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EFFECTIVENESS OF SMART TECHNOLOGIES IN CHEMISTRY TEACHING AND LEARNING OF GRADE ELEVENTH STUDENTS IN THE GAMBIA

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Abstract: Chemistry education in The Gambia is challenged by a lack of laboratory and human resources. The consequences have been unsatisfactory learning outcomes in the Gambian secondary school system. Smartboards, Smart notebook software, and touch-screen laptops were considered to influence learning outcomes. Therefore, a comparison was made between this method and the traditional method. The study used the randomized pre-test-post-test group design to select 284 students by convenient sampling and place them in each experimental and control group. While the experimental group was taught using multifunctional approaches, the social constructivism paradigm, and smart learning objects, the control group was taught using traditional methods, laboratory equipment, and worksheet problem-solving. The effectiveness of the teaching methods was determined by the mean scores on pre-tests and post-tests. Pre-test mean ranks on academic achievement computed using the Mann-Whitney U test indicated no significant difference between the experimental and the control group. However, in the post-test, there was a significant difference ($p = 0.003$) between the groups, favouring the experimental group. In addition, a higher mean rank was found in the experimental group than in the control group on concept knowledge and application. The results support the current use of modern technology in science teaching and imply that smart technologies can lead to better learning outcomes in the Gambian context if they were to be used extensively in the secondary school system. However, a further study that will determine the level of effectiveness of each of the methods of teaching by comparing the difference between pre-test and post-test scores for each group may be needed in the future, as this will indicate a better measure of the effectiveness of the methods in enhancing students' academic performances.

Keywords: smart technologies, Chemistry teaching and learning, and secondary school

Introduction

The Gambia is divided into seven education directorates at regional levels, and each of the directorates is headed by a director with supporting staff. Each directorate manages and coordinates programmes as enshrined in the Educational Blueprint and under the supervision of the central coordinating unit headed by the Permanent Secretary. As a nation remains committed to developing its human resources base

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with priority given to free basic education for all, the policy has attached high regard to poverty alleviation with emphasis on the realization of the Sustainable Development Goals (SDGs), Education for All (EFA), and New Partnership for Africa's Development (NEPAD). The guiding principle for education is premised on Accessible, Equitable and Inclusive Quality Education for Sustainable Development (Education Policy [EP], 2016-2030). The main objectives are to improve quality education for all, develop life skills, provide relevant vocational education and technology literacy, and expand secondary education. Under these objectives, schools are expanded to increase enrolment from primary to secondary levels, called *uninterrupted basic education* for every school-going age. The education system in the country is six- three-three-four, which implies that six years (grade 1 to 6) at primary, three years at Middle/Upper basic (grade 7 to 9), and three years (grade 10 to 12) at secondary education, and four years at the University. From grade one to nine is called *Uninterrupted Basic Education* before enrolling in secondary education. Candidates with successful academic performance through Gambia Basic Education Certificate Examination (GABECE) can be enrolled for secondary education. Otherwise, the candidate may either repeat the class for better marks or decide on the best option. Secondary education is the last stage of Basic Education and is coordinated by the Ministry of Basic and Secondary Education (MoBSE). After a successful performance at the West Africa Senior Secondary Certificate Examination (WASSCE), students can be admitted into the University or any higher institution of learning. However, *uninterrupted basic education* is happened to be a challenge for science and mathematics learning outcomes in the country (Government Report [GR], 2015).

Particularly chemistry teaching and learning, which have been affected by classrooms' overpopulation with students and overloaded syllabi (Joof, 2014), teaching and learning resources (Igharo et al., 2011), teacher quality (Ryoko & Tanya, n.d.), pedagogical approaches (Bayram-Jacobs et al., 2019), and inadequate content knowledge by teachers (Teemu et al., 2020) there are weak learning outcomes by students at WASSCE. These challenges are the main agenda in science educational discourse, including insufficient instructional hours (Kayulilo et al., 2016). According to Igharo et al. (2011), insufficient instructional hours and inadequate laboratory resources in The Gambia are not permitting teachers to carry out the appropriate pedagogy or experimentation.

To improve the status quo, in 2012, through World Bank support, MoBSE equipped 12 classrooms in the country with Smartboard, SMART Notebook software, Student assessment tools (Clickers), and touch screen laptops (*Smart technologies*) for teachers. In addition, three-year quarterly technology training, including pedagogical approaches, is provided for pilot teachers in the country by trained personnel from the New Jersey Centre for Teaching and Learning-United States of America (NJCTL-USA). The aim is consistent with the policy focus but not limited to enhancing science and mathematics teaching and learning, including technology literacy (Education Policy, 2016-20130). These modern technologies, according to studies, have been found effective in teaching and learning (Akar, 2020; Aktas & Aydin, 2016; Edith et al., 2011; Goodman et al., 2013; Ryoko & Tanya, n.d.).

However, chemistry teaching and learning remain challenging in the Gambian classrooms even after the introduction of these technologies (Government Report [GR], 2015; Chief Examiner's Report [CER], 2017-2019). According to the internal monitoring report in 2014 (Unpublished), the attributes are found to be teachers' attitudes and skills toward technology application. This is also in line with the findings from the current studies (Elizabeth & Paul, 2012; Spiteri & Chang, 2020;). However, few evaluation studies show positive learning outcomes in science and mathematics but only in students' performances at the national examination compared with the non-smart schools (Research [R], 2014; Ryoko & Tanya, n.d.). Moussa et al. (2020) use designed questions to compare students' performance, which might not describe smart technologies and their effect on teaching and learning. Therefore, quasi-experimental study, which is limited in studies, particularly in The Gambia can be studied. The scope and focus can be limited to acids, bases, and salt concepts teaching and learning using smart technologies on the selected grade eleven students in urban regions. The study approach differs from other studies because it includes multifunctional approaches from soft authentic chemistry context preparation to accessing interactive smart learning objects (Activity-Builder, multimedia platforms, student response systems, and online learning platforms) under the social constructivism paradigm. By comparing with the conventional approaches to teaching and learning, the effectiveness is found under the following aims:

i) To investigate the effectiveness of Smart technologies in chemistry teaching and learning of acids, bases, and salts concepts,

ii) To compare the academic performances of students taught in the smart classroom with students taught in the conventional classroom on their Mean values, and

iii) To compare the Median Values of students taught in smart classrooms with students taught in the conventional classroom on their Post-test.

iv) To compare the Mean Ranks of students on Concept-Knowledge Application of the two groups.

