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VIRTUAL LABORATORY'S EFFECTIVENESS ON GRADE 11 LEARNERS' ACADEMIC PERFORMANCE TOWARDS LEARNING ACID-BASE REACTIONS

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Abstract

This study investigated the effectiveness of virtual laboratories on Grade 11 learners' academic performance in learning acid-base reactions. A titration model was developed using the Scratch programming platform to simulate neutralisation reactions and facilitate related calculations. Employing a mixed-methods approach, the study collected qualitative data through interviews and non-participant observations, while quantitative data were obtained via a Likert scale questionnaire and pre- and post-tests. The Solomon four-group design was adopted as part of a convergence triangulation model. A total of 408 learners from four secondary schools participated in the study. Qualitative data were analysed using thematic analysis and the Mann–Whitney U test, while quantitative data were analysed using the Friedman test. Thematic findings revealed that learners found the Scratch-based learning experience engaging and interactive, particularly due to its multisensory approach that incorporated both visual and auditory modalities. Post-test results indicated that learners in the Scratch-based group outperformed their peers who were taught using PowerPoint presentations. The findings suggest that virtual laboratories designed through Scratch can significantly enhance conceptual understanding and academic performance in acid-base chemistry.

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INTRODUCTION

Acid-base reactions are among the fundamental concepts essential to the understanding and application of chemistry. These reactions are characterised by the transfer of one or more hydrogen ions (H^+) between chemical species, which may be electrically neutral—such as water (H_2O) or acetic acid (CH_3COOH)—or charged ions, including ammonium (NH_4^+), hydroxide (OH^-), and carbonate (CO_3^{2-}). Bases are substances that, when dissolved in water, typically feel soapy to the touch and turn red vegetable dyes (such as litmus) blue. When acids and bases react, they undergo neutralisation, producing salt and water as the only products. Notably, acid-base reactions are often reversible, with the resulting products capable of interacting to regenerate the original reactants. This reversibility introduces the concept of chemical equilibrium in acid-base chemistry (Garry & Donald, 2017).

According to the Examination Council of Zambia (2023), many learners encountered difficulties when answering questions related to acid-base reactions, primarily due to a lack of practical exposure during school-based assessments. Additionally, the 2023 School Certificate Examination recorded a decline of 1.26 percentage points in the proportion of candidates awarded school certificates. In response, the Council recommended strengthening school-based assessments to enhance learners' understanding and performance. Identifying the underlying factors contributing to this decline is essential for developing effective, evidence-based solutions. Notably, the residual effects of the COVID-19 pandemic and prolonged school closures in 2021 likely impacted the academic preparedness of the 2023 candidates, highlighting the urgency of addressing these challenges to prevent similar outcomes in the future.

In light of poor academic performance in science subjects, there was a compelling need to explore innovative approaches to teaching, particularly through the use of virtual laboratories. This study focused on developing a titration laboratory activity using the Scratch programming platform. Virtual laboratories have emerged as viable alternatives to traditional laboratory settings, offering interactive and engaging simulations that provide learners with practical, hands-on experiences in various scientific disciplines (Dede, 2009). These digital platforms aim to bridge the gap caused by limited access to physical laboratories, thereby supporting students' conceptual understanding and improving academic outcomes. Virtual laboratories simulate real-world experiments and offer learners flexibility in terms of time and location, overcoming many of the logistical and financial constraints associated with physical laboratory environments (Amagai, Cordon, & Liu, 2001). By leveraging these digital tools, educators can ensure that learners gain critical practical skills that enhance their performance in both formative and summative assessments.

Virtual laboratories provide an opportunity for learners to bridge the gap between theoretical knowledge and practical application, enhancing their understanding of scientific concepts and fostering critical thinking skills. As a result, the virtual laboratories could be the best alternative and supplement to schools with inadequate laboratory instruments and apparatus, more especially because these schools have computer laboratories. These computer laboratories could be timetabled such that science lessons are offered using virtual laboratories. This would enable the learners to learn science concepts practically in schools which do not have adequate science laboratory infrastructure and would serve as a supplement to traditional instruction in those schools which have laboratories. In all the science subject areas, practical learning activities are recommended (Curriculum Development Centre [CDC], 2013).

