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The interactive classroom: Integration of SMART notebook software in chemistry education

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Abstract

The integration of SMART notebook software was one of the modifications to the teaching and learning environment since the post-coronavirus. Despite the extent of literature about the importance of this software to teaching and learning, there have been conflicting views and an overall lack of intervention in the Gambia regarding its importance in chemistry teaching and learning. Nevertheless, studies conducted about the impact of this software in the Gambia traditionally focused on evaluating regional examination results, where conceptual understanding of qualitative determination and quantitative study of acid-base reactions in the secondary school curriculum are continuous challenging for students. Further, these bodies of evaluation could not present support for the software on chemistry teaching, moreover, on the three domains namely recall, knowledge and application. On this basis, the purpose of the study was to investigate how interactive classrooms could support students' learning the topics. Through quasi-experimental design and systematic random sampling technique, 314 students were selected and split into two independent groups, the treatment, and the control. The treatment group were taught using interactive learning objects in SMART notebook in conjunction with laboratory experimentation, while the control group mainly conventional teaching methods, including laboratory experimentations. After 24 days of parallel interventions, a non-parametric (Mann-Whitney U test mean rank) statistical test was conducted at a .05 level of significance. The results revealed that students in the treatment group had better knowledge retention and application than their peers in the control group as indicated by a significant difference (p=.001). These results align with the experimental literature and were particularly effective for developing alternate strategies for educating secondary students in chemistry class.

Keywords: acid-base reactions, interactive classrooms, interactive learning objects, integration, SMART notebook software

INTRODUCTION

Innovation into technology-based instruction is in a state of continuous change, which has a direct impact on the education and training (students and teachers). As innovation constantly evolving, education programs and teaching methods also evolve to adapt to education changing demands. This rapid advancement of technology and its increasingly use in the field of education have led to profound changes to the future skills and competences required from students. Concerning 21st century generation, chemical reasoning skills are among the key competences to be developed since they are linked to higher order analytical and logical thinking skills that are essential for solving genuine and multidimensional problems. The ability of students to effectively reason about complicated real-life circumstances, make quick decisions, engage in logical and systematic argumentation, and draw conclusions may all be strongly impacted by the development of their chemical reasoning skills. Therefore, improving students' chemical reasoning cannot done with a single method but integration of multifaceted methods (Lemma, 2013), particularly areas of qualitative

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Contribution to the literature

- This study investigates how students' conceptual understanding has changed as a result of integrating SMART notebook software after teaching qualitative determination and quantitative calculation of acid-base reactions on selected secondary schools students at 11th grade. This was supported through interactive classrooms and accessing of interactive learning objects in the software. As a result of its significant contribution in teaching and learning, its adoption has been recognized in different fields of education but not in chemistry teaching and learning in the Gambia.
- However, in the Gambia, studies conducted about the software have been focusing only on students' performances in mathematics and science at reginal examination, where chemistry teaching and learning continue to be challenging. Thus, to understand how SMART notebook software could support chemistry teaching and learning, an interactive classroom was designed with the software, including laboratory experimentations, and the social constructivism learning theory to teach students on acid-base concepts.
- After 24 days of parallel interventions on the two different groups, the study reveals the significance of interactive classrooms as a necessary strategy to support acid-base teaching and learning.

determination and quantitative study of acid-base reactions. One of the multifaceted methods initiated is to introduce interactive classrooms to teach students. These include SMART notebook software integration with laboratory experimentations and social constructivism learning theory. The main purpose of this intervention is to investigate uncertainty in order to make informed decisions about how these topics (qualitative determination and quantitative study of acid-base reactions) become public concern in the Gambia (West Africa Examination Council [WAEC], 2019).

Acid-base reactions are crucial concepts of basic stoichiometry and in the secondary school level. It also provides the theoretical foundation for the development of atomic reactions. Therefore, teaching acid-base reactions at the intermediate grade eleventh have becoming increasingly important, especially during the last years (WAEC, 2019). According to Tal et al. (2021) and Yitbareh (2011), learning chemical reactions or reaction mechanisms in particular students should be allowed to understand everyday life situations characterized by uncertainty. Despite being an integral part of our life and in the secondary curriculum, acid, and base is considered among the concepts that are mostly difficult for students to learn and for educators to teach (Lemma, 2013; Yitbareh, 2011). One of underlying challenges is the misconceptions and unsatisfactory learning outcomes (Marchak et al., 2021; WAEC, 2019). These challenges may be prompted by teaching strategies (Keller, 2018), inappropriate instructional materials and experimentations (Igaro et al., 2011) and teachers' teaching experiences and content knowledge (Jammeh et al., 2022). Other challenges have attributed to controversies from the nature of the discipline for example, between intuitions of the acid-base concepts and reasoning of proton transfer or donation (Drechsler, 2007; Tunesi, 2020).

To build sound intuitions about such concepts or reasoning, students need support (Dillon & Avraamidou, 2021). Instead of being constrained to conventional classroom settings, where chemistry problems are constantly solved through a specific method or procedure, students need to be provided with modern learning environments supported by soft worksheets with appropriate activities, relevant teaching and learning materials. Under this framework, SMART notebook software and its accessories are used to investigate their contributions in chemistry teaching and learning on the selected grade eleventh students in the Gambia.

Since the introduction of this software with the integration of SMART board in 2012, from the support of the World Bank and New Jersey Center for Teaching and Learning, there are no impact studies, particularly on chemistry teaching and learning. However, studies conducted about the software have centered only on evaluation of students' performances in the national and regional examinations (Hanover Independent Research [HIR], 2014; Moussa et al., 2020; Tomita & Savrimootoo, n. d.), but no studies have been conducted to compare the outcomes of the impacts of smart technology-based and the conventional teaching approaches more specifically in the Gambia.