Furthermore, answers to the following Null Hypothesis are sought:

i) The scores of Pre-test Mean Ranks for the Experimental and Control Groups are the same across groups.

ii) The scores of Post-test Mean Ranks for the Experimental and Control groups are the same across groups.

iii) The scores of Mean Ranks on Concepts Knowledge Application are the same for both groups.

iv) The Median Value for the Experimental group in Post-test is equal to the Hypothetical values.

v) The Median Value for the Control group in Post-test is equal to the Hypothetical values.

vi) The Median Values in Post-test for the Experimental and Control group are the same across groups.

Literature Review

The use of smart technologies is fast growing in science teaching and learning, and most practitioners are looking to their uses in classrooms to enhance learners' affective and cognitive domains. There has been increased progress in science education in countries that have used technology and followed the technology rules. In contrast, countries that have not used technology and have not followed the technology rules have had setbacks in many aspects of development (Blonder & Mamlok-Naama, 2019). Therefore, sound education systems nurture creative and productive individuals who are Masters of Technology Application and capable of expressing their potential in the scientific arena. As a result, of the current state of affairs, education systems are effective with technology integration, which encouraged many countries in the world to introduce smart technologies into their education systems. The United States of America (USA), the United Kingdom (UK), Turkey, and Kenya, among other countries, introduced smart technologies in teaching and learning. They are hybrid learning systems, which can be online, offline, or blended learning modes to provide learners with an elated learning process and the same time, achieve learning outcomes (Rosmansyah et al., 2022). These technologies are self-directed, motivated, adaptive, and resource-enriched for learning purposes. Through this modernization, learning devices, communication media, and protocols in science education have all undergone impressive advancements. If the supply of electricity and internet connectivity are constant, then the development of science education is thought to be the most significant.

Nowadays, within smart learning environments, people can access knowledge, search for a piece of information, and use data with less time and effort. According to Zhu et al. (2016), there are three essential elements in technology integration: learner, teaching, and technology presence. All these presences can be supported and enhanced in a single instructional software called Smartboard (Akars, 2020; Aktas & Aydin, 2016; Aldosari et al., 2022; Higgin, 2010; Phoong et al., 2019), SMART Notebook (Goodman et al., 2013; Nitza & Roman, 2017; SMART Tech, 2014) or their integration with students' assessment device-Clickers (Krajcik & Mun, 2014). Learning is transformed, and physical experimentation needs to be modernized (Phoong et al., 2019), replacing it with virtual demonstration and visualization (Aldosari et al., 2022). Particularly Smartboard has moved teachers from a teacher-centred to a student-centred approach (Nicoll, 2001), and it is effective in a situation where glassware and reagents are inadequate (Aldosari et al., 2022). The pedagogical approach in smart classrooms makes the modern classroom different from conventional classrooms because learning is flexible and interactive (Nitza & Roman, 2017). Learning objects such as Smart Learning Suits, Activity Builder, students' response systems/clickers, multimedia platforms, Smart Exchange, and direct online search makes Smartboard or SMART Notebook application unique compared with other types of technology. For example, physical structure and visualization of combination reactions of chemical compounds can be studied without physical interaction with the materials but through learning objects (Aldosari et al., 2022).

In most teaching and learning processes, Smartboards improve performance by accessing online resources or embedded learning tools such as YouTube links (Aldalalah, 2021; Tsayang et al., 2020). Aktas and Aydin (2016) and Inaltekin (2020) found more learning retention in students instructed through Smartboards than in conventional classrooms. The interactive features in Smartboard or SMART Notebook software encourage and motivate students to participate and solve problems. For example, a Smartboard could be touched with a pen or finger to draw a molecular structure while motivating students' participation. Such molecular structures can be sketched, dragged, cut, or copied from relevant sources and past, another critical aspect of Smart technology integration. It also found that student-centred learning is encouraged and promotes students’ academic performance (Nicoll, 2001). Many current studies found significant academic performances of students taught through Smartboards or SMART Notebook software than those taught through chalkboards and textbooks problem-solving (Akar, 2020; Edith et al., 2011; Kirbas, 2018).

Students' response systems or assessment tools (Clickers) can be installed with Smartboard or SMART Notebook software to coordinate incredible formative assessments and, at the same time, monitor students' learning (Krajcik & Mun, 2014). Around the world, there is no unique name given to these incredible assessment tools. They can be called Smart Santos (Graham, 2013), Smart Response System (Egelandsdal & Krumsvik, 2017), Personal Response System (Bojinova & Oigara, 2013), Audience Response System (Laxman, 2011), Students Response System (Goodman et al., 2013), or Clickers (Krajcik & Mun, 2014). During formative assessment with a clicker, called in The Gambia, waiting time for students is encouraged to discuss and share, as a critical component in the pedagogical approaches. This approach is not necessary to obtain immediate answers per se but testing students' understanding and learning process, which many thought is a waste of instructional hours (Kirbas, 2018). Because teachers and students may spend more time correcting malfunctions or calibration while teaching and learning, in each clicker, the teacher provides each student with a unique code (Identification number) that they will be used to answer formative questions after group discussion. In such a situation, adequate waiting time is imperative for students to discuss and share their thoughts before sending their answers on either the Smartboard or SMART Notebook software through a touch screen laptop, which indicates the percentage of students who answer A, B, C, or D. So if there are misconceptions, it would be reflected in percentages. The task of a teacher during this process is to restate the questions or move forward.