To address the lack of practical exposure in science education, this study developed a virtual titration laboratory activity using Scratch programming software. The design of the Scratch-based simulation was informed by the theory of perceptual learning modalities, which posits that the mind processes information primarily through visual (seeing), auditory (hearing), kinesthetic (movement), and tactile (touch) channels (Willingham, 2005). The project was deliberately structured to engage all four modalities. It visually demonstrated the setup of laboratory apparatus for a titration experiment and identified the required reagents. Additionally, the procedure and related calculations were explained through audio narration, while animated movements illustrated the titration process in a vivid, dynamic manner, making the activity accessible and engaging for Grade 11 learners.

Given the challenges learners face in acquiring practical skills through traditional methods, exploring alternative teaching and learning strategies becomes essential. One such approach is the integration of educational technologies—specifically the use of computers to support and enhance laboratory activities. This strategy aligns well with learners' familiarity and enthusiasm for digital tools and technological gadgets, thereby creating stronger connections between their digital experiences and classroom learning (Balkan et al., 2002). Consequently, virtual laboratories represent a promising learner-centred approach that not only addresses resource constraints but also fosters engagement, understanding, and academic achievement.

A study conducted by Becky, et al., (2013) at Boise State University in the United States focused on the use of the Scratch programming platform as an instructional tool. The primary aim of the study was to develop a teaching method that could enhance learners' content knowledge while simultaneously fostering essential 21st-century skills. Specifically, the researchers designed an instructional intervention in mathematics that sought to improve learners' attitudes towards the subject through game-based learning. As a result, a computer-aided instructional programme incorporating Scratch was developed. This tool was aligned with the mathematics curriculum and was intended to deliver practical, learner-centred instruction that supported the development of creativity, problem-solving skills, and a positive disposition towards mathematics.

The study adopted a quantitative research design, utilising pre- and post-tests alongside a Likert scale questionnaire to measure changes in learners' performance and attitudes. In contrast, the present study employed a mixed-methods approach, combining quantitative instruments with interviews and non-participant observations to gain deeper insight into learners' attitudes and learning experiences. While the focus of Becky et al.'s study was on mathematics, the findings similarly support the value of Scratch as a versatile educational tool. Their results indicated that the Scratch-based intervention successfully stimulated learners' cognitive abilities—including logical thinking, creativity, and problem-solving—while also contributing to improved attitudes and academic performance in mathematics. These findings highlight the potential of Scratch to serve as an effective alternative teaching method across subject areas, including chemistry, by engaging learners and enhancing learning outcomes.

To address the persistent challenge of limited or inadequate laboratory equipment and materials, virtual laboratory activities—such as computer-based simulations and educational games—have emerged as promising alternatives. A growing body of research has explored the effectiveness of learning science through interaction with digital simulations and games. These studies examine the potential of such tools to enhance science learning not only within formal school settings but also in informal and everyday contexts beyond the classroom. Digital simulations and educational games offer interactive, engaging, and often immersive experiences that can support conceptual understanding and foster scientific thinking.

According to Achuthan et al. (2015), virtual laboratories represent an Information and Communication Technology (ICT)-based initiative that is gaining traction in educational institutions. These platforms are increasingly being utilised to supplement and enrich traditional classroom instruction, particularly in resource-constrained environments. Virtual laboratories enable students to conduct experiments in a simulated environment, thereby bridging gaps in access to physical lab facilities while promoting active, learner-centred engagement in science education.

Regarding the problem trigerring this study, candidates who sat for the Chemistry 5070 syllabus in 2022 encountered significant difficulties with Question A10 on acids, bases, and salts—specifically titration—which required the application of practical skills gained through School-Based Assessments (SBAs) (ECZ, 2022). Many were unable to demonstrate familiarity with standard titration procedures, including the identification of suitable acid-base indicators and the recognition of appropriate colour changes to distinguish between acidic and alkaline solutions. These gaps suggest insufficient engagement with practical exercises during SBA activities. The Examinations Council of Zambia (ECZ) further noted that candidates struggled to apply practical knowledge from SBA experiences when answering theoretical examination questions (ECZ, 2023).

Moreover, performance reports from ECZ between 2017 and 2023 consistently indicate that candidates face persistent challenges with chemistry questions requiring laboratory experience. For instance, Question 12 from the 2023 Chemistry Paper 2 assessed students' understanding of acid-base reactions and the nature of acids, bases, and salts. The report revealed that 79 percent of candidates misinterpreted the definition of a base as an electron donor—confusing it with the proton-donating properties of acids. Such misunderstandings point to a lack of conceptual clarity, which could be mitigated through regular practical work. These issues underscore the importance of reinforcing theoretical instruction with experiential learning to better prepare students for examinations that incorporate practical scenarios.

In light of these concerns, the study sought to address two key research questions: (1) What are the differences in the attitude of learners taught acid-base reactions using the Scratch program compared to those taught using PowerPoint presentations? and (2) What are the differences in academic performance between learners taught using the Scratch program and those instructed through PowerPoint presentations?

METHODS

Research Designs

This study is grounded in the theory of pragmatism, which emphasises the practical application of ideas and evaluates theories based on the success of their real-world outcomes. Pragmatism supports methodological flexibility, making it particularly suitable for educational research that seeks both understanding and practical impact. In alignment with this philosophical stance, the study employed a mixed-methods approach, which involves the collection, integration, and analysis of both quantitative and qualitative data within a single research design. This methodology allows for a more comprehensive exploration of the research problem by drawing on the strengths of both data types.

Specifically, the study adopted the Convergence Model of triangulation design—also referred to as the parallel convergent mixed-methods approach. This design enables researchers to collect quantitative and qualitative data simultaneously and then merge the findings during the interpretation phase. The purpose of this convergence is to compare, contrast, and validate results from both strands of data, thereby enhancing the credibility and depth of the research outcomes. Quantitative statistical findings can be directly juxtaposed with qualitative insights to identify consistencies, contradictions, or complementary patterns. Such cross-validation contributes to a more nuanced understanding of the research problem and supports the development of more robust conclusions. When discrepancies arise between the two data sets, they are further investigated to uncover deeper meanings or contextual explanations. This approach aligns well with the pragmatic worldview, where the aim is not only to generate knowledge but also to apply it meaningfully in educational practice.

Research Settings and Participants

The study was conducted in four Upgraded Secondary Schools in Mongu district of Zambia. Two and forty learners wrote at pretest stage whilst four hundred and eight learners wrote the post test who were in grade 11 classes.

Data Collection Techniques

As part of data collection, scratch program on titration was created based on principle of modality. In this regard, learners tend to acquire concepts better from multimedia lessons when graphics are explained by audio narration than on screen text.

Figure 1

Scratch program on acid-base reaction.

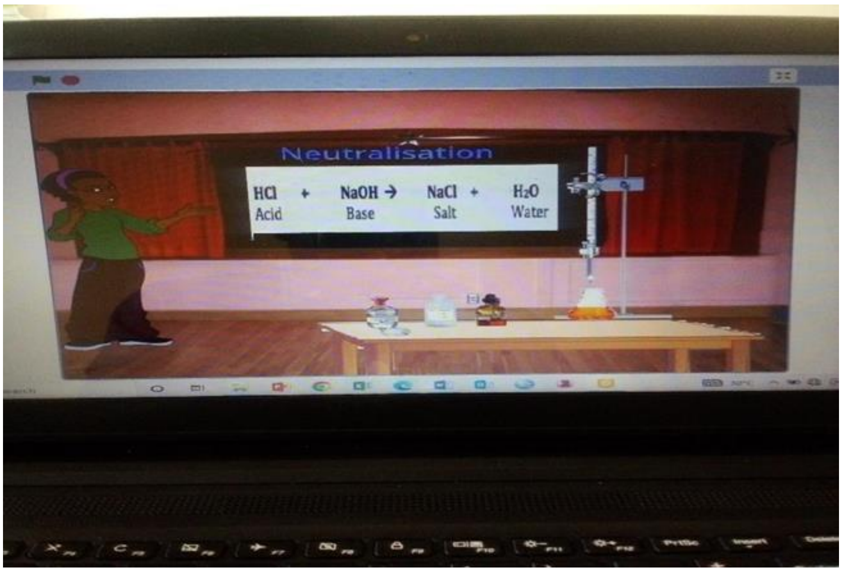

Figure 1 shows the arrangement of a titration experiement animation which was accompanied with a narration on what is happening. The animation showed the change of colour when the acid-base reaction reach the end point. The apparatus and narrations were coded and timed such that the learners follow the steps and calculations. Several learner centred approaches were considered and principles were included for the better retention of the concepts.

The modality principle which suggested that learners learn better when information is presented through a combination of auditory and visual channels rather than through a single modality (Mayer, 2009) was used when creating the scratch program. The scratch project has both graphics and animation which would enable the learners to conceptualise the process of neutralisation. Therefore, learning is better enhanced when corresponding words and pictures are presented near rather than far from each other on the page or screen.

Quantitative data were collected through an academic performance assessment using both pre-test and post-test results, as well as Likert scale questionnaires administered to both groups—those taught using the Scratch program and those taught using PowerPoint presentations. These instruments measured learners' academic performance and attitudes towards learning acid-base reactions. In parallel, qualitative data were gathered through semi-structured interviews and observation notes recorded throughout the learning process, providing insights into student engagement and learning behaviours.

The study was conducted in four selected upgraded secondary schools located in Mongu District, the provincial capital of Western Province. A true experimental design was employed, specifically adopting the non-equivalent control group pre-test/post-test format, in alignment with the Solomon Four-Group Experimental Design. The participating classes were divided into four groups: two served as experimental groups, while the other two acted as control groups. Of the four groups, two received both pre-tests and post-tests. The experimental groups were taught using the Scratch program, whereas the control groups received instruction via PowerPoint presentations. Two groups—one experimental and one control—completed only the post-test. This design allowed for the control of pre-test sensitisation effects and enhanced the internal validity of the study. The structure of the experimental arrangement is detailed in Table 1 below.

Table 1

Solomon Four Group Designs

	Time 1		Time 2	
	Assignment	Pre-Test	Intervention	Post-Test
Group 1	R	O_1	X	O_2
Group 2	R	O_3	X	O_4
Group 3	R		X	O_5
Group 4	R			O_6

In Solomon four group design, the participants were randomly assigned to four different conditions as follows:

Group 1 which was the experimental group was given an intervention with both pre-test (O_1) and post-test (O_2). This O_1 represents observations that were made during the pre-test measures. Thereafter an intervention(X) was given to this experiemental group followed by a post-test

(O_2) which was teaching the group using scratch project. The O_2 represents observations that were made at post-test measures. The experiemntal group was taught the concept of titration using the project from scratch programme. Post-test determined if the intervention

which was teaching titration using a scratch project program had an effect on the learners' academic performance and attitude. The outcome of interest was measured twice, once before the treatment group gets the intervention which was the pre-test and once after that was the post-test. The objective was to measure the effect of the intervention.

Group 2 was a control group where a pre-test (O_3) and a post-test (O_4) were administered with an intervention in between the two tests. The control group was taught using the PowerPoint presentation method on titration concept. O_3 represents the observations which were be made at pre-test measure whilst O_4 were observations made during post test for the group.

Group 3 was also an experimental group but it didn't take part in the pre-test. However, it was given an intervention and a post-test (O_5). O_5 was the observations made at post-test measure. This was to determine if the first group's performance was influenced by the pre-test including the effectiveness of the intervention instituted.

Group 4 was a control group where it didn't have both a pre-test and intervention but just the post-test (O_6). O_6 was the observation made at post test for the fourth group. Solomon four group design allowed the researcher to exert complete control over the variables and allows the reseacher to check that the pre-test did not influence the results. The outcome of interest was measured only once after the intervention took place in order to determine its effect.

The study used a simple random sampling as part of quantitative methodology because the target population had a known, equal, fair and a non zero chance of being selected. The random sampling method was used as it was easy as assigning numbers to the individuals (sample) and then randomly choosing from those numbers through an automated process. Finally, the numbers that were chosen were the members that were included in the sample besides the data was triangulated, naturalistic and interactive in nature(Ary et al, 2010 & Lewis, Thornhill & Saunders, 2012).

However, for participants who were included in the observation and interview sessions, non probability sampling techniques such as purposive sampling was employed as part of qualitative research methodology. Below are the discussions of the sampling techniques used for each instrument.

Learners' attitude scale questionnaire (Likert scale) participants: Two hundred and forty learners selected using probability sampling was asked to answer the learners' attitude scale questionnaire (Likert scale) both at pre-test stage and at post test stage. This was to determine the difference in the learners'attitude towards learning acid-base reactions from pre-test stage to post test stage.