Moreover, on recall, knowledge, and application of qualitative determination and quantitative study of acid-base reactions, which happens to be the most challenging topics for students (WAEC, 2019). An intervention studies conducted about the software focused on its adoption in different subjects or fields of education and discussed little on chemistry teaching and learning (Nichols, 2015; Sadykov & Čtrnáctová, 2019). Therefore, present study initiated an intervention through interactive classrooms with multifunctional strategies to investigate whether SMART notebook software could support chemistry teaching and learning. Through this intervention, the integration of the software as a possible contribution compared to the conventional teaching methods and students' conceptual understanding and academic achievement on the topics highlighted (Li et al., 2019).

Integration of SMART Notebook Software

The integration of SMART notebook software for teaching and learning has a unique function that can change the mode of lesson presentation and content learning (Nichols, 2015; Nurmukhamedova et al., 2021). This inclusive learning software is used to help teachers to create dynamic, interactive lesson delivery on a SMART board through a laptop (Goodman et al., 2013). SMART board can be mounted on the wall with an overhead projector to show the reflection of the content from SMART notebook. Traditionally, the teacher and students communicate directly through chalkboard-notes sharing, mostly verbal and written. SMART notebook software makes teaching more indirect as the teaching and learning usually occur through the system. SMART notebook software can be used to mapped curriculum with 2D and 3D digital content, which can be accessed right in the classroom and projects on an interactive whiteboard or SMART board to explain critical concepts. It has a digital graphic organizer, note-taking slides, click-and-drag activity features, a video streaming icon, and assessment platforms called response system (clickers) to facilitate formative assessments (SMART Tech, 2014). As a result, many researchers have categorized this learning software under smart learning environments (Huh & Lee, 2019; Kim et al., 2013). Because knowledge or information can be searched and accessed both online, offline, or in blended mode (Rosmansyah et al., 2022). In addition, the teacher or student can directly use the software through a laptop's touch sensitivity. The laptop does not have to be near SMART board for projecting the content but with a LED pointer, regular presentation can be done.

Research has shown that this software is self-directed, motivated, adaptive, and resource-enriched designed for learning purposes (Zhu et al., 2016). Suppose the supply of electricity and internet connectivity are constant, chemistry teaching and learning would be very exciting. This is because all three presences (learner, teaching, and technology) in smart technologies integration are considered and interactive in the interactive classroom (Zhu et al., 2016). For example, virtual manipulation of experimental activities technology, the students, and the teaching are indeed essential not only lesson presentation but also showing reaction mechanism to confirm that hydrogen chloride is an acid in a reaction between sodium chloride and hydrogen (Aldosari et al., 2022). With graphic designers an equation can be produced by showing or explaining transfer of protons to water molecules to yield hydronium ions and solvated chloride ions. In addition, the molecular structure of such reaction can be drawn using on-screen note shapes, drag by hand or selected from the notes, and pasted on SMART notebook slides for students to interact and demonstrate. The design or structure developed can be saved for future use without purchasing materials or starting again from scratch to alter the lesson (Nichols, 2015). Physics education technology software (PhET), for example, is another learning software that can be installed into SMART notebook software to support the demonstration of quantitative measurement and study of acid-base reactions.

The learning feature such as smart exchange, teachers and students may use the feature to share or search for information from a variety of high-quality, peer-reviewed digital content (SMART Tech, 2014). According to Education Research Center-Boston College Library (2018), smart exchange has thousands of resources, including standard-correlated lessons to facilitate collaboration and promote conceptual understanding. That is, a sample lesson can be searched or browsed quickly and easily by subject, grade, curriculum, or media type, with a suggestive pedagogy to be adopted or adapted depending on the class level to teach. Activity-builder or embedded multimedia learning platform (YouTube) in SMART notebook, for example, are essential tools for molecule designing and virtual simulations or demonstrations. With these additional resources in the software, students can draw chemical molecule to show the reactants and the product, or sketched and visualized how molecules can be react to form products (Aldosari et al., 2022). The study further found that molecules can be learned without physical interaction with the materials but through audio-visual teaching and learning aids (Aldosari et al., 2022). Continuous exploration of these features has the potential to transform students from being knowledge consumers to creators (Anita, 2015).

Assessment platforms (clickers) can be installed in SMART notebook to coordinate incredible formative assessments and monitor students' learning (Russell & Person, 2017; Schmid, 2008). After brief, direct instruction, students discuss questions, which are mostly multiple-choice. Multiple-choice questions used in this method are referred to as concept tests aimed at describing students' knowledge while solving problems. It is further believed that clicker technology are used to monitor students' participation, contributions, and performance, including tracing learning difficulties (Russell & Person, 2017), which could be challenging in everyday classrooms. In addition, it encourages 'waiting time' for students to discuss concepts in a small group before voting their answers using clickers. While answering formative questions using clickers, each student is provided with a unique code, which transmitted their answers on SMART board to show the percentages of students who answered A, B, C, or D. According to studies, wait time is one of the recommendations in social constructivist classrooms (Owens, 2012; Tomita & Savrimootoo, n. d.), which is not necessarily for immediate answers per se but for the immediate feedback for teachers (Egelandsdal & Kyumsvik, 2017). Other opportunities such as automated response to question using clickers, instead of raising hands, and clarification of misconceptions using YouTube learning videos and direct internet search. Students in groups can interact, discuss, share, and support each other for improvement (Li et al., 2019). However, Schmid (2008) found this process as a waste of instructional time and do not adequately encourage students to interact and improve. This is because teachers spend more time fixing malfunctions or calibration than is required. Jammeh et al. (in press) also attributed to teachers' technology integration, which they described as inadequate and can cause a loss of instructional hours, which may consequently affect students' academic achievement.

Integration of SMART Notebook for Students' Academic Achievement

According to Nitza and Roman (2017) and Sadykov and Čtrnáctová (2019), SMART notebook application for teaching and learning encourages student-centered learning and a recipe for students' academic improvement. Consequently, many teachers appreciate the software integration and many studies have also found significant differences in academic achievement of students compared with traditional blackboard use (Skibinski et al., 2015). Phoong et al. (2019) examined academic achievement of two independent groups of students. One group used smart technology (experiment), while the other is conventional teaching methods (control). Even though the mean differences between the two groups at post-test, learning growth is more significant in the experimental group than the control group. A similar intervention is done with 40 students during Edu-Camp organized to exposed two groups of students on different teaching methods. The first group is introduced to rigorous problem-solving with SMART tools called *smart session*, while the second group introduced to traditional ways of solving problems called *ordinary session.* At the end the camp, achievements are assessed, and the results indicated that *smart session* had a higher mean value than the *ordinary sessions* (Sharma, 2016). The study attributed the higher mean value for *smart session* to flexible opportunities in the software, which might be controlled in the *ordinary sessions* (Sharma, 2016). Renan and Tezcan (2017) conducted a similar experimental study to investigate the contributions of technology facilities on learning outcomes. The study concluded that the functions of the adaptive toolbar constitute a critical determinant of learning gain than other methods. Many other studies have supported the superiority of SMART notebook integration over more conventional methods of teaching science (Batdi et al., 2018; Talan, 2021).

Furthermore, the contribution of SMART notebook software to students' examination results has also been highlighted in studies. HIR (2014) evaluated and compared the national examination results of schools using the software to those without the software. The report indicated that students who utilize the software had a 12.4% point increase at basic examinations and 21.0% higher at senior examinations than their peers in the schools without the software. Moussa et al. (2020) and Tomita and Savrimootoo (n. d.) had similar learning growth with students in smart classrooms than students in non-smart classrooms on their examination results. In 2018, HIR team in the USA also revealed an impressive improvement of students in vocational high school compared to other state secondary school regarding national test ranking scores (HIR, 2018). The success of vocational high school students is attributed to the usage of SMART notebook integration with SMART board (HIR, 2018).

Due to these conveniences of teaching and learning, the present study investigated whether SMART notebook integration could support improving students' conceptual understanding of qualitative determination and quantitative study of acid-base reactions. These topics for years has been a concern at the secondary level and SMART notebook software integration initiated as a possible intervention through interactive classrooms (students engagement, and collaboration, among others) to support learning. The effect of the intervention is measured by comparing academic achievements of the two independent groups with different instructional interventions. Therefore, the following questions guided the research processes:

1. How does SMART notebook software improve and support teaching and learning of quantitative determination and study of acid-base reactions?
2. How do the independent groups differ on the post-test scores?
3. How do the independent groups differ in their knowledge retention?

MATERIALS AND METHOD

How the interactive classroom through SMART notebook software integration supported chemistry teaching and learning among the selected students is highlighted here. It shows how participants were selected, data were collected, and measurements of the variables, including a detailed explanation of data analysis.

Research Design

A quasi-experimental design was used to investigate the interactive classroom: Integration of SMART notebook software in chemistry teaching and learning. The complementing approach was the treatment and the control group, a randomized pre-/post-test, and the delayed post-test (knowledge retention) methods. The approach that guided the treatment group's instructional interventions was the features of the

Table 1. Distribution of items amongst three domain or protocols

Description	Number of items
Recall	5
Knowledge	5
Application	10
Total	20

software (interactive learning objects such as interactive worksheets, graphic organizers, streaming videos, formative assessment platforms-students respond system (clickers), activity-builder, smart exchange, and galleries), as well as specific strategies for maximizing their use in the learning environment were emphasized. The software integration with SMART board was discussed, and the suggestions, where teachers and students can find existing functional tools and resources for classroom instruction and learning. Automatic assessment of students' learning (clicker integration) was the central theme, instead of raising hands to respond to questions. Online videos were provided to show how easily teachers and students could use SMART notebook software to enhance qualitative determination and quantitative study of acid-base reactions instruction including laboratory trial.

In comparison, the control group was taught using direct instruction, physical experimentation, and textbook problem-solving. They had the opportunity to interact with glassware, reagents, textbook, worksheets, and lesson activities to solve problems and clarify or verify concepts using the internet. Physical experimentations were encouraged to find solutions to the topics. Social constructivism and option for expression and communication were given through opportunities such as unit tests and working on formative assessment questions; however, students raised hands to respond to questions during lessons.

Both interventions lasted for about 24 days, and each group was provided with research assistants (teachers) to provide instructions, necessary materials, and one-to-one support for students. This approach stimulates and facilitates conversation by harnessing the natural flow of conversation in the classroom (Davis et al., 2017).

Participants

Through systematic random sampling, 314-grade eleventh chemistry students were selected and divided into eight classes (that is, four classes for the treatment and the same for the control groups). Students were matched for equivalence using their academic records. These samples were drawn from 12 secondary schools of 568 students in two of the six administrative regions. That is, regions 1 and 2 because of the relatively large chemistry student population and availability of SMART notebook software resources (Muralidharan, 2015). In addition, the prior knowledge of these students on the topics was considered even though their social backgrounds, demographics, attitudes, and prepositions were not studied.

Further, the treatment groups were mainly from public secondary schools as these were provided with SMART notebook software, SMART board, and clickers by the Government). Whereas the control group were mainly from public and private schools (without smart technologies but normal teaching infrastructures).

Sampling

The sample sizes of 314 students split into two independent groups (treatment and control) and each group was 157, which gave the power to the analysis and to detect differences between the groups (Fagerland, 2012). Notwithstanding, 14 research assistant or teachers were purposively selected, prepared and placed into treatment (seven assistants) and control (seven assistants) to support the interventions. These teachers were national trainers for SMART notebook integration, pedagogy, and chemistry content teaching in the country. All participants (teachers and students) signed a consent form and voluntarily accepted to participate.

Instrument

20 academic achievement test items (AATI) were developed based on areas reported by the chief examination report (WAEC, 2019)–qualitative determination and quantitative study of acid-base reactions. 11th grade curriculum and the Aki-Ola series core chemistry textbook for secondary schools were used for AATI preparation. This preparation was aligned with the items design protocol by WAEC considering the three domain namely recall, attitude, knowledge, and application. However, because of the scope and focus, the study only used three, namely recall, knowledge and application of chemical facts, as shown in **Table 1**. Soft lessons on these topics were prepared and uploaded on SMART notebook software to maximize the integration on students' academic achievement.

Validity and Reliability

Content validity was provided by knowledgeable people from Gambia College-School of Education, the University of the Gambia-School of Education, and the Science and Technology Education Directorate. They reviewed and validated the instrument using interrater reliability to ensure that the questions were factual, and the conceptual questions were critically applicable. 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. Then, pilot testing took place using 40 11th graders who had previously taken this course but were not part of the study sample to determine the test's reliability and discriminant level.

Table 2. Statistics of items after validating & piloting

Description	Number of items developed	Number of items after validation	Number of items after piloting
Recall	5	4	4
Knowledge	5	4	3
Application	10	9	8
Total	20	17	15

At pilot testing, each response from students was graded for item analysis. The items with the highest scores were mentioned first and the highest group included 44.0% of the responses was on the list. Then, a sub-group was created using the exact number of the lowest-scoring values through the difficulty and the discrimination indices on all items. Consequently, the number of items on AATI was reduced to 15, and the resulting data was found to have a reliability coefficient of .84 Cronbach's alpha, which revealed to what extent the questions measured according to the difference among the questions and the variances of questions (Hinton et al., 2004). See **Table 2** for a detailed explanation of items distribution after validation.

Data Collection Procedures

Data were collected after obtaining a letter of permit from the Ministry of Education. This was followed by a meeting for research participants for study aims, their roles, activities, and the importance of research to chemistry teaching and learning. Then procedures like

(a) reviewing training modules for teachers and students,

(b) reviewing AATI,

(c) validating instruments,

(d) piloting instruments,

(e) pre-testing,

(f) training instructors/research assistants on SMART notebook integration and textbook problem-solving, including physical laboratory experimentation for the treatment and the control group, respectively,

(g) follow-up teaching students at designated centers,

(h) post-testing, and

(i) delayed post-testing were followed.

Pilot testing helped the researchers to align tests (pre-test, post-test, and delayed post-test), including training modules for students accordingly. But arrangement of AATI was changed from pre-tests to delayed post-tests to avoid the risk of memorization, as it contributed to the study's reliability (Patrick & Julius, 2010).

Each student was given a unique code instead of their name during pre-testing to promote confidentiality and avoid biases. This unique code was by the students to answer questions during formative assessments, for example, treatment groups. Concepts were marked according to marking scheme developed and computed for analysis. The internal validity of the research findings were controlled using the treatment groups against the control groups to measure the dependent variables (Creswell & Plano-Clark 2018).

Instructional Interventions

There were two different instructional interventions these include the integration of SMART notebook software and conventional teaching methods for two independent groups on the same topic. Seven research assistants/teachers and 157 students as one group only on SMART notebook integration including laboratory trials, while other seven researchers or teachers and 157 students as another group only on conventional teaching methods including laboratory experimentations (see **Table 3** and **Table 4** for more detail).

Table 3. Two weeks training for teachers

Treatment groups	Control groups
SMART notebook installation (v. 11) in touch screen laptops. How to connect SMART board with a touch screen laptop for lesson projection.	How to install a laptop, troubleshoot, connecting to the Internet, among others. Also, how to prepare soft lessons & upload them into laptop, including chalkboard preparations, among others.
How to install clicker software into SMART notebook for formative assessment & its interpretation.	How to use solve problems such as quantitative measurement & calculation of acid-base reactions.
How to use SMART notebook to prepare soft lessons as slides. It also includes searching for information from relevant sources, uploading, downloading, editing, cutting, pasting, saving, importing content or scores sheet, & graphic designers application, among others.	Instructors were encouraged to prepare a lesson & observed through micro-teaching about topic. While in practice, they had an opportunity to interact, collaborate, & share for improvement.
Instructors were encouraged to prepare a lesson & observed through micro-teaching about topic. While in practice, they had an opportunity to interact, collaborate, & share for improvement.	How to do experimentations with glassware & reagents about topics. Examples, were titration, volumetric analysis, mole ratio calculation, & pH value determination, among others.

Table 3 (Continued). Two weeks training for teachers

Treatment groups	Control groups
How to put students into groups using smart-grouping technique to ensure heterogeneous grouping to promote social constructivism approach. How to integrate direct instruction with social constructivism approach to teaching concepts for students' engagement & participation.	How to search for information using the Internet searching. This helps them to clarify, demonstrate, & explore the most relevant & simplest activities or approaches to topic.
How to do laboratory experimentations with glassware & reagents about topics. Examples, were titration, volumetric analysis, mole ratio calculation, & pH value determination, among others.	How to integrate direct instruction with social constructivism approach to teaching concepts for students' engagement & participation.
Instructors were encouraged to prepare a lesson & observed through micro-teaching about topic. While in practice, they had an opportunity to interact, collaborate, & share for improvement.	
How to interact & installed PhET simulation into SMART notebook for calculation of concentration or mole ratio. It involves pH value & ionic reaction determination, among others.	
Laboratory experimentations with different samples concerning quantitative measurement & study of acid-base reactions.	

Table 4. Step-down teaching students at designated centers

Treatment groups	Control groups
Installation of SMART notebook software into touch screen laptop.	Setting up chalkboard, laboratory glassware, reagents, & other materials needed for conventional teaching methods.
Accessing & navigating information from either the Internet sources or within interactive learning objects to slides in SMART notebook.	Direct instruction from instructor, which includes recapping, brainstorming, introduction of topic, & problem-solving on chalkboard, among others.
How to use clickers for formative assessments. These include login in with their unique code, entering password, sending answers, & deleting answers, among others.	How to use voting cards during formative assessments. It also involves troubleshooting laptops, login, clarify concepts through an internet search, among others.
How to do editing & save chemistry content into software, downloading, uploading, & browsing through software.	How to access or search information from the Internet, saving, uploading, & downloading chemistry topics using their laptops.
How to access adaptive toolbar (**Figure 1**), specifically streaming learning videos, simulation, & virtual demonstration, among others for ionic reactions, mole concentration calculation, pH values determination, & interpretations.	Group discussion, interaction, & collaboration to solve problems.
How to use software integration with PhET simulation to calculate & measure acid-base concentration, mole ratio, and percentages.	How to conduct laboratory experimentations using glassware & reagents about topic. These include titration & its calculation, ionic reaction demonstration, & pH value determination, among others. Results obtained from real practical were compared with results shown through their interaction with internet searching.
Peer instructions, group works, interaction, & collaboration as social groups for learning.	Peer instructions & group work were encouraged as social groups for learning.
Daily classwork & homework on topics.	Daily classwork & homework on topics.
How to conduct laboratory experimentations using glassware & reagents about topic. These include calculating titration values, demonstrating ionic reactions, & determining pH values, among others.	How to encourage social collaboration during solving problems. These include changing seating arrangements from rows to round-table, in groups of 5 students with a laptop. Within table, each student was provided with voting card.
How to encourage social collaboration to solve problems. These include changing seating arrangements from rows to round-table, in groups of five students with a laptop. Within table, each student was provided with clickers for formative assessment.	

Note. All groups were provided with same instructional hours (four hours a day) for about 24 days; same chemistry topics of quantitative measurement & calculation of acid-base reactions; weekly meetings were organized for both groups to discuss strengths & way forward; & to avoid disconnection or interruption while teaching, internet connectivity & constant electricity supply were provided for both groups

These essential pieces of trainings for the two different groups provided the extent to which knowledge, skills and creativity have influenced the creation and successful presentation of learning materials (Nichols, 2015).

The rehearsal training for teachers lasted for about two weeks, while step-down teaching students was about 24 days (that is, four hours daily), which have emphasized the strategies for maximizing instructional

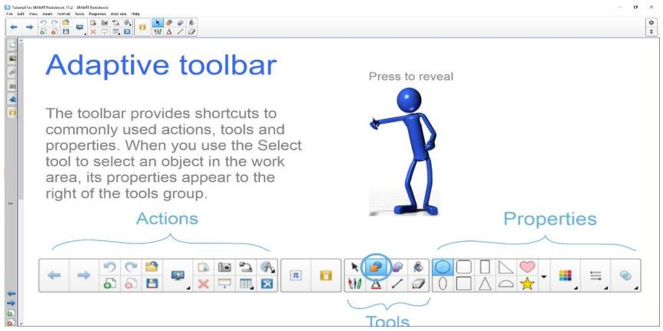

Figure 1. Adaptive toolbar (Source: SMART Notebook Software)

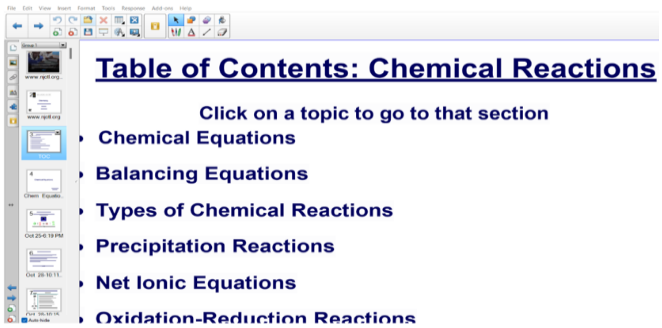

Figure 3. SMART notebook software version 11 (Source: SMART Notebook Software)

Figure 2. Clickers for formative assessment (Source: MoBSE-Clicker)

interventions, especially with the technology (Takawale & Kulkarni, 2016).

Generally, instructors spend a few minutes explaining each concept to students, and students take the responsibility to work towards solving problems (Owens, 2012). Discussion, interaction, and collaboration were encouraged to solve in-class questions (multiple-choice) for each concept. Peer instructions were highly practiced for each concept, and formative questions were answered through clickers (**Figure 2**) or raising hands.

They discussed and convinced each other before sending their answers through SMART notebook software to SMART board for the treatment groups, and on the chalkboard for the control groups (**Figure 3**).

As scores projected on SMART board in percentages, for example, unequal percentage scores, their instructor/teacher may encourage retaking the questions and gave extra minutes to the students to discuss. In a few minutes, students sent in their answers again for another score, on one hand. On the other hand, the instructors may continue to another concept or assessment if the percentages projected on SMART board were convincing.

Both groups of students explored and clarified concepts through the Internet searching and physical experimentation to learn about the topics. Peer instructions was also encouraged for students to learn from each other for improvement. While in group work, instructors move around to offer support, encouragement, and motivation to students. Furthermore, students were given options to self-regulate by retaking assessments and completing the number of classwork problems if they felt it was necessary for their mastery. They also practiced self-assessment using the answer key provided and through the consistent use of formative assessment questions in the classroom. Options for recruiting interest were created through embedding videos, virtual laboratories, and demonstrations. Students were also encouraged through classroom conversation, options for expression and communication, which have promoted them to be independent learners (Owens, 2012).

In a nutshell, these approaches used for data collection show the degree of significance in students learning (see Takawale & Kulkarni, 2016). Particularly social constructivism, which maintains that learning can be socially constructed through interaction with others (Akyol & Fer, 2010; Davis et al., 2017). Group work is an integral component, where students collaborate and learn in an interactive classrooms to solve problems and do assessments together. Students are also encouraged to delegate roles and responsibilities, pool their knowledge and skills, and receive support from one another. Akyol and Fer (2010) suggests that successful integration highly depend on interpersonal interaction and discussion, primarily focusing on the student's understanding. As a result, the distinction between the two independent groups was SMART notebook integration and was basis on which students' academic achievements were measured (Sari & Guven, 2013).

The next phase was the two-hour pre-test before the intervention using 15 theory questions (AATI) to determine the level of competence in terms of the three domain (**Table 1**). Time allocated for the pre-test, including post-test and delayed post-test to test for knowledge retention was similarly used by WAEC for chemistry papers in the country.

Table 5. Summary of topics distributions

No	Topics	Number of questions framed	
		In draft tool	In final tool
1.	Introductory concepts of acids, bases, & salts, which was an opportunity to test for their prerequisite knowledge	2	2
2.	Substances identification or interpretation through pH scales & testing of common substances using indicators (red cabbage or red camelina communis flower, phenolphthalein, methyl orange, & bromothymol blue)–Qualitative measurement	2	2
3.	Quantitative study of acids & bases reaction, which include mole ratio & concentration.	5	3
4.	Measurements & calculations of numerical values of pH for each sample to determine color representation by comparing with values	5	4
5.	Titration of antiacids with distilled water, bromothymol blue indicator, & 1M HCl	3	2
6.	Weak acids-weak base titration & calculations	3	2
Total		20	15

Delayed post-test test was conducted after four weeks of post-test to test knowledge retention and application by the students. This was in line with Bloom's Taxonomy, to measure high-order thinking as in the current study (Aktas & Aydin, 2016), to determine the comprehensive contribution of SMART notebook in chemistry teaching and learning.

Data Analysis

Considering the subject of the study, which is quite extensively presented in current literature, this study, approaches the data analysis to show the statistical significance between the two groups. Marks were recorded for each concept and entered in a Microsoft Excel spreadsheet. Each correct response was worth one point. Zero point was recorded for either non-response or wrong response. Therefore the test was worth a total of 72 points, computed and analyzed at a .05 level of significance. Statistical packages for social science (SPSS) v. 21 software was used for statistical analysis under the following assumptions:

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.
4. The observations were statistically significant but approximately not normally distributed to compare the differences of dependent variables for two independent groups (Fagerland, 2012).

These assumptions guided the study to infer the statistical significance between the two independent groups of students in chemistry class. Similarly, not normally distributed, shows that the pre-test scores were lower for a group, while the post-test scores were much higher for another group. It also means that there was significant variation and deviation from the mean, which initiated the study to use a non-parametric (Mann-Whitney U test) test to compare differences between the two independent groups when dependent variables were ordinal, not normally distributed (Obumneke, 2012).

Unlike the independent t-sample, the Mann-Whitney U test supports the study by drawing different conclusions about the data concerning the assumptions (Fagerland, 2012). It also stands to validate that whether the two independent groups differ as they reflect the shape of the data distribution (see Obumneke, 2012).

RESULTS

As the research questions the results were described and interpreted based on the statistical evidence generated. **Table 5** shows the summary of the topics distributions. As the research question (how does SMART notebook software improve and support teaching and learning of quantitative determination and study of acid-base reactions?) just before the commencement of the intervention most of the students could not provide and explained products formed after adding magnesium ribbon to the dilute sulfuric acid. They stated different products such as *water*-$H_2O_{(l)}$, *hydrochloric acid*-$HCl_{(aq)}$, *sodium hydroxide*-$NaOH_{(aq)}$, among others, instead of magnesium sulphate and hydrogen gas ($MgSO_{4(aq)}$ *and* $H_{2(g)}$) as two products formed. Similarly, when sulfuric acid was added to copper (II) carbonate, the products formed were supposed to be *copper (II) sulphate, carbon dioxide gas and water*. However, students wrote *Sulphur gas*-$SO_{2(g)}$, *copper (II) carbonate*-$CuCO_{3(s)}$, *sulfuric acid, water, and magnesium*. Both groups were not very different in terms of conceptual understanding of qualitative determination and quantitative study of acid-base reactions. On the other hand, they were able to balance and name the type of reaction, including their physical states (sodium hydroxide and dilute sulfuric acids). In addition to the color change after the reaction between sulfuric acid and copper (II) carbonate, the inferences given by the students was correctly explained

As shown in **Figure 4**, before the intervention and on pre-test the mean rank for the treatment was 158.16, while the control group was 156.84. This shows that the two groups were not very different (u=12,221.00, p=.898) at a .05 significant level even though it favored the treatment group.

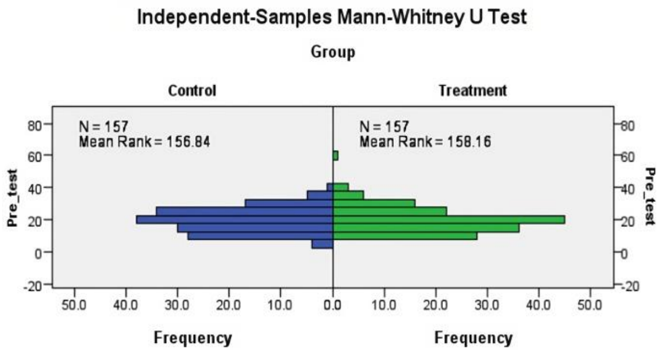

Figure 4. Mean ranks at pre-test (Source: Authors' own elaboration, using SPSS version 21)

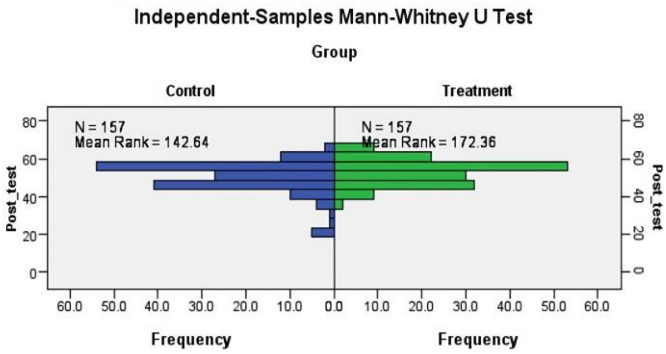

Figure 5. Mean ranks at post-test (Source: Authors' own elaboration, using SPSS version 21)

However, after the intervention and on post-test, the two groups were significantly different (u=9,991.500, p=.004) in terms of academic achievements (**Figure 5**). Therefore, the research question (how do the independent groups differ on the post-test scores?) could be explained that the academic achievements of the two independent groups were differ as the mean rank for the treatment was 172.36, while the control group was 142.36.

For knowledge retention as well as the research question (how do the independent groups differ in their knowledge retention?) similar learning growth was found at the permanence test. This shows that regarding mean ranks of the two independent groups, students taught using SMART notebook software differs significantly with those taught using conventional teaching methods (u=9,629.500, p=0.001), favored the treatment group (**Figure 6**). The mean rank for the treatment group on knowledge retention was 174.67, while the control group was 140.33.

DISCUSSION

The results obtained in the study show that the interactive classroom: the integration of SMART notebook software in teaching and learning of qualitative determination and quantitative calculations of acid-base reaction has been improved and supported. This was demonstrated positively at their subsequent

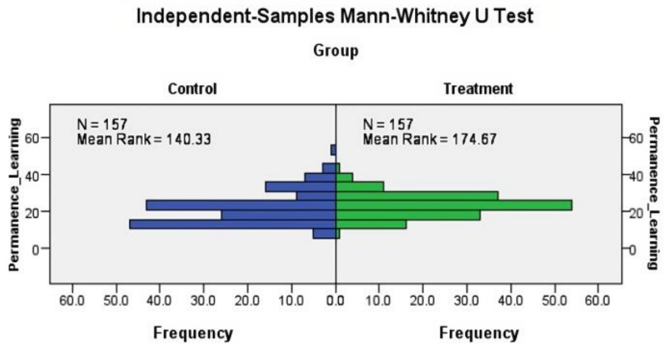

Figure 6. Mean ranks at permanence test (Source: Authors' own elaboration, using SPSS version 21)

tests (post-test and permanence test) by comparing with a test (pre-test) before the instructional interventions.

For examples, the identification and interpretation of common substances as acidic, basic, or neutral was an introductory curriculum course for secondary schools in the Gambia. As a result, most of the students through a mathematical scale were able to correctly identify and interpret many common substances as acidic, basic, or neutral before the intervention. In addition, they were able to be balance and name the type of reaction, including their physical states and inferencing of experimental findings. The current study has similarly provided appropriate examples of the mathematical influence on scientific understanding of pH value and scale (Park & Choi, 2013).

Notwithstanding their understanding before the intervention about basic stoichiometry, where they were required to write coefficients in a bid to balance the chemical equations, as well as indicate the state symbols. Unfortunately, the results of their assessment towards solving such problems were sometimes unscientific (Tal et al., 2021). For example, the coefficients in the stoichiometric equation, students thought each reactant was a liquid, and each product was aqueous at the sub-microscopic level. Furthermore, they thought ions of opposite charges attract and continue paring without putting the formula correctly. This learning challenges were also found by WAEC, Banjul, the Gambia, 2019.

While the intervention intensifies and progresses, most of the abstract concepts about the qualitative determination and quantitative study of acid-base reaction were concretized through the effort of the interactive classrooms and physical laboratory experimentations. Consequently, students conceptual understanding about the topics were improved as it reflected positively on their academic achievement, particularly the treatment group from pre-test to permanence test. The indicative evidence shows that the mean ranks for treatment group was progressive as they moved from pre-test (mean rank at pre-test=158.16, mean rank at post-test=172.36, and mean rank at knowledge retention test=174.67) to delayed post-test. This progressive and positive learning growth for the treatment groups have been attributed to the integration of smart technology (Batdi et al., 2018; Nichols, 2015; Phoong et al. 2019; Sharma, 2016; Skibinski et al., 2015; Talan, 2021) than using the conventional teaching methods. Anita (2015) similarly found learning improvement with students taught using smart technologies than the conventional methods. While using SMART notebook, students used interactive learning objects extensively to improve their conceptual understanding through series of demonstrations, and simulations to learn the topics (Aldosari et al., 2022; Takawale & Kukarni, 2016) in one hand.

On the other hand, the control groups were decreasing in terms of mean ranks as they moved pre-test (mean rank at pre-test=156.84, mean rank at post-test=142.64, mean rank at knowledge retention test=140.33) to delayed post- test. This shows that only blackboard instruction may not help students to improve their knowledge and understanding on the topics (Skibinski et al., 2015). In addition, what must have accounted for this may be the factor reported by two similar studies. They found that students unsatisfactory learning outcomes and misconceptions was correlated with teachers' content knowledge and teaching strategies (Lemma, 2013; Tomita & Savrimootoo, n. d.).

Regarding knowledge retention, after four weeks of post-test, students who taught using SMART notebook software were increased by 2.31 in terms of mean ranks from post-test and delayed post-test. The motivation to understand higher-order thinking in terms of knowledge and application of qualitative determination of pH values and quantitative calculation of mole ratio, and concentration, among others, has improved with the treatment group, which happens to be unsatisfactory for the control group. Several other studies could only find knowledge retention in the treatment group better than the control group with the use of smart technologies (Aktas & Aydin, 2016; Nitza & Roman, 2017; Renan & Tezcan, 2017). Moussa et al. (2020) similarly evaluated students' knowledge retention after few years of intensive teaching students on algebraic mathematics and science. The finding revealed that students in smart schools perform better than their peers in the non-smart schools using a design test questions. While other studies have reviewed relevant literature about knowledge retention with smart technology integration and have find significant contribution in improving students conceptual understanding and academic learning outcomes (Anita, 2015; Kaplan-Rakowski et al., 2021).

In contrast, other studies contradicted the support of such software. Instead of supporting students to understand the structure of functional groups on the molecules, for example, they were challenged to understand from virtual demonstration (Aldosari et al., 2022). According to the findings during slides presentation on SMART board, some learning features were not adequately visible because some lenses were blurred and affected students, especially the visually impaired. In addition, Skibinski et al. (2010) could not find much difference when they compared technology instruction with the traditional methods. Further, Schmid (2008) could only make a little progress with the lesson content, as most of the instruction hours were spent correcting technology malfunctions, including calibration. This was similarly found in the present study when students were preparing virtual demonstration of acid-base titration side-by-side with laboratory experimentation. Many students could not compare the results found with the virtual simulation and physical experimentations. One of the reasons was time constraints and precision of measurement to obtain results.

CONCLUSIONS

The interactive classrooms have many effects on students' academic achievement. It also shows the importance of SMART notebook software in teaching and learning of qualitative determination and quantitative study of acid-base reactions. In terms of the three domains (recall, knowledge, and application), the interactive classroom has demonstrated a significant impact, which have been found to be challenging for the Gambian students.

Comparing the initial results (pre-test) with the final results (post-test) has indicated that learning has occurred in the treatment groups but inadequate in the control group. Similar learning growth was found for knowledge retention, which indicated that students were different in academic achievement as the instructional interventions differed, favoring the treatment groups. Further, the delayed post- test results for the treatment group also revealed and attached higher importance to the interventions provided by the researchers, neglecting the consequences of intrinsic or extrinsic factors.

The findings concluded that the present study is another literature on the importance of SMART notebook in chemistry teaching and learning. It also implied that interactive classroom: the integration of SMART notebooks software could lead to better teaching and learning chemistry in the Gambian context if it continues to be integrated extensively and effectively in secondary schools. By extension, since SMART notebook software promotes knowledge retention, then it is a worthwhile for the education sector to create significant expansion about software use, including regular monitoring.

Limitations

The study only limited to regions 1 & 2, and it may not be a representative study. The schools selections were also based on SMART notebook software resources and the chemistry students' population. Future researchers may cover good number of regions and schools, including provisions of smart resources for better impact investigation than only small sample population. Furthermore, three domains of skills studied (recall, knowledge, and application of chemistry concepts) may not be adequate for empirical studies but with the addition of attitude test, comprehensive data on students learning chemistry could be revealed.

Recommendations

Future researchers may investigate the contribution of students unsatisfactory academic achievement by considering instructional teaching pedagogy, teacher quality, students' attitude, gender, demography, as well as academic background than only prior knowledge testing and prepositions on recall, knowledge, and application. In addition to capacity building, future researchers may have knowledge of integration of SMART notebook software so that the interactive classroom could be thoroughly investigated, as this study heavily relied on national trainers as research assistants. However, knowledge about research design and findings was an additional literature to be used by future researchers or institutions preparing to introduce SMART notebook integration to support science and mathematics education.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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