The teaching approach mediated with Smart technologies integration is intertwined with the social constructivism paradigm from teacher-centred to student-centred methods (Goodman et al., 2013). The learning objects in these technologies provide a suitable learning environment for concept discussion and problem-solving (Mihindo et al., 2017). Additionally, it is easier to access and modify virtual practical testing of chemical events. The physical exploration of various activities can be compromised in traditional classrooms, which may be caused by insufficient teaching and learning resources. With the integration of Physic Education Technology software (PhET) into Smart Notebook software, such concepts can be fully described, for instance, displaying the computation of a mole or concentration ratio, which can occasionally be difficult (Chief Examiner's Report [CER], 2017-2019).

Moreover, the variable can be adjusted toward obtaining results or products. However, the effective operations of PhET require skills and knowledge, which may be challenging to some people if there is no or inadequate prior training. As a result of these conveniences in smart technologies, a comprehensive study design and methods is explained how smart technologies are studied to determine the effect on chemistry teaching and learning.

Materials and Method

The approach study used to analyze the effectiveness of smart technologies in chemistry teaching and learning was highlighted here. It shows how participants were selected, data collection procedures, and measurements of the variables, including detailed information about data analysis.

These teaching and learning concepts have been challenging for students and affect their performance in the regional examination (Chief Examiner's Report [CER], 2017-2019).

Research Design

The study employed a quasi-experimental design to gain insights into the effectiveness of smart technologies in chemistry teaching and learning. The complementing approach was experimental with the control group and a randomized pre-test-post-test group approach. Social constructivism learning was the complementing approach that guided instructional interventions for about 24 days (Akyol & Fer, 2010).

Assumptions and Limitations

The internal validity of research findings was controlled using an experimental group to measure the dependent variables and the effect size (Cohen, 1988). The effectiveness of smart technology integration in the school curriculum was limited to the concepts of acids, bases, and salts. We assumed that students' characteristics and backgrounds were recognized during student selection. Additionally, we assumed that experimental and control groups were instructed primarily as per the instructions provided.

Participants

Study participants constituted 284 grade eleven chemistry students from 12 secondary schools located in two out of the six administrative regions of The Gambia. In addition, schools in regions 1 and 2 were selected because of the chemistry student population and smart technology resources, which are consistent in studies about sampling characteristics (Muralidharan, 2015).

Convenient sampling was used to constitute the sample of study participants, who were matched for equivalence using their academic records. Students were selected from the Government/Public and private secondary schools and were placed into them the experimental and the control group. For the intervention, 14 chemistry teachers were randomly selected and split into experimental and control groups to support researchers in study activities.

These sample sizes gave the analysis power to detect differences between the groups (Fagerland, 2012). However, one absentee from the Experimental Group was reported sick during the post-test, which accounted for different samples from 284 at pre-test to 283 at post-test. Both research participants (teachers and students) signed a consent form and accepted participating voluntarily.

Instruments

Using the eleventh-grade syllabi and Akio-Ola series core chemistry textbook, the researchers developed 20 free-response assessment items (AI). These assessment items were aligned with the areas reported as challenging for students (qualitative and quantitative description of acids, bases, and salt concepts) in the Chief Examiner's Report [CER], 2017–2019). On this basis, smart technologies were used to investigate the effectiveness of teaching and learning these concepts.

While preparing AI initially, the following assessment protocol by the West African Examination Council (WAEC) but not limited to were considered and reinforced as described in Table 1. In addition, the general training modules for authentic chemistry context for experimental and control groups were also developed, including training guidelines for smart technology integration.

Table 1: Setting of Achievement Items.

Description	Number of items
Recalling chemical facts	5
Concept Knowledge & Application	15
Total	20

On instrument validation, knowledgeable people from Gambia College-School of Education and the University of The Gambia-School of Education were enlisted to review. First, they reviewed and provided content validity for the training module and assessment items to serve the purpose. Next, AI reviewed and validated using Interrater reliability to ensure that the questions were factual and the conceptual questions were applicable and critical. Questions that did not meet these criteria were revised by the researchers and returned to the raters for re-scoring. Items that failed to meet the criteria after three rounds were excluded from the study, thus reduced to 17 items. Then pilot testing on 40 students was further reduced to 15 for the pre-test. That is, 'Recalling facts' remained five (5) items, and chemical 'Knowledge and Application' was reduced to 10 items. Again, reliability was found, which shows to what extent the instrument can consistently produce the same results if it is used in the same situation on repeated occasions at 0.84 Cronbach’s Alpha (Hinton et al., 2004).

Data Collection and Procedures

The data were collected after obtaining a permission letter from the Ministry of Education. Teachers and students were invited to an introductory meeting on the study's aims, roles, and importance to chemistry teaching and learning, which has led us to proceed with the study activities: a) enlisting the assistance of knowledgeable individuals; b) reviewing and developing training materials for teachers and students; c) reviewing AI for students, d) validating instruments, e) piloting instruments, f) pre-test for students, g) training teachers on smart technology integration and content for the experimental group, h) training teachers on the content and physical laboratory experimentation for the control group, i) follow-up teaching students at schools by trained teachers, and j) post-tests for students. Pre-tests were administered immediately to the students before the commencement of the intervention, which also helped researchers to align teaching modules accordingly. However, the arrangement of AI was changed from pre-tests to post-tests to avoid the risk of memorization. In addition, each student was given a unique code instead of names during pre-tests to promote confidentiality.