Lesson observation participants: The study targeted the four hundred and eighty learners who were participants in the research process. The observations were made as the researcher was conducting the acid-base reaction lessons using scratch program and PowerPoint presentation method. The researcher conducted the lessons on titration alone hence had no need to observe other teachers but observed the learners as they learn in different groups. The researcher was guided by the observation guide and ticked as the learners were in groups.

Acid-Base Pre-Test Participants: The two hundred and forty learners who were selected at random in the classese where lesson observations were conducted wrote a pre-test. This provided the learners a level to be placed at the equally before the intervention in terms of academic performance. At each of the four selected upgraded secondary schools, sixty learners were randomly assigned to two groups the experiemental and control groups of thirty each. The science teachers at these schools assisted in invigilating the tests.

Acid-Base Post Test Participants: All the four hundred and eighty learners selected using a random sampling technique in the classes where the lesson observations were conducted were eligible to write a pre-test and post test. This provided an opportunity for learners to exhibit their understanding of acid-base chemical reactions after the intervention. At each of the four selected upgraded secondary school, one hundred and twenty learners were randomly selected to participate in the research process. The one hundred and twenty learners were then randomly assigned to the four groups of solomon where each group had thirty learners.

Learners' interview participants: Twelve learners from each school were interviewed where they were selected as the highest, average and lowest from each of the four groups. This meant that it followed the academic performance of the learners from the post test (Ary et al, 2010 & Lewis, Thornhil, Saunders, 2012). The average was determined by the performance of each group hence varied from one school to another. This helped to ensure that the data was balanced, and reflected the opinions and experiences of the population under study as interviewees come from the drawn sample.

The solomon four group design helps to control threats to validity and realiability of the intruments as some groups are denied either pre-test or an intervention (Solomon Four Group Design, 2018). By using a pretest, a control group, and random assignment, this design controls all internal threats to validity. The first two groups are able to control threats to internal validity while the last two groups control threats to external validity. Therefore, solomon four group design was developed to control threats to both internal and external validity (Campbell, 1963). The equivalent forms would determine the reliability of the instruments as the same type of test would be given to the learners at pre-test stage and a similar but equivalent test would be given at post test. This is an alternative form of the test from pre-test and post test. This would show consistency of results when the test would be repeated on the same sample at a different point in time.

Therefore, in order to make the interpretation of data collected as valid and reliable as possible, this study piloted the developed structured data collection instruments. Triangulation in the analysis and interpretation of data from different sources of data to provide a deeper understanding of the problem, cross data validity checks and the reliability of the findings made the interpretation of data valid and reliable.

Data Analysis Procedures

The data collected from learners' pre-test and post-test and attitude test (Likert scale) was analysed using descriptive and inferential statistics. Likert scale factors were reduced using the Factor analysis techniques. The data collected from lesson observations, and interviews was analysed using qualitative data analysis (QDA) techniques. Interviews were recorded then transcribed to form codes where themes were generated using thematic analysis. The responses from open ended teachers' questionnaires were coded to form thematic themes using fact analysis so that there was a basis for the interpretation.

FINDINGS

A Normality Test

Testing for normality is important in statistics because many statistical methods and tests assume that the data come from a normal distribution. If your data significantly deviates from normality, it may affect the validity of these assumptions and the results of your analysis. The normality test has got two tests namely the Shapiro-Wilk Test and the Kolmogorov-Smirnov test.

The Shapiro-Wilk test is a widely used parametric test for assessing normality. It tests the null hypothesis that a dataset comes from a normally distributed population. If the p-value obtained from the test is less than a chosen significance level (e.g., 0.05), you may reject the null hypothesis and conclude that the data is not normally distributed.

The Kolmogorov-Smirnov test is another test for normality that compares the empirical cumulative distribution function (ECDF) of the data to the cumulative distribution function of a normal distribution. Like the Shapiro-Wilk test, if the p-value is less than the chosen significance level, you may reject the null hypothesis of normality.

Table 2

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Different groups	.223	360	.000	.793	360	.000

a. Lilliefors Significance Correction

The Shapiro–Wilk test for normality yielded a p-value of 0.000, which is less than the threshold of 0.05. This result indicates a statistically significant deviation from normality, leading to the rejection of the null hypothesis that the data are normally distributed. Consequently, it can be concluded that the variables do not follow a normal distribution, as the data significantly diverge from the characteristics of a bell-shaped curve. Given the non-normal distribution of the data, a non-parametric statistical approach was deemed appropriate. Therefore, the Mann–Whitney U test was employed to compare the groups, as it is suitable for analysing differences between two independent groups when the assumption of normality is not met.

