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The Impact of Teaching and Learning of Chemistry of Acids and Bases in the Context of SDG 6 on Water Quality and Sanitation

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Abstract

Purpose: Research has shown that incorporating social-scientific issues and societal concerns in the teaching and learning of STEM subjects, such as Chemistry, can enhance their relevance and appeal to learners. However, STEM experiences often fail to connect with learners' experiences and societal issues.

Materials and Methods: To address this, a study was conducted with grade 11 learners (n=60) at a secondary school in Kasama town, northern Zambia. The study explored the impact of teaching acids and bases in the context of SDG6 on water quality and sanitation, using the REACT teaching model (Relating, Experiencing, Application, Cooperation, and Transferring).

Findings: Results showed that the experimental group (n=30) performed significantly better than the control group (M experiment =67.07, S= 13.09, M control = 45.87, S=11.73, t (df =58, two-tailed =6.05, p < 0.05). The gains from pre-test to post-test were significant in the experimental group (Gain = 26.03 points, t (df=29, 2-tailed) = 8.496, p < .000) and not significant in the control group (Gain = 6.17 points, t (df=29, 2-tailed) = 1.893, p = 0.068).

Implications to Theory, Practice and Policy: These results are both statistically and practically significant.

Keywords: *Chemistry, Teaching, Learning, Bases, Acids, SDG6*

1.0 INTRODUCTION

The lack of interest and fear of natural science and mathematics among learners in Zambia is a cause for concern (Shumba, 2017). To address this issue, it is important to use effective teaching and learning methods that can engage learners and alleviate their fears. One approach is to make science relevant to learners' personal, familial, and social experiences. By connecting learning experiences to real-world issues, such as humanistic concerns and the Sustainable Development Goals (SDGs), learners can better understand and engage with the subject matter.

This paper aims to investigate the effectiveness of the REACT (Relating, Experiencing, Applying, Cooperation, and Transferring) model designed by Crawford (2001). The model is applied in teaching the chemistry of acids and bases in the context of SDG 6 on water quality and sanitation (UNESCO, 2017). The REACT model emphasizes collaboration, communication, and problem-solving skills, which are all outcomes of education for sustainable development (ESD). By embedding content in the teaching and learning process and drawing out social-scientific situations and personal hygiene messages, the model can help learners develop a better understanding of the subject matter.

Studies conducted in different curriculum areas, such as geography, chemistry, and English language, have shown positive results in contextualized subject mastery and skills development, such as communication and other social competencies (Utami, Sumarmi, Ruja, & Utaya, 2016; Rohayati & Tutim, 2013). The REACT model could be a valuable tool in improving learners' engagement and understanding of natural science and mathematics in Zambia.

In this study, learners were encouraged to apply their knowledge of acids and bases to gain a better understanding of important social-scientific topics such as water quality and sanitation. By using everyday acidic and basic materials and products that they encounter in their homes, schools, and communities, students in a chemistry class were able to gain a deeper understanding of these complex issues. The approach intentionally bridged the gap between chemistry and social sciences, engaging learners in a meaningful way.

Purpose of the Sudy

The purpose of this study was to explore the impact of teaching and learning the chemistry of acids and bases in the context of a sustainable development goal on water quality and sanitation (SDG 6). The research was guided by the research question:

- What is the impact of the REACT teaching model on the teaching and learning of the chemistry of acids and bases in the context of sustainable development goal 6 on water quality and sanitation?

Study Settings and Participants

Research was carried out at a secondary school for girls in the Kasama district of Northern Zambia. The school had an enrolment of 650 female students. For the study, the researchers intentionally selected two classes from grade 11, which were the only ones in the school. The total number of students involved in the study was 60, with each class having 30 learners.

Research Design and Procedures

The action research study adopted the pre-test post-test quasi-experimental control group research design. The two classes were allocated intact into the experimental and control groups by tossing

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a coin. In the first phase, pre-test on topics prerequisite to the teaching of acids and bases was given to both the control and experimental groups. This was to check if or not their knowledge level was the same on chemical formulas, writing simple chemical equations, and chemical bonding and also to uncover the type of challenges they would mostly encounter when studying reactions of acids and bases.

