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Enhancing Titration Accuracy in Zambian Secondary Schools: A Case Study of Mansa District of Luapula Province

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Abstract- Titration, a crucial technique in chemistry, is often poorly executed in many secondary schools across Zambia, particularly in the rural and semi-urban regions such as Mansa District in Luapula Province. This study explores the impact of targeted instructional interventions, such as enhanced teacher training and the use of digital tools (e.g., instructional videos and simulation software), on improving titration accuracy among students. Using a mixed-methods approach, which incorporated both quantitative pre- and post-test assessments as well as qualitative interviews with teachers, the study found significant improvements in both student understanding and precision when performing titration experiments. The study also identified key challenges, including inadequate laboratory equipment, lack of proper training for teachers, and the absence of standardized protocols across schools. This research highlights the need for comprehensive reforms in the teaching of practical chemistry in Zambia, with a specific focus on addressing resource gaps and improving teacher professional development.

Keywords- Grade Twelve examination performance, Science education, ICT in education, Educational technology, Rural education.

I. INTRODUCTION

Chemistry, as one of the key science subjects in secondary education, plays a pivotal role in shaping students' understanding of the physical and chemical processes in the world around them. Titration, a core experimental procedure, is fundamental for understanding concepts such as molarity, concentration, and acid-base reactions. However, many Zambian secondary school students, especially in Mansa District, struggle with performing titrations accurately due to various challenges, including limited access to quality instructional materials, insufficient teacher training, and inconsistent laboratory practices.

This study investigates the impact of targeted interventions aimed at enhancing the accuracy of titration experiments in secondary schools within Mansa District. Specifically, the research explores how improvements in teacher training, laboratory resources, and the integration of digital tools can foster a more effective learning environment for chemistry students. The goal is to improve both student performance in titration exercises and the overall teaching quality of practical science.

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II. LITERATURE SURVEY

Several studies have demonstrated the critical role of hands-on science education in helping students develop practical skills. Titration, a widely used laboratory technique in secondary school chemistry, is often a challenge for students due to its reliance on precision and attention to detail. Research by Pithers & Soden (2000) and Wright (2006) has highlighted that practical science education can be hindered by various factors, including inadequate teaching resources, insufficient teacher preparation, and poor laboratory conditions.

In Zambia, studies by Haambokoma (2007) and Shafika (2007) emphasize the challenges faced by secondary schools in delivering high-quality practical chemistry education. The integration of ICT tools such as simulations and instructional videos has been shown to improve the quality of science education in other regions (Sivin-Kachala, 1998; Volman & van Eck, 2001). However, the application of these technologies in the Zambian context remains limited, especially in rural and peri-urban areas.

III. DISCUSSION/METHODOLOGY

This research utilized a mixed-methods approach, combining both quantitative and qualitative research techniques to investigate the effectiveness of interventions designed to improve titration accuracy. The study was conducted in three purposively selected secondary schools in Mansa District, which were chosen based on their ability to provide adequate laboratory resources and a willingness to participate in the study.

- **Participants:**
- 4 Chemistry Teachers
- 100 Grade 12 Students (50 in the experimental group, 50 in the control group)
- **Data Collection Instruments:**
- Quantitative: Pre- and post-test assessments to measure student performance in titration experiments.
- **Qualitative:** Semi-structured interviews with teachers and focus group discussions with students to gather insights on their experiences with the interventions.
- **Data Analysis:**
- Quantitative data were analyzed using statistical methods, including paired t-tests to compare pre- and post-test results.
- Qualitative data were analyzed thematically to identify common patterns and themes related to the effectiveness of the interventions.

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IV. RESULTS

The study revealed several key findings regarding the effectiveness of the interventions:

- **Improved Titration Accuracy:**

Students in the experimental group, who received enhanced teacher training and used digital tools like simulation software and instructional videos, demonstrated significantly higher accuracy in titration experiments compared to the control group.

- **Positive Teacher Feedback:**

Teachers reported an increase in confidence and competence in guiding students through titration procedures. The incorporation of digital tools was particularly helpful in illustrating abstract concepts such as endpoint detection and titrant calculation.

- **Student Engagement:**

Both students and teachers noted a significant increase in student engagement during practical sessions, with students expressing greater interest in performing titrations when digital tools were used to supplement traditional methods.

- **Challenges Identified:**

Despite the positive outcomes, challenges such as inadequate laboratory equipment, inconsistent electricity supply, and a lack of standardized teaching protocols persisted.

V. DISCUSSION

The results of this study are consistent with previous research that has shown the positive impact of instructional innovations and ICT integration in science education. The significant improvement in titration accuracy among the experimental group underscores the potential of combining teacher training with digital tools in practical science education. The positive feedback from both teachers and students indicates that such interventions not only enhance learning outcomes but also foster greater enthusiasm for science subjects.

However, the study also highlights the systemic challenges that continue to hinder the full implementation of these innovations, particularly in resource-constrained settings. These challenges include inadequate laboratory infrastructure, insufficient teacher training, and inconsistent access to digital tools.

VI. CONCLUSION

This study has demonstrated that targeted interventions, such as teacher training and the use of digital tools, can significantly improve the accuracy of titration experiments in Zambian secondary schools. The integration of ICT tools into the teaching of practical chemistry enhances both student performance and engagement, while also addressing some of the traditional barriers to effective science education.

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