Friedman Test

The Friedman test is a non-parametric alternative to the one-way ANOVA with repeated measures. It is particularly useful when the data are not normally distributed, as indicated by non-parametric conditions. The test is designed to compare mean ranks across related groups in order to determine whether statistically significant differences exist between them. It is especially appropriate when the dependent variable is ordinal, though it may also be applied to continuous data that violate the assumptions required for parametric tests—such as marked deviations from normality.

Functionally, the Friedman test serves as an extension of the sign test and is suitable when there are more than two related groups or treatment conditions. By ranking the scores across treatments for each subject, the Friedman test identifies whether the observed differences in ranks are likely to have occurred by chance. This makes it a robust choice for repeated-measures designs in which traditional parametric approaches like the repeated-measures ANOVA are not appropriate due to the violation of normality assumptions.

Table 3

Friedman Test

Ranks

	Mean Rank
Scratch Program 1	1.51
PowerPoint Presentation 1	1.49

Test Statistics[a]

N	120
Chi-Square	.084
df	1
Asymp. Sig.	.772

a. Friedman Test

When the mean ranks are compared, Scratch program group 1 had a highest mean rank at 1.51 compared to the PowerPoint presentation group at 1.49. The difference in mean between the two groups is 0.02 which is quite insignificant. Therefore, at pre-test, the two groups started at the same level in terms of academic performance. In this regard, the two distinct groups started at the same level at pre-test as their academic performance was the same at the pre-intervention level.

Table 6 shows both scratch program and PowerPoint groups had a p value of 0.772 which was greater than 0.05 ($p>0.05$). As a result, the null hypothesis is retained which states that there is no significant statistical difference in academic performance between the two independent groups. Therefore, at pre-test there was no significant statistical difference in academic performance between the two groups. At pre-intervention, the two groups began at the same level in terms of knowledge acquisition.

At the pre-test stage, the groups were at the same level in terms of knowledge of performing titration experiments. Therefore, there is no relationship between the two variables of academic performance and the teaching methods. For the groups to have performed almost the same at pre-test it means they have almost the same knowledge level at this stage because no method was used to teach them.

Academic Performance at Post Test.

The four hundred and eight learners from four different schools were divided into four groups as a requirement in solomon four experiemental design. The first group was an experiemental group named Scratch program group 1 (SCR 1) which was taught using scratch project method.

The second group was a control group named PowerPoint presentation group 1 (POWERPOINT 1) which was taught acid-base reactions using PowerPoint presentation method. The third group was Scratch program group two (SCR 2) another experimental group was taught using the traditional methods of teacher exposition commonly referred to as lecture method on learning acid-base reaction. The fourth group was another control group named PowerPoint presentation group 2 (POWERPOINT 2) which was not given any intervention.

Fried Test at Post-Test Stage

Friedman test was also conducted at post-test as there were more than two groups which were supposed to be measured in academic performance test scores. This test would help in either retaining or rejecting the null hypothesis. Table 7: shows the Fried test at Post Test stage.

Table 4

Fried Test at the post-test stage.

Ranks	Mean Rank
Scratch Program Group 1	3.93
Powerpoint Presentation Group 1	3.08
Scratch Program Group 2	1.70
Powerpoint Presentation Group 2	1.30

Test Statistics[a]	
N	120
Chi-Square	331.286
df	3
Asymp. Sig.	.000

a. Friedman Test

Table 7 above shows that the Fried Test for all the four groups where three of the groups were taught using scratch program, PowerPoint presentation and lecture method while the last group (POWERPOINT 2) had no intervention respectively.

From table 7 above, it was reviewed that the p-value was 0.000 for the groups which was less than the alpha value ($p<0.05$). This meant that the null hypothesis was rejected. The null hypothesis was that there was no statistical difference in academic performance between the groups taught acid base reactions using different teaching methods. The null hypothesis was rejected because there was a statistical significant difference in academic performance between the variables (teaching methods) influencing the post-test results of the groups. The null hypothesis was rejected which meant that there was a significant difference in academic performance between the four independent groups which existed at the post-test stage. Among the three teaching methods employed, the scratch program method yielded better results at post-test as compared to the PowerPoint presentation and the traditional method.

