post-survey, they showed positive disposition to the topic 'acids and bases' but there was no substantial change in the proportion expressing positive attitudes towards the environment (a positive change was realized on 5/10 of the items). While they had favorable attitudes about learning about acids and bases in society, there was also no net gain in the proportion with positive expressed attitudes towards acids and bases in society.

Analysis of the responses in the post-5E survey showed that that more than 75% of the students had a positive disposition to the teaching approach, the topic, and the relevance of the topic to society. Of the students responding (n= 38), 77-87% of the students agreed to positive items and 67-80% disagreed to the same items expressed negatively on the teaching approach. For example 77% agreed to the statement the "The teaching approach used in teaching acids and bases should be used to teach other topics in chemistry" and 67% disagreed when the statement was "The teaching approach used in teaching acids and bases should not be used to teach other topics in chemistry". Their attitudes towards the topic 'acids and basis' was positive with 64-87% agreeing to the positive statements and 64-85% disagreeing to the negative statements. In either case the least favorable response of 64% was with reference to the positive and negative versions of the item that contained an ionic equation, i.e., "It is easy for me to understand this equation:

$CO_3^{2-}(s) + 2H^+ (aq) \rightarrow CO_{2\,(g)} + H_2O_{\,(l)}$".

Between 77-87% of the students showed favorable disposition towards the connection of acid and bases to their application to real life (the household, industry, or the environment) (77-87% agreeing to positively stated items and 74-92% to negative items). For example, 87% greed to the positive version and 92% disagreed to the negative version of the item: 'Working with household products like JIK and SODA made me like the lesson on acids and bases.' Finally, their awareness of acids and bases in the environment was satisfactory with 59-82% recognizing that acids and bases can be pollutants in the environment. At the personal level of action, the 56% agreed to the statement "I choose to use a small amount of detergents when washing utensils". It would appear that the students had favorable disposition to the 5E approach to inquiry activities and this had contributed to them having favorable disposition to the topic 'acids and bases' and their applications and impacts at the level of the household, industry, and/or the environment. Three illustrative excerpts from the open-responses of the students suffice:

*Excerpt 1: "*The teaching was very interesting because we were always taken to real life situations. The teacher made it very interesting because he was even showing us household chemicals which contain acids and bases. On top of that the writing of projects on the topic made it very easy for me to understand. I was able to write the project without problems'" (POQ19).

Excerpt 2: "Learning of this topic is very important to everyone not only to farmer because acids are also found in household chemicals and I believe that everyone leaves in a home. The approach used by teaching this topic made me more interested. It helped me to discover that there are also acids in household chemicals because we were experimenting. It was very interesting" (POQ35).

DISCUSSION AND IMPLICATIONS

This research drew its motivation from the reported impact and efficacy of the 5E model in the learning of chemistry concepts in different cultural contexts (Demircioğlu, Ayas, & Demircioğlu, 2005; Mostafa & Dermircioglu, 2012; Elvan, 2005; Kolomuc, et al., 2012) and thus an action research was conducted to evaluate its impact on secondary school students studying chemistry in an African context of Zambia. In this action research, the 5E model inspired activities produced modest gains in achievement on the acid-base concept test used in the study. An item analysis showed that the frequency of correct responses had remained constant or regressed as much as 2% on items requiring molar computation, conceptual or theoretical comprehension, or interpreting ionic equations. However gains of up to 20% in the number of pupils obtaining correct responses was realized for questions that required knowledge of chemical properties of acids and bases, and of the chemical reactions between acid and bases and identification of products. In questions that required awareness of uses and applications and environmental impact of acids and bases, as many the number of pupils making correct choice of answers improved by up to 17%.

The evidence from the attitudes' survey and the observation of students as they worked showed joyous engagement and interaction as the 5E cycles were implemented. In the survey, students had a favorable disposition towards the chemistry topic. They expressed favorable attitudes and awareness of acids and bases, their applications at household and industrial level, and their environmental impact. The following open response by one student is illustrative:

Excerpt 2: "Acid and base lesson was really interesting. It has imparted both negative and positive effects of how people and the environment are being affected. The topic was really interesting in that when household chemicals were brought, that's when I realized that even foods we take, such as carbonated drinks have acids. It has really improved my thinking capacity and I have fully benefited from the lesson. Thereby being interested to learn about or rather study more about chemistry in future" (POQ34).

That there was a positive gain on student's comprehension of acid-base concepts upon implementation of the 5E model is consistent with other previous studies (Akar, 2005; Kilavuz, 2005). While in the current study, the positive gains did not reach statistical significance, anecdotal evidence in which students constructed concept maps and wrote experimental reports showed their developing understanding of acid-base concepts. In groups, students showed motivation and ability to construct meaningful acid-base concept maps and to apply acid-base concepts in their projects, understand techniques involved in carrying out the projects and their ability to analyze the data in relation to the concepts learnt. They showed ability to explain acid-base concepts in browning of apples, pH of household chemicals, pH of soil in roan township, study of acidity and alkalinity of milky as it goes sour, and titration of anti-acid tablets (milky of magnesia) was a clear indication that students understood acid-base concepts and related them to real-life situation. The efficacy of the 5E model seems to lie in this deliberate engagement and exploration in the context of studying real-life substrates and issues. It is possible that the impact of the 5E instructional model depended on the effectiveness of the teacher in guiding the learners through the cycles of the 5E and the chemistry activities, and to provide feedback and feedforward as lessons progressed. As Kilavuz (2005) puts it, by restructuring learning activities into a 5E learning cycle sequence (in this case using acid-base real-life projects), students get more engaged in explorations, and in the elaboration, explanation, and evaluation for their experiences. The students as observed in this study became more attentive and at the same time more interrogative as they pursued chemistry activities through the 5Es.