Two weeks of training of teachers began for both experimental and control groups. However, the experimental group was trained using smart technologies, as in Figure 1. They were trained to prepare soft authentic chemistry context by uploading and designing in a SMART Notebook software through a touch-screen laptop. How to use functional tools in Smartboard and SMART Notebook were also part of the training module, including the application of students' response systems/Clickers to facilitate formative assessment. During this phase, teachers were provided with continuous power and internet connectivity to access multimedia platforms and other learning objects in smart (Smart Learning Suits). Teachers used these opportunities to interact, collaborate, discuss, and share during concept discourse to enhance their understanding, including technology application and content teaching. At the end of the two weeks of training, the concept-based assessment was administered to teachers, which was positive.

On the other hand, the control groups (teachers) were trained using conventional methods, which included training teachers on physical experimentation (qualitative and quantitative measurement and calculation of acids, base, and salt reactions) and textbooks or worksheet problem-solving. A pedagogy to teach chemistry concepts and safety rules in the laboratory was highlighted in training too. Through this approach, they collaborate and support one another to improve.

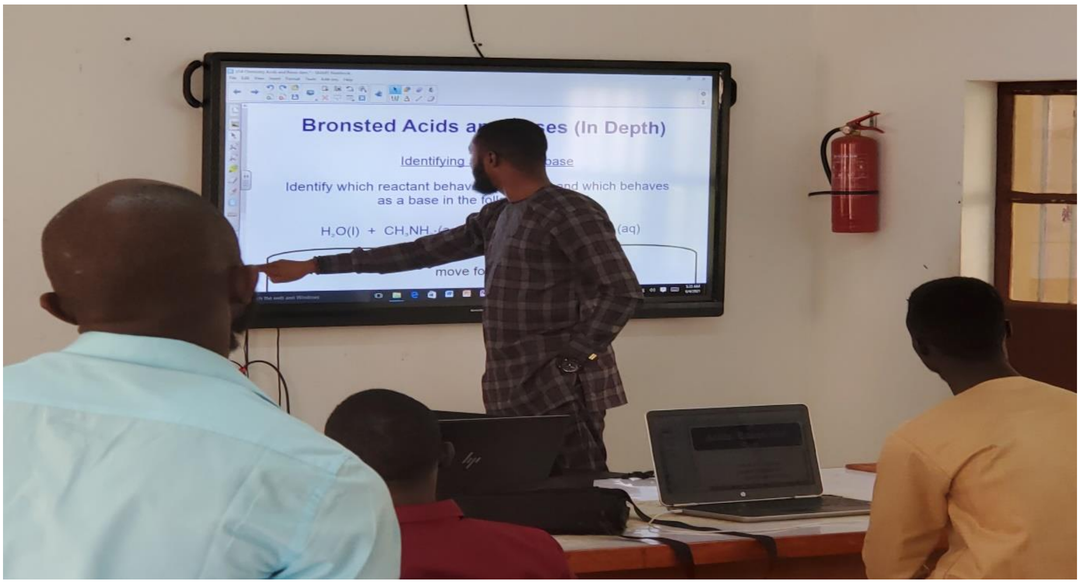

Figure 1, Teachers' training smart technology application in the smart classroom.

After two weeks of training of teachers, follow-up teaching started for students at the designated centres. The teaching of students lasted for about 24 days. The experimental groups were taught using smart technologies with the same approaches as teachers in the experimental groups (Figure 2). Students explore, clarify, and demonstrate through virtual experimentation through learning objects in smarts (Multimedia platforms, Smart Exchange, Online resources/search, assessment platform or clickers). This approach promoted them from consumers to creators because of freely working relationships and instructional guidelines.

Figure 2: Students' on group work problem-solving in Smart Classrooms.

However, the control group were trained using conventional teaching methods as teachers in the control group. That is, working and solving qualitative and quantitative measurements of acids, bases, and salt reactions through physical laboratory experimentation, as shown in Figure 3. The pedagogical approach was changed from teacher-centred to student-centred. These groups provided glassware, reagents, electricity supply, internet connectivity, and chalks to control the internal thread. They collaborate, share, and discuss during concepts discourse.

Figure 3: Students in Traditional Classrooms.

The general training modules for all groups include:-

i) Introductory concepts of acids, bases, and salts, which serves as an opportunity to review their prior knowledge and develop hypotheses,

ii) Qualitative classification of substances using a pH indicator extracted from red cabbage and other conventional indicators such as phenolphthalein, methyl orange, and bromothymol,

iii) Quantitative measurement for acids and bases,

iv) Measurement and calculation of numerical values of the pH, which took them to construct a pH scale with both numerical and colour representations for each sample,

v) Salts' identification through exploring and distinguishing acids, bases, and salts while conducting solubility properties,

vi) Titration of antiacids with distilled water, bromothymol blue indicator, 1M HCl,

vi) Strong acid-strong base titration and calculation, and

vii) acids-weak base titration and calculations.

The training guidelines for the experimental groups:-

i) Soft lesson preparation in smarts,

ii) Installation and calibration of Smartboards and Smart notebook software with touch screen laptop,

iii) Accessing interactive learning objects in smarts.

iv) Social constructivism approaches,

v) Occasional practices of improvisation, and

vi) Social constructivism approach.

Training guidelines for the control groups:-

i) Safety rules,
ii) Handling of physical materials,
iii) Physical laboratory experimentations for testing, observation, reporting,
iii) Solving or working problems on activities worksheets,
iv) Verification of concepts using an internet search or improvisation, and
v) Social constructivism approach.

The explanatory distinction between the experimental and the control group was the smart technologies, which the study used to determine the effectiveness. Both were given equal instructional hours, and the researchers supervised sessions until all activities were completed. However, schools, mainly in the control group, were delayed in completing the activities on time due to the announcement of a suspected COVID-19 in the neighbourhood by the Health Ministry; an additional four days were allocated to complete. In total, 28 days of the intervention and after which post-tests follow to compare with pre-tests. It was found that the number of students who wrote for both tests was dropped by one at the post-test due to the sickness of a student in the experimental group. It was noted that the suspected case of COVID-19 might interfere with students' performance at post-test.

Data Analysis

Data were collected through pre-tests and post-tests scores. Points were awarded based on the correct application of any concept. A point was recorded for each correct concept and a wrong concept with no point. The total points each student expected to score was 73 points. These points were computed for quantitative analysis using Statistical Packages for Social Science (SPSS) v. 21 software. However, to determine ‘Median Values’, half (36.50) of the total points (73) were used as the hypothetical values.

The non-parametric statistical technique (Mann-Whitney U Test) was used based on the following assumptions (Obumneke, 2012):

1) The dependent variable of students’ scores was on an ordinal scale,

2) The independent variable was two independent categorical groups,

3) The observations were independent, and

4) The observations were statistically significant but approximately not normally distributed, which was suitable for comparing the dependent variable's differences for two independent groups (Mishra et al., 2019), and the distribution of the dependent variable is the same for the two groups and, therefore, from the different populations (Fagerland, 2012). However, the pre-test and post-test scores of Wilcoxon Signed Rank were used to compare one group.

Effect Size

The effect size was determined using Cohen's (1988) equation formula, which gave magnitude mean values of scores from pre-tests and post-tests. The effect size was calculated by dividing the absolute (Positive) standard test statistics (Z) by the square root of the number of pairs) (z/√N).

Results

The results of this study were discussed as research aims and null hypotheses.

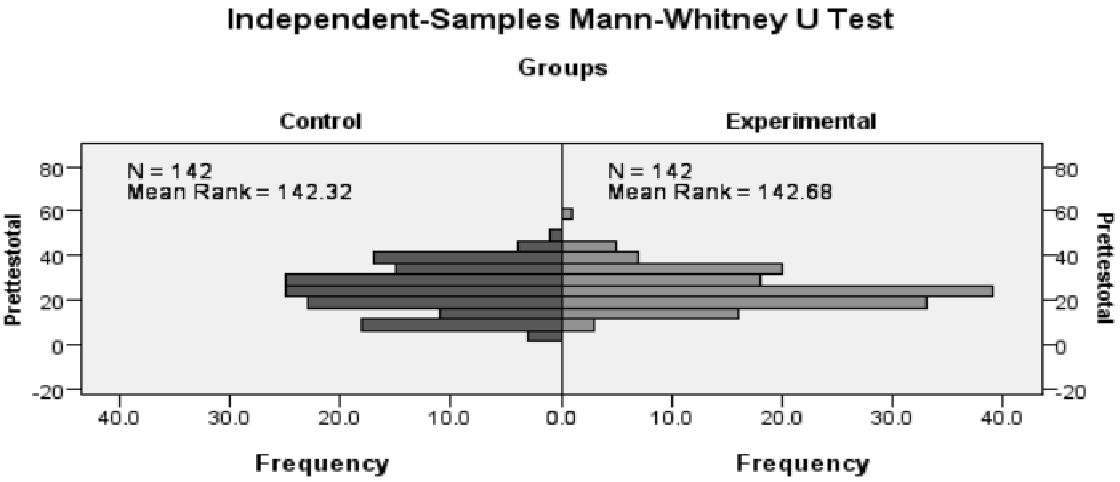

Figure 4: Mann-Whitney U Test Mean Rank for Experimental and Control group on academic achievement-Pre-test.

The Mann-Whitney U test showed no significant difference (U=10056, Z= -.037, P=.971) between the experimental and control groups on pre-test scores (Figure 4). That is, the difference between the two groups was .36 favouring the experimental groups, indicating that the null hypothesis “The scores of Pre-test Mean Ranks of the experimental group and control group is the same across group categories" can be rejected.

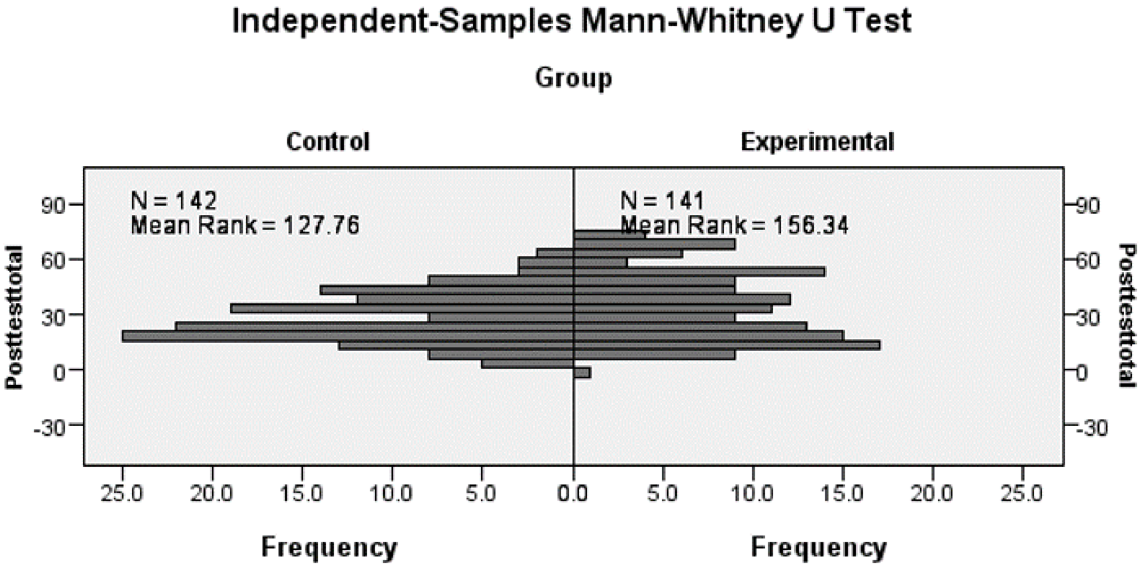

Figure 5: Mann-Whitney U Test Mean Rank for Experimental and Control Group on Academic Achievement-Post-Test.

Independent-Sample Mann- Whitney U test was also tested after the intervention on the two groups at post-test. It shows that (U= 7989, Z= 2.938, P= 0.003) there was a significant difference between the two groups (Figure 5). Furthermore, the calculated effect size ($\frac{z}{\sqrt{N}} = \frac{2.938}{\sqrt{283}}$= 0.175) shows a significant difference between the two independent groups, even though it was small (Cohen, 1988). Therefore, the null hypothesis "The scores of Post-test Mean Ranks of the experimental and control groups are the same across group categories" can be rejected.

Concept Knowledge Application

Mann-Whitney U-test on the post-test mean rank of concept knowledge application was 127.80 for the control groups, while the experimental group's Mean rank was 156.30 (Figure 6). Therefore, the null hypothesis "That there is no statistically significant difference between pre-test and post-test mean scores on students’ academic performance on concept knowledge application can be rejected as determined by their means ranking”.

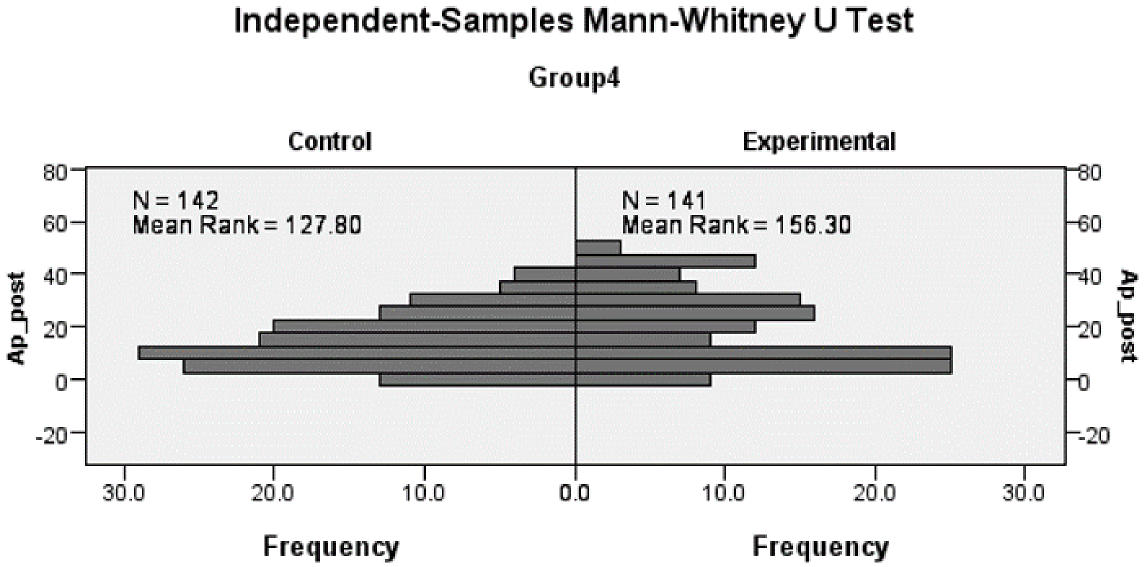

Figure 6: Mann-Whitney U Test Mean Rank for Experimental and Control group on Knowledge and Application-Post-Test.

The hypothetical Median Value on post-tests was 36.50 using Wilcoxon Signed Rank Test. However, the results for the experimental group show that the observed Median was 34.00 at a 0.376 significant level, greater than .05 according to Wilcoxon Signed Rank Test. The observed Median value was less than the hypothetical Median value of 2.5 (Figure 7). Therefore, the null hypothesis "The Median values of experimental group equal to 36.50" after the intervention may not be rejected.

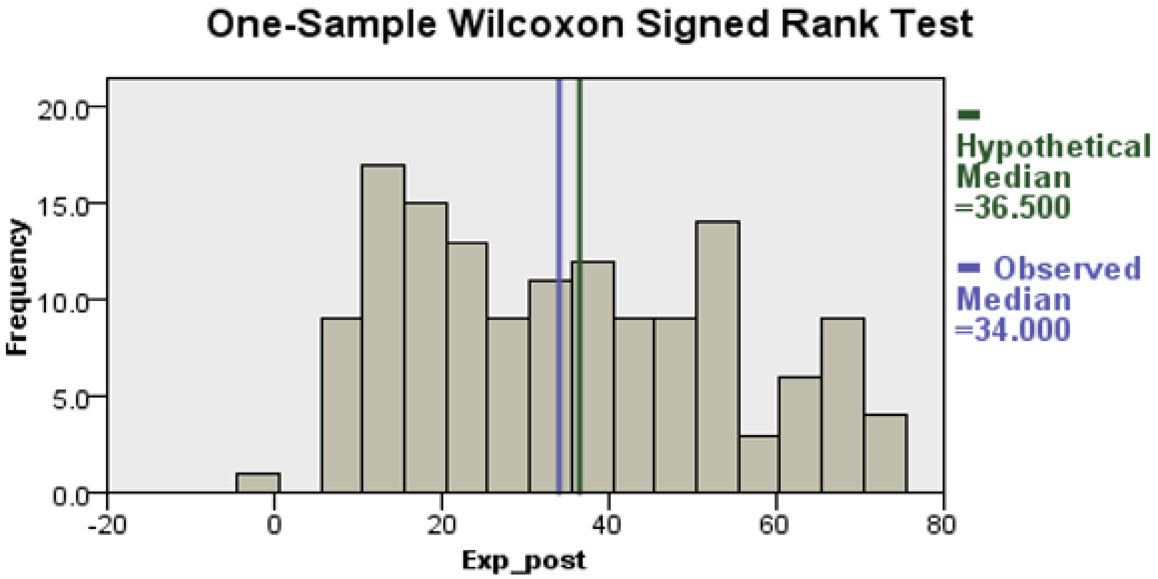

Figure 7: Wilcoxon Signed Rank Test for Experimental Students Attaining Median Value-Post-Test.

On the other hand, based on the hypothetical Median value (36.50), the Observed Median for the control group at the post-test was 25.00 less than the hypothetical Median by 11.50 at a 0.000 significant level

(Figure 8). Therefore, the null hypothesis "The Median values of the Control group equals 36.50" may be rejected.

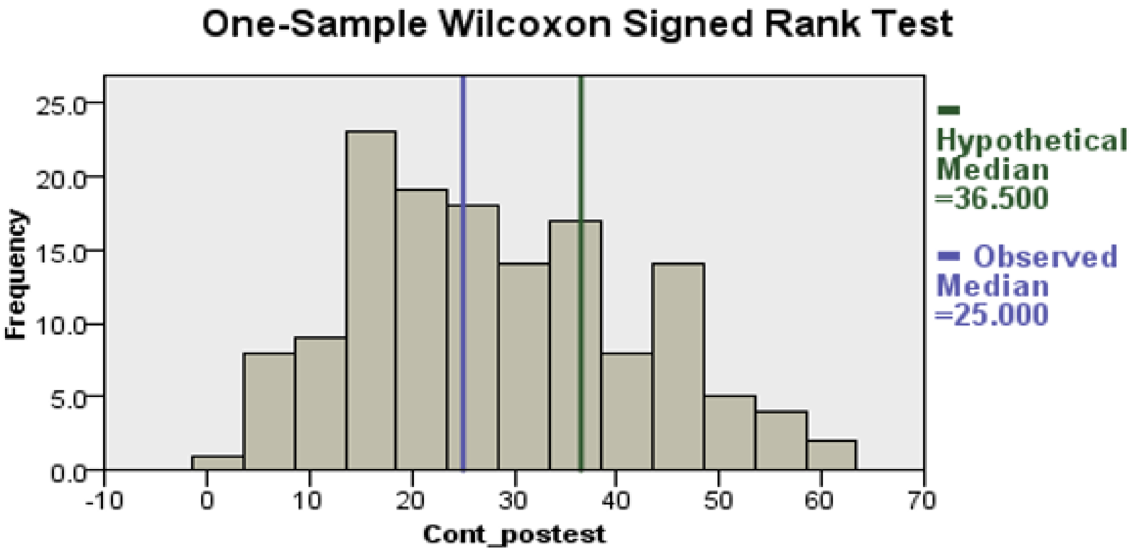

Figure 8: Wilcoxon Signed Rank Test for Control group Attaining Median Value-Post-Test.

Furthermore, the total performances of the two groups (Exp. & Cont.) for post-tests were found using an independent-samples-of Grand Midpoint (30.00). The test Statistics (3.845), Chi-square (3.392), and the Asymptotic Sig (0.065) show the difference was insignificant (Figure 9). Therefore, the null hypothesis “The Median values for post-test scores for the experimental and control groups are the same across categories of groups” may not be rejected.

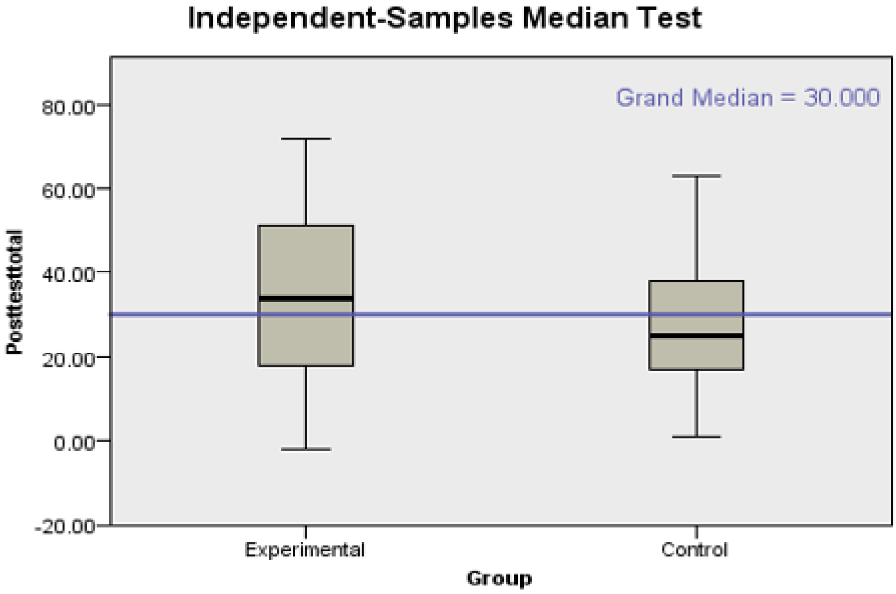

Figure 9: Independent-Samples Median Test of Experimental and Control Group-Post-test.

Discussion

Due to the glassware and reagents in schools, smart technologies can be used to support concepts in teaching and learning (Aktas & Aydin, 2016). The significance of these technologies was highlighted as other essential instructional tools in educational research as a comparison was made between pre-test and post-tests scores of the two independent groups. Before the intervention and at the pre-test, the two groups were not significantly different. However, Mean Ranks at post-tests show significant changes favouring experimental groups, with a margin of 28.58. Furthermore, the performance of the experimental groups was also reflected positively in the effect size after the intervention, even though it was a small size (Cohen, 1988). The small effect size may be attributed to smart technology integration. However, other factors include COVID-19 fear during the post-test, students' backgrounds, attitudes, teachers' instruction, or content understanding.

Notwithstanding, both groups were trained on the same content and given the same instructional hours, assessment items, and equal supervision. The only difference between the two groups was the smart technologies. In-class questions were answered using clickers, which engaged the experimental group more than the control group (Egelandsdal & Krumsvik, 2017). The current studies also supported this notion, stating that using clickers motivates students to participate and promotes a permanent understanding of the concepts (Shapiro et al., 2017).

Due to the convenience of smart technologies in education, many studies found positive learning outcomes (Aktas & Aydin, 2016; Akars, 2020), and many of those were conducted using experimental and control groups. Aktas and Aydin (2016) also found that students in the experimental group retain knowledge longer than those taught through traditional methods. In this study, therefore, students in the smart classrooms apply a better understanding of chemistry knowledge than in the traditional classrooms. Similarly, Research (2014) and Ryoko and Tanya (n.d.) found positive learning growth in the experimental group than in the control group using examination results. In the literature review, Akar (2020) found that many studies provide positive conclusions about smart technologies' contribution to teaching and learning. However, Kirbas (2018) found the technology insufficient as many schools have challenges with adequate instructional hours. The study found significant academic achievement of students in the experimental group than in the control group (Kirbas, 2018).

Other studies provided evidence to the contrary, noting that teacher performance had improved despite little change in student learning outcomes (Higgins, 2010; Goodman et al., 2013). According to Goodman et al. (2013), teachers might publish, update, and distribute content for their other teachers to view or study using a centralized server system. This was a multifunctional approach, which only not engaged teachers or students in active participation but also knowledge acquisition through animations or simulations (Aldosari et al., 2022). Concept clarification may be easier in the smart classroom than in the traditional classrooms due to alternative learning objects. Traditional classrooms only used physical materials with no other sources to explore clarification. However, the internet provided for the control group was underutilized, as many thought it was a waste of time (Kirbas, 2018), as it involves searching, especially under weak internet connectivity.

In this study, however, the control group's performance was reduced from pre-tests to post-tests, which may be due to teachers' experimental and content knowledge (Teemu et al., 2020) or attitudes and skills

(Spiteri & Chang, 2020). Musengimana et al. (2020) added that students' conceptual understanding could affect the expected results. For example, the calculation and reporting of the addition of 2 cm3 of bench sulphuric acid (H2SO4(ag)) to 2 cm3 of barium chloride (BaCl2(ag)). Most students reported having observed (BaSO4) barium tetraoxosulphate (VI) instead of a white precipitate in the test tube. During our investigation of "why" and "how," coincidentally, we found the same answer in the teacher’s marking scheme, which shows that teachers also have challenges (Bayram-Jacobs et al., 2019). There was no way to observe the formula or name of a white precipitate or substances in the test tube because these are not observable features.

The median values obtained using the Wilcoxon Signed Rank Test also provide an exploratory conclusion that the experimental group performed better in obtaining a hypothetical median than the control group. The difference in the median value of 11.50 indicates positive learning growth (Koyunluunlu & Dokme, 2020). Based on this premise, the symbolic contribution of Smart technologies did not stop at the course content development but teaching and learning. However, it does not necessarily imply that the strategy was high quality or could improve teaching and learning processes (Talan, 2021). It depends on how technology was used in the classroom because the learning outcome could be compromised if it was under teacher control (Higgins, 2010). Therefore, technology integration should be flexible for learners, including instructors, to discover new things and test to improve their initial thoughts about chemical phenomena. This suggestion can give a positive relationship and interaction between technology use and learning outcomes. Therefore, it is imperative for chemistry teachers worldwide, including in The Gambia, to recognize technology in teaching and learning, but not for choice in classrooms or administrative functions.

Conclusion

The descriptive study investigated the effectiveness of smart technology integration by comparing it with the conventional teaching and learning approaches in chemistry education. The aim was to investigate the appropriateness of smart technologies to support the teaching and learning of qualitative and quantitative measurement and calculation of acids, bases, and salt reactions. Before the intervention, these groups (the Experimental and the control group) were not significantly different *(P=.971)*. However, at post-test, the Mean Ranks of the two groups were significantly different (*P=.003*). Furthermore, a higher mean score was found in the experimental group on knowledge application than in the control group, indicating a positive contribution to smart technologies. However, other factors may also contribute, which were not determined by this study, such as the influence of Covid-19 suspect cases in the neighbourhood on the final assessment, and students’ attitude towards chemistry, among others.

In comparing the test scores, the experimental group improved from the pre-test to the post-test. Nevertheless, there was no improvement for the control group as they moved from the pre-test to the post-test. In addition, for the attainment of the hypothetical value (36.500), the experimental group performed better than the control group.

Limitation

The results support the current use of modern technology in science teaching and imply that smart technologies could lead to better learning outcomes in the Gambian context if teachers used the technologies extensively in the secondary school system, particularly in schools with a shortage of chemicals and glassware. Through discussion with teachers, it was clear that all teachers should have the skills to use smart technologies to support students as this can be effectively investigated. However, the scope and focus of the study were to describe the effectiveness of smart technologies among the selected students in the Urban region of the Gambia but not to provide a conclusion about the smart technologies' integration. Further research is encouraged to expand the knowledge for generalization as this study is only limited to urban regions of the country. Further studies were also encouraged to combine quantitative and qualitative methods. The results can be used to triangulate and provide empirical evidence of the integration of smart technologies in chemistry teaching and learning.

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Declaration of Interest Statement

The authors declare that they have no conflict of interest.

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