When the mean ranks are compared, the first group which is the scratch program group 1 indicated that it had a high mean rank of 3.93 as compared to the PowerPoint presentation group 1 which had a mean rank of 3.08 whilst the other experimental group taught using the traditional method had a mean rank of 1.97. Therefore, the group which was taught using scratch performed better academically as compared to the other two group which were taught using PowerPoint Presentation and using traditional method mostly teacher exposition. Both group three (SCR 2) and Four (POWERPOINT 2) had the lowest mean ranks at 1.97 and 1.53 respectively. These last group had no intervention hence the low academic performance which is exhibited. This means that there was no filtration of information between the groups in the school because the group could have performed better at post-test had it gained the concepts through filtration of information from those groups which were being taught. Therefore, the difference in academic performance was really due to the different teaching methods which were given to the different groups. In this regard, scratch program was seen to be an effective approach in teaching acid-base reactions to grade 11 learners as compared to PowerPoint presentation method and the usual business of traditional teaching methods exhibited in most secondary schools.

DISCUSSION

Scratch program on Learners' attitude and academic performance.

Both teaching methods brought about a significant change in attitude towards learning acid-base reactions but scratch program exhibited better attitudinal differences comapred to PowerPoint presentation methods. For instance, Scratch program groups proved that it had improved the learners' attitude towards learning acid-base reactions as compared to the PowerPoint presentation. The first question was answered as the learners had a positive change in attitude when compared at pre-test and at post test. Therefore, the method engaged learners to be working together to solve the problems which were involving in titration during learning acid-base reactions. As learners enjoy working with peers, they involved themselves actively in the learning process. The learners' active involvement and participation in the learning process enables them to apply scientific concepts and test their ideas and theories.

On the contrary, Flan, Garcia, and Serrano, (2023) pointed out that there were statistically significant differences in favour of traditional laboratories in all studied variables. This was because students had showed more positive attitudes towards traditional experiements. This was so because to learn using virtual laboratorues, both the teachers and learners need to be computer literate with basic computer skills and knowledge. Those learners who may be involved in the virtual laboratories and are not having basic coding skills may find it hard to learn scientific processes using virtual laboratories. In support is Armoni (2015) who indicated that sometimes learners would rush to the computer laboratory to learn than they would do in a traditional classroom setting. This shows that when the learners are well knowledgeable in computer and what they can learn from the computer, they would be the first ones to get into the computer laboratory to learn. As the learners get to be familiar with the importance of virtual laboratories such as self reliance and autonomy with individual responsibility in the learning process, they would really be ready to use the digital world to learn. This would in turn improve the academic performance of the learners using the virtual laboratories. In support of this is Spernjak and Surgo (2018) who states that most learners prefer a computer supported laboratory mostly followed by a classic laboratory with a computer simulation. This improves both the academic performance and attitude of the learners. Even

Tuysuz (2010) supports that virtual laboratory applications made positive effects on learners' academic performance and attitudes when compared to traditional methods of conventional laboratories.

Additionally, conventional laboratories and virtual laboratories complement each other in terms of knowledge acquisition. Andrew, Leung, and Nicolas,(2022) reviewed that scratch program projects brings about independent learning which had an overal positive impact on learning when used in conjuction with traditional methods. This means that the schools which have better conventional laboratories would use the virtual laboratories to make the learners continue to learn even outside the classroom. This would make the learning process to be continous such that they learn even in their homes. This would enable the learners to be responsible for their learning. As they become independent learners, they become responsible for their learning process hence acquiring the necessary scientific skills and knowledge. Herraez (2022) supports that learners were able to assess themselves automatically as the virtual laboratory was on going hence they were motivated to continue practising as they had immediate feedback. This increased their interest in learning because of motivation as compared to conventional laboratories.

The learners who were taught acid base reactions had better attitudes compared to the learners who were taught using PowerPoint presentation because scratch program incoporates all the four learning modalities of the various individual learners. Scratch program has auditory characteristics where those learners who grasp concepts using their hearing aspects are included. Even those who learn effectively when they see are met at their point of need. Both those learners who learn through feelings and movement are included when learning acid base raections are done using scratch program. Learning style (2008) reviewed that how information is presented determines the retention level of the information delivered. Thus, scratch program assists in having the learners to grasp the concepts as it promotes high retention of the materials presented.

Besides, scratch program when used in the learning process encourages a shirt from short term memory to long term memory through repetition of the same activities on a particular concept. Long term retention is improved through the spacing between as repetitions increases (Coffield et al, 2004). Spacing can improve retention especially when combined with retrieval leads to better and effective learning. When scratch program is used in class, the learners would continue doing the same activity even at their homes. As a result, through repetition, the concepts are assimilated in the long term memory. This brings the retention to be higher when scratch program is being used. Each time that information is repeated or reinforced, different sets of neurons fire simultaneously, strengthening the synaptic pathway that connects them with one another therefore creating a long term memory (Dumbo, Myron, & Howard 2007).

Scratch program yielded better results both academic performance and attitude of the learners because it used to rely information in piece meals as a learner must actively process and analyse the new knowledge for it to be intergrated into the cognitive structure. Meaningful learning depends on active cognitive processing in learner's working memory. However, if learners encounter too many elements in the presentation of multimedia information

(animation, graphics, sound, text), working memory can be overwhelmed resulting in poor retention (Coffield et al, 2004). Therefore, excessive cognitive load impedes effective learning. As a multimedia, scratch program can be created in such a way that it provides concepts in pieces to avoid a cognitive overload which would impede effective acquisition of concepts.

The learners were able to revisit the concepts as need arise at different times, in rearranged contexts, and from different conceptual perspectives of the acid –base reactions. This resulted in the learners performing better at post test academically.

Most of the upgraded secondary schools lacked or have indequate laboratory apparatus hence the concepts were learnt in an abstract manner. Therefore, the created scratch program on titration enabled learners to manipulate variables then keenly observe the outcomes as if it were in real environments with real objects. The learners acquire skills and knowledge when learning is concrete. For instance, learners fail to comprehend when its abstract learning on titration unless a practical is give hence the created titration project on scratch program being a concrete example helped learners to comprehend the acid-base reaction concepts. This means that when Scratch program are used to depict the real environment the learners comprehend better hence improving their academic performance. As a result, the Scratch program is recommended for bringing real learning situations to a classroom situation particularly when the concepts which are suppose to be learnt can be displayed in a classroom situation. This enables the learners to aquire necessary skills and knowledge toppled with more practical work.

Scratch program brought out better attitudinal and academic scores because of its interactiveness between the activities and the learners. The formulated scratch program activity on titration was more engaging and the learners learnt practically how to titrate. As the scratch program was interactive, they learners collaborated with one another on successfully completing the tasks. For examples, learners were able to slow down or stop the titration process and start all over again. Therefore, these purposiveful stops enabled the learners to appreciate the colour changes which takes place at the end point of titration. As a result, both attitudes and academic performance of the learners improved as the scratch program was used.

CONCLUSION

The findings of this study revealed that active learner participation significantly enhances the acquisition of knowledge, skills, and values essential for meaningful and effective learning. Both the Scratch program and PowerPoint presentation methods facilitated full learner engagement in the instructional process. The integration of Information and Communication Technology (ICT) tools aligns with the principles of connectivism, a learning theory suited to the digital age. Connectivism emphasises that learning occurs not only within the classroom but also beyond it, as learners interact with digital networks and resources independently.

In this context, skill acquisition becomes more prominent when learners are actively engaged in constructing knowledge. The use of ICT tools transforms the teacher’s role from that of a traditional knowledge transmitter to a facilitator who guides learners in navigating and applying information. This learner-centred approach fosters greater commitment and responsibility among students, as they are actively involved in classroom activities. The process encourages deeper understanding and retention of content, while simultaneously building digital literacy and problem-solving skills.

In conclusion, both the Scratch program and PowerPoint presentations have demonstrated their value in enriching communication, fostering creativity, and enhancing learning experiences. Scratch, as an introductory coding platform, provides learners with an interactive and engaging way to develop fundamental programming skills while creating meaningful projects. Meanwhile, PowerPoint remains a widely used tool for visual communication, enabling users to present complex information clearly through the integration of text, visuals, and multimedia. Each tool offers distinct advantages and applications that cater to varied learning needs and communication goals, underscoring the importance of leveraging diverse ICT tools in modern education.

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Nicholas Sibinda: principle investigator, collecting data and writing the article; Nachiyunde and Kaulu: supervising the data collecting and proofreading the article.

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