CONCLUSION

In the context of southern Africa where contextualization of science courses is topical, the 5E model with its beneficial impacts on students' attitudes towards subject matter and its applications to real life may be relevant for connected learning. In the context of Africa, the curriculum and the instructional approaches are often critcised for lack of relevance and for lack of contetxualisation (Shumba, 2012) and thus this study may have modestly demonstrated how this may be done in chemistry. This requires creative experimentation with various aspects of the 5E model by teachers. For example, Acish, et al (2011) showed the relevance of teachers using activities and examples that relate to real life as the context of investigative activities. Özmen, Demircioglu and Demircioglu (2009) as well as Kolomuc and others (2012) showed how teachers basing learning activities on the 5E model helped their students overcome alternative conceptions chemistry topics involving physical and chemical changes and chemical bonding. There is therefore much scope for further experimentation with the 5E model in the African context, with a view to improving contextualization and relevance of science education.

REFERENCES

Akar, E. (2005). *Effectiveness of 5E learning cycle model on students' understanding of acid-base concepts*. Unpublished masters' thesis, Middle East Technical University, Turkey. Accessed at https://etd.lib.metu.edu.tr/upload/12605747/index.pdf.

Ascili, S., Yalcin, S.A., & Turgut, M. (2011). Effects of the 5E learning model on students' academic achievements in movement and force issues. *Procedia Social and Behavioral Sciences, 15* (2011), pp. 2459–2462

Bradley, J. D., & Mosimege, M. D. (1998). Misconceptions on in acids and bases: A comparative study of student teachers with different chemistry backgrounds. *South African Journal of Chemistry*, *51*, 137-155.

Bybee, R. & Taylor, J. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs, Co: BSCS

Chola, J. (2013). *Impact of the Biological Sciences Curriculum Study 5Es instructional model on grade 11 students' comprehension and attitudes toward chemistry 5070 acid-base concepts taught in real world context*. Unpublished masters' thesis, Copperbelt University, Zambia.

Curriculum Development Centre. (2000). *Chemistry 5070 high school syllabus*. Lusaka, Zambia: Ministry of Education.

Dejong, O. (2006). *Context-based chemical education: how to improve it?* Paper based on the plenary lecture presented at the 19th ICCE, Seoul, Korea, and 12-17 August 2006. Accessed at http://old.iupac.org/publications/cei/vol8/0801xDeJong.pdf.

Demircioğlu, G., Ayas, A. & Demircioğlu, H. (2005). Conceptual change achieved through a new teaching program on acids and bases. *Chemistry Education Research and Practice, 6*(1), 36-51.

Kilavuz, Y. (2005). *The Effects of 5E Learning Cycle Model Based on Constructivist Theory on Tenth Grade Students' Understanding of Acid-Base Concepts*. Unpublished Masters' Thesis, Middle East Technical University. Accessed at https://etd.lib.metu.edu.tr/upload/12608670/index.pdf.

Kolomuc, A., Ozmen, H., Metin, M. & Acisli, S. (2012). The effect of animation enhanced worksheets prepared based on 5E model for the grade 9 students on alternative conceptions of physical and chemical changes. *Procedia - Social and Behavioral Sciences, 46*, pp.1761 – 1765.

Mustafa, Y. & Dermircioglu, G. (2012). Effect of activities based on 5E model on grade 10 students understanding of gas concept. *Procedia - Social and Behavioral Sciences, 47*, pp. 634–637.

Özmen, H. & Yıldırım, N. (2005). Effect of work sheets on student's success: Acids and bases sample, *Journal of Turkish Science Education, 2*(2), 64-67.

Özmen, H., Demircioglu H. & Demircioglu G. (2009). The effects of conceptual change texts accompanied with animations on overcoming 11th grade students' alternative conceptions of chemical bonding. *Computers and Education, 52*(3), pp. 681-695.

Shumba, O. (2012). Learning for Sustainability in Science Education in Africa: 'Learning as Connection' an Imperative for Transformation. In Arjen E.J. Wals and Peter Blaze Corcoran (2012) (Eds.). *Learning for sustainability in times of accelerating change* (Chapter 27). Wageningen, The Netherlands: Wageningen Academic Press.

Singer, F.H. & Moscovici. H. (2008). Teaching and learning cycles in a constructivist approach to instruction. *Teaching and Teacher Education, 24*(6), pp. 1613–1634.