The second phase, the intervention, lasted 5 weeks. The experimental grade 11 was taught using the REACT approach with selected SDG6 learning objectives from the resource guide ESD Learning(http://unesdoc.unesco.org/images/0024/002474/247444e.pdf). Objective (UNESCO, 2017). The control group followed learned the same material with conventional practical work and chemical explanations without SDG6 objectives. The following are the approximate REACT activities in the order offered to the experimental group (this approach was to be used for the control group after the initial study reported here).

Relating: learners were asked to explain what they knew about acids, acidic rain, and its effects. After some discussions, a video was shown to the pupils which involved acid-base reactions and some of the effects of acidic substances on the environment. After watching the videos pupils were asked some questions about what they thought was happening in the video and what they had learnt. The teacher then explained the definitions of acids and bases after the pupils explained acids and bases in their contexts. The target *SDG 6* cognitive learning objectives:

- Pupils must understand that water is life and the importance of water quality.
- Pupils understand the effects of acids and bases on the quality of water and living organisms.

Experiencing: learners were taught how to use litmus paper and a pH meter to identify different solutions of domestic materials by stating whether it's acidic or basic using color changes and the pH scale, respectively. Products tested included hand handy, boom force cream, vinegar, harpic, milk, lemon juice, and battery water. The target *SDG 6* social-emotional and learning objectives:

- Pupils must know how they can improve water and sanitation in their communities
- Pupils must confidently be able to communicate on the impacts of acids and bases substances such as washing near rivers on water quality and sanitation. Learner must feel responsible for their water use.

Application: an environmental health technician was invited to come and explain how acids and bases concepts and careers on water quality. They carried out some water analysis tests with help of the environmental health technician. Some of the target *SDG* 6 social-emotional and learning objectives:

- The learner is able to feel responsible for their water use.
- The learner is able to see the value in good sanitation and hygiene standards

Cooperation: the class was divided into smaller groups of five and given a task on how to tackle and resolve water quality issues in their communities. They completed a worksheet and made a presentation on their outputs to the whole class. The target *SDG 6* social-emotional and learning objectives:

- Learners able to cooperate and contribute to water quality and sanitation.

Transferring: learners conducted an experiment on the identifications of metal ions in solution that might affect the quality of water. Ions such as the iron (II) and iron (III) that affect the quality of water in almost all the parts of the country were analyzed qualitatively. Target SDG6 behavioural learning objectives:

- Learners must able to plan, implement and evaluate activities which are contributing to water quality and sanitation
- Learners must participate and evaluate decision making on water quality and sanitation

After five weeks, a researcher developed acid-base achievement test which contained water quality concepts for contextualisation was given. The achievement test contained 18 contextualised items, for example:

Question 15:

i. Why do we give children milk of magnesia?
ii. Write the likely equation of the reaction between milk of magnesia and dilute hydrochloric acid.

Overall, the items tested understanding and application of knowledge of acids and bases in real-life contexts. The results for the two classes were compared.

2.0 FINDINGS

The results were analysed using the t-test using the Statistical Package for Social Sciences (SPSS) version 20. Table 1 shows the independent t-test comparing the experimental group (mean = 41.03) to the control group (mean = 39.70) on the pre-test. They showed no significant statistical differences on the girl's knowledge of chemical concepts carried the test ($p = .776 > .05$).

Table 1: Independent T-Test Results on the Pre-Test of Experimental and Control Groups (N = 60)

Groups	N	Mean	sd	df	t-test	p-value
Experimental	30	41.03	10.85	58	0.299	0.766
Control	30	39.70	11.59			

Table 2 shows the results of comparing the two groups on the post-test

Table 2: Independent T-Test Results on the Experimental Group and Control Group Post-Test (N = 30)

Group	N	Post-test Mean	sd	t-test	df	P-value
1. Experimental group	30	67.07	13.09	6.05	58	0.000
2. Control group	30	45.87	11.73			

The results show significantly better performance of the group (n=30) in the REACT than the control class ($M_{\text{experiment}} = 67.07$, $S = 13.09$, $M_{\text{control}} = 45.87$, $S = 11.73$, $t_{(df = 58, \text{ two tailed})} = 6.05$, $p < 0.05$). Table 3 shows that the gains from pre-test to post-test were significant in the experimental group (Gain = 26.03 points, $t_{(df=29, \text{ 2-tailed})} = 8.496$, $p < .000$).

Table 3: Paired T-Test Results Comparing Pre-Test and Post-Test Achievement Scores for the Experimental Group (N = 30)

Experimental Group	Means	sd	t	SE	df	Sig (2-tailed)
1. Post-test	67.06	13.09	8.496	2.39	29	0.000***
2. Pre-test	41.03	10.85		1.97		

Table 4 shows that the gains from pre-test to post-test were not significant in the control gain (Gain = 6.17 points, $t_{(df=29\text{ , }2\text{-tailed })}$ = 1.893, p = 0.068).

Table 4: Paired T-Test Results Comparing Pre-Test and Post-Test Achievement Scores for the Control Group (N = 30)

Control Group	Means	sd	t	SE	df	Sig (2- tailed)
1. Pre-test	39.70	11.342	1.893	2.071	29	0.068
2. Post-test	45.87	11.726		2.141		

Overall, the results above showed significantly better performance of the class that used (n=30) the REACT strategy plus SDG6 learning objectives than the class that served as the control class. The gains from pre-test to post-test were significant in the REACT experimental group and not significant in the control group. The REACT teaching strategy had a greater positive impact on the contextualised teaching and learning of acids, bases and salts in real contexts of the SDGs. Noteworthy in the study was the fact the REACT strategy made learning joyous (Photograph 1) while remaining engaging (Photograph 2).

Figure 1: Pupils Happily Explore Acids and Bases

The facial expressions of the pupils conducting the experiments in Photograph 1 shows that the pupils were really enjoying the activities in the experiencing stage of REACT teaching strategy.

Figure 2: Pupils Performing an Experiment Using Different House Hold Products

3.0 DISCUSSION AND CONCLUSIONS

Discussion

The positive results reported here are practically significant. They demonstrate what can happen when teachers adopt innovative teaching approaches such as the REACT model. The efficacy of such models lie in their ability to bring relevant examples and to contextualise the entire learning process. It is also important to see efforts to have learners engage with experiences that contribute to the learning objectives of the sustainable development goals. We see in this example the possibility of equally focussing on hard and soft skills acquisition when teaching and learning of a science subject such as chemistry. Much is to be gained in this kind of learning approach; most likely this will reduce the phobia associated with chemistry and other natural sciences. This is particularly relevant for girl learners who are underrepresented in many natural science courses.

There is much scope to improve the design and evidence for strategies such as REACT on different areas of the curriculum and at different levels of studying science subjects. Better qualitative documentation and analysis of how much learners get activated and to what long-term impact is worth investigating. In this study, just getting a chemistry teacher to implement lessons of the kind reported and getting him/her to appreciate the SDGs as demonstrated here can lead to our cherished vision, learning for sustainable development. After all, even at international level, UNESCO, counsels that "sustainability starts with teachers".

Conclusion

Overall, the case study demonstrates the possibility of innovation in teaching and learning of science in a manner that help to connect school knowledge and social experience. Getting acquaintance with social-scientific issues such as water and sanitation issues in SDG 6 can begin to open up young minds to a better and safer life. These young minds is what society needs for its effective transformation from its unsustainable ways to a better quality life; they can be critical agents of change. This study shows that it is possible to deliberately and simultaneously engages learners with scientific content (i.e., the chemistry of acids, bases and salts) and societal and humanistic concerns (e.g., in the SDG 6 on water quality and sanitation). Just getting a chemistry teacher to think and act in this way is the value added to science education for sustainable development.

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