

Contribution of Computer-Assisted Simulation on Students' Learning of Chemical Bonding in selected secondary Schools of Rwanda

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Abstract

This study delves into the impact of computer-assisted simulations on students' comprehension of chemical bonding. Employing an explanatory sequential design, the research initially gathered and analyzed quantitative data before delving into qualitative perspectives. The study involved 86 students, aged 16 to 17, from a twelve-year secondary school. Two classes were selected, with one designated as the experimental group and the other as the control group. The experimental group received instruction utilizing computer-assisted simulations, while the control group received traditional instruction methods. Both groups underwent pre- and post-tests to evaluate their understanding of chemical bonding. The chemical bonding achievement test yielded quantitative data with a reliability coefficient of 0.791, supplemented by qualitative insights from participant interviews. Statistical analysis of the quantitative data, conducted using the Statistical Package for the Social Sciences (SPSS) software, indicated a statistically significant difference in performance between students taught with computer-assisted simulations and those without it, favoring the experimental group ($df=85$, $p<.05$). Additionally, within the experimental group, no statistically significant difference in performance was observed between male and female students ($df=85$, $p>.05$). Interviewed students expressed that the integration of computer-assisted simulations significantly enhanced their understanding of chemical bonding compared to conventional teaching methods. These findings highlight the effectiveness of computer-assisted simulations in improving students' comprehension of chemical bonding, suggesting its integration into chemistry education.

Keywords: Computer-assisted simulation; students' learning; performance; chemical bonding

INTRODUCTION

The integration of technology into education has proven to enhance both the quality and value of the teaching and learning experience (Maslin *et al.*, 2010). This incorporation has brought about substantial transformations in educational practices, particularly in the realm of knowledge acquisition fostered by collaborative engagement between educators and learners. This amalgamation has facilitated more dynamic, enthusiastic, inventive, and holistic learning approaches, along with refined assessment techniques. Consequently, there is a strong imperative for governments to actively promote the integration of technology within educational establishments (Wakil *et al.*, 2017). The CBS proves to be highly effective in elucidating challenging and intricate learning topics, particularly those that are challenging to communicate solely through verbal explanations, equations, or classroom activities. Its vivid colors and precise imagery make the CBS particularly adept at clarifying complex concepts related to chemical bonding (Mihindo *et al.*, 2017). Several studies have found that chemical bonding units are difficult for students who want to pursue chemistry (Dawati *et al.*, 2019). The challenges students face in understanding chemical bonding units stem from teaching approaches and teachers' insufficient responsiveness to their students' existing knowledge, misconceptions, and the absence of clear

guidelines for problem resolution (Nahum *et al.*, 2010).

Three-dimensional thinking is required, as well as the study of new terminology. Another cause could be the subject's nature and students' understanding of learning (Allouche, 2012; Raeker & Depristo, 1991). Some topics in chemical bonding units, including types of chemical bonds, and properties of ionic, covalent and metallic bonds are challenging to learn (Raeker & Depristo, 1991). The utilization of the lecturing approach in teaching chemical bonding presents significant challenges (Joki & Aksela, 2018). In response, employing simulation techniques could prove highly effective, as they vividly illustrate the formation and various types of bonds, showcasing electron sharing and transfer. Simulation-based learning has emerged as a viable method for enhancing chemistry education, offering students immersive and interactive experiences (Oladejo, 2021a). This investigation delved into the efficacy of utilizing simulations to impart chemical bonding concepts in a high school chemistry setting. We assessed both learning outcomes and student perceptions regarding simulation-based instruction compared to traditional lecture-based methods. Computer-assisted simulations emerged as the central methodological approach for the teaching and learning of chemical bonding. Research indicates that such simulations enhance understanding across diverse student cohorts, as evidenced by increased chemistry knowledge and concentration levels (Nsabayezu *et al.*, 2023). Additionally, outcomes from preparatory exercises and testing underscored the method's effectiveness in bolstering students' grasp of scientific concepts (Jhenly, 2019).

Various educational resources, including technology, are readily accessible to enrich the teaching and learning process, thereby fostering student success. The importance of technology in science education, particularly in practical disciplines like chemistry, is acknowledged by both developed and developing nations (Nsabayezu *et al.*, 2022a; Nsabayezu *et al.*, 2023a; Nsabayezu *et al.*, 2023b). Consequently, technology has long been utilized to support teaching and learning. With the world evolving rapidly, nations are diligently striving to meet these demands. An exemplary instance is the incorporation of information and communication technology (ICT) throughout all levels of education (Nsabayezu *et al.*, 2022b). Educational technological tools such as animations, simulations, and videos are widely employed globally due to their effectiveness in enhancing students' content knowledge (Riley *et al.*, 2019). Students studying chemistry not only prefer theoretical learning but also value practical engagement through conducting experiments or observing experiment processes to better comprehend concepts. Similarly, Falvo (2008) asserts that using simulations, videos and animations in chemistry education enhances student performance by fostering engagement and interest. Research suggests that the COVID-19 pandemic resulted in an increase in the use of videos, simulations, and animations for conducting virtual laboratory experiments (Raman & Vinuesa, 2021). Technology played a crucial role in facilitating the teaching and learning process during the COVID-19 pandemic (Nsabayezu *et al.*, 2020; Nsabayezu *et al.*, 2022c). According to Falvo (2008), simulations can help students capture topics better when used effectively by providing mental representations of concepts. Although simulations are valuable, it has been observed that using those instructional technology tools might lead to misinterpretation and misunderstanding. It was discovered, for example, that pupils believe that the models of atoms' colours and forms closely depict the specified items. As a result, when students are misguided by their teachers, it can lead to confusion and the perpetuation of misconceptions (Falvo, 2008).

This research was guided by the constructivism theory. Constructivism promotes student engagement by encouraging them to utilize their actions within a specific learning environment to broaden their understanding. Implementing a simulation-based teaching approach offers numerous benefits for enhancing students' comprehension of academic concepts.

Significance of the study and its contribution to the existing body of literature

The findings of this study provide valuable insights for chemistry educators, especially those endeavoring to employ



effective methods in aiding students to grasp the concepts of chemical bonding. The findings indicate that teaching chemical bonding enhances students' motivation, confidence. The gathered data will support curriculum development, instructional practices, and educational administration, aiding in planning and decision-making processes. Educators can utilize these findings to develop systematic approaches for planning, assessment, and incorporating simulations to facilitate students' learning of chemical bonding. Empowering students to take ownership of their education involves encouraging them to actively engage in critical thinking and self-assessment. Moreover, the study outcomes enrich the field of chemistry education by investigating the effects of computer-assisted simulations on students' understanding of chemical bonding. The research sought to determine how these simulations influence students' performance in chemical bonding courses, guided by hypotheses examining the correlation between simulations and students' comprehension of chemical bonding principles.

The current study was directed by one null hypothesis:

Null hypothesis (Ho1): There is no statistically significant difference in performance between the control and experimental group.

METHODOLOGY

Research design and approaches

An explanatory sequential research design was utilized in this study, which is a systematic plan or strategy for conducting a study that incorporates both qualitative and quantitative research approaches (Dawadi *et al.*, 2021). It comprises collecting, analyzing, and synthesizing quantitative data first and qualitative to answer research questions (Doyle *et al.*, 2009). This concept enables researchers to gain a more complete view of the topic under investigation by combining qualitative and quantitative methodologies. This study collected and analyzed both qualitative and quantitative data.

Sample and sampling methodology

The current study included a sample of 86 students from a single secondary school who were chosen specifically because they were enrolled in senior two, a grade level where chemical bonding is a major topic. The selection criteria were purposeful, as the researchers aimed to assess the impact of simulations on students' academic performance in chemical bonding. By concentrating on this particular group, the study aims to offer insights into the effectiveness of simulations as an instructional aid within this academic domain. The findings of this study hold promise for enhancing teaching methodologies and student academic achievements in the realm of chemistry.

Instruments

The current study collected quantitative data using achievement tests. Pre and post-tests were used to assess students' grasp of chemical bonding units before and after using computer-assisted simulations. Before being exposed to the simulations, the pre-test was used to measure students' comprehension. In contrast, the post-test assessed their comprehension after using the computer-assisted tools. The tests were criterion-referenced and scored on a thirty-point scale. Interviews were also done to determine students' perceptions on the efficiency of computer-assisted simulations in facilitating their understanding of chemical bonding concepts. These interviews were conducted to assess the effectiveness of such simulations in the teaching and learning process.

Ethical consideration

The authors obtained research authorization from the education commissioner, and the contestants clarified the goal of the study. Every potential participant was permitted to sign the agreement and freely contribute to the research. The standard of privacy and confidentiality was upheld.

Data collection procedures

Data collection employed an explanatory sequential research design, combining achievement tests for quantitative data and interviews for qualitative insights. The achievement test assessed levels of knowledge and conceptual understanding, with pre- and post-tests evaluating the impact of computer-assisted simulations on students' comprehension of chemical bonding. Interviews were conducted to gather students' perspectives on the use of computer-assisted simulations in their learning process (Alshenqeeti, 2014). The study involved 86 senior two-secondary school students from the Bugesera district of Rwanda. Simulations focusing on chemical bonding were accessed via YouTube and were limited to this subject matter. Each student in the experimental group had access to these simulations for exploration. All students completed pre- and post-tests, with thirty scores allocated to each test.

Data analysis encompassed quantitative and qualitative methods, employing descriptive analysis for quantitative data to compute standard deviations and means. Qualitative data underwent interpretive analysis, enabling researchers to understand participants' experiences (Alase, 2017). Data integrity was ensured, with research instruments refined by researchers from the University of Rwanda's College of Education. A pilot test of the study was conducted at another school in the Nyarugenge District of Rwanda to confirm the reliability of the chemical bonding test. The reliability coefficient, determined to be 0.791 through split-half reliability analysis, validated the test's consistency. Participants provided informed consent after thorough explanation of the study's objectives, with utmost consideration for their privacy and anonymity.

Experimental technique and data analysis

The control groups underwent instruction on chemical bonding units without the use of computer-assisted simulations, while the experimental groups received instruction on chemical bonding units utilizing the computer-assisted simulations technique. Chemistry teachers underwent a two-week training session on teaching the selected chemical bonding units using computer-assisted simulations. Course summaries were then provided to the chemistry instructors as instructional guides, with separate summaries prepared for the experimental and control groups based on the specified course outlines that served as the framework for the research. The chemical bonding units covered in the study encompassed the formation of chemical bonds, their various properties, and their types, including ionic, covalent, and metallic bonds. Prior to regular instruction, both groups underwent pretesting. Following four weeks of regular instruction, a post-test was administered in the fifth week. To mitigate the memory effect, the pre-test items were rearranged before being used in the post-test to present a different appearance. The achievement test comprised 15 test items. The results of the post-test were recorded and utilized to assess the students' understanding of chemical bonding concepts. Mean and standard deviation (SD) were employed to analyze all gathered data, elucidating the focal points of the study.

RESULTS AND DISCUSSION

Contribution of simulation on students' academic performance in chemical bonding

The study employed a Chemistry achievement test to assess the influence of simulation on students' academic performance. An independent t-test was conducted to compare the means of the control and experimental groups in both pre- and post-tests. Table 1 displays the pre-test scores for both groups.

Table 1: Descriptive and inferential statistical analysis of the pre-test scores

Pre-test Score	Group	N	Mean	Std. Deviation	T	df	Sig. (2-tailed)
2016	Experimental	43	5.68	2.11	-2.08	85	.18
2017	Control	43	5.08	1.86			
Total	86						

Based on the data, the control group averaged a score of 5.08 out of 43, while the experimental group scored 5.68. The calculated p-values of 0.18 ($p > .05$, $df=85$) indicate that there was no notable distinction in test outcomes between the control and experimental groups before simulation was incorporated into the chemical bonding lesson. Thus, the pre-test scores for both groups were comparable. Subsequently, students in the control group underwent conventional teaching methods without simulations, whereas those in the experimental group engaged with simulations as part of their learning experience. A post-test was then performed by both the control and experimental groups to assess the effect of the intervention. A descriptive and inferential analysis of the post-test score is shown in Table 2.

Table 2: Descriptive and inferential statistical analysis of the post-test scores

Pre-test Score	Group	N	Mean	Std. Deviation	T	df	Sig. (2-tailed)
2016	Experimental	43	7.18	1.00	1.004	85	.000
2017	Control	43	6.00	1.62			

According to the study's findings, the experimental group's post-test mean score was 7.18, whereas the control group's was 6.00. This significant statistical difference between the control and experimental groups is in favour of the experimental group. This suggests that using simulation has a greater impact on student performance than the traditional technique. This demonstrates that utilizing simulations to teach chemical bonding is beneficial because student performance has improved. As a result, the alternative hypothesis should be accepted in place of the null hypothesis, as indicated by the p-value less than 0.05 ($df=85$, $p < .05$). Students who studied through simulation did statistically better than those who learned through more traditional methods.

Hence, the statistical analysis findings demonstrated that employing simulations had a notable effect on students' academic performance in chemical bonding. Figure 1 depicts the effect of simulation on students' academic achievement in chemical bonding. The experimental group outperformed the control group. This implies that using simulations increases students' ability in chemical bonding.

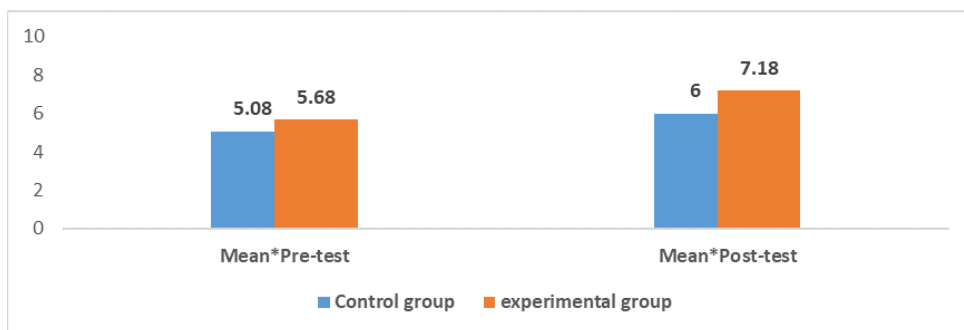


Figure 1 depicts the effect of simulation on students' academic achievement in chemical bonding.

Figure 2 depicts the improvement in performance for each student between the pre-and post-tests following the use of computer-assisted simulations. The 43 students who took part in the experiment in the experimental group reported a significant improvement in their academic performance overall.



Figure 2: Improvement in performance for each student in the experimental group

Upon analysis of qualitative data, it emerged that among the 20 students surveyed, half, or ten individuals, expressed that “computer-assisted simulation aided their comprehension of chemical bonding more effectively than traditional methods.” According to five students, constituting 25% of the sample, “computer-assisted simulation stands as a successful pedagogical tool, fostering motivation, self-assurance, critical thinking, and student interaction during chemical bonding lessons.” Despite the prevailing sentiment among the interviewed students favoring computer-assisted simulation as the superior teaching modality, a minority of five individuals (25%) acknowledged certain limitations, such as “the scarcity of available computers and the brevity of session durations.” Noteworthy restrictions include “the limited availability of computers and the short duration of sessions.”

Content Grasp by Students

The study's findings revealed that previous to the intervention, student achievement was comparable, with no statistical difference in mean scores between the control and experimental groups. However, following the intervention, it was clear that pupils exposed to cartoons, simulations, and videos outperformed their counterparts who received traditional

instruction. Consequently, a statistically significant contrast emerged in post-test outcomes between the traditionally instructed and simulation-exposed groups. The criterion of $p < .05$ indicates the rejection of the null hypothesis. These findings are consistent with the observations made by other researchers, such as Samuel and Ikwuka (2017), highlighting the substantial influence of simulation-based teaching in chemistry on students' academic achievements. Similarly, Nsabayeze *et al.* (2022) found that integrating simulations into lessons enhances student engagement, fosters active learning, and facilitates the acquisition of essential skills and knowledge in a conducive environment. Such findings underscore the transformative potential of simulations in education, offering personalized and immersive learning experiences. Moreover, the present study's outcomes resonate with existing literature on enhancing exploratory learning in online educational settings. Research indicates that computer simulations are frequently employed as pedagogical tools to cultivate students' abilities (Nsabayeze *et al.*, 2022). Exploratory learning, a teaching strategy that encourages students to explore unfamiliar concepts and discern connections between contextual knowledge and nascent ideas, has been associated with superior outcomes when facilitated through computer-assisted simulations (Kabigting, 2021). Furthermore, our findings corroborate previous research on teaching chemistry through computer simulations. It has been demonstrated that computer simulations are instrumental in enhancing students' chemistry achievement and promoting substantial learning, particularly among senior high school students (Oladejo, 2021b). Additionally, it was observed that computer-assisted simulations enhance students' satisfaction with tasks and bolster their confidence and comfort levels during simulation exercises (Mohsen, 2011). Moreover, collaborative opportunities facilitated by visual modes through computer-assisted simulations have been noted (Mohsen, 2011).

CONCLUSION AND RECOMMENDATIONS

This research has unveiled a significant correlation between the utilization of simulations and enhanced student competency in chemical bonding. With a calculated p -value of less than .05, it is evident that students who engaged with simulations outperformed their counterparts who employed more conventional learning methods. Furthermore, the statistical analysis underscores the profound contribution of simulations on students' academic advancement in chemical bonding. Beyond mere statistical significance, students exhibited a notably positive attitude, interest, and impression towards the incorporation of simulations into their learning experiences. This indicates a promising avenue for the integration of computer-assisted simulations as an effective pedagogical tool for fostering comprehension and performance in chemical bonding. Moreover, the study highlights the ancillary benefits of using simulations, including bolstered self-esteem and motivation among students. To leverage these advantages fully, it is recommended to adopt a flipped classroom approach. This approach allows students ample time to explore simulations independently before class, thereby enabling classroom sessions to be dedicated to interactive discussions. In this setting, the teacher's role transitions to that of a facilitator, adept at addressing any misconceptions students may encounter. Looking ahead, it is imperative to expand the scope of research by involving additional scholars and employing larger sample sizes. Such collaborative efforts can yield more comprehensive insights into the efficacy of computer-assisted simulations in chemistry education. Additionally, educational stakeholders are urged to prioritize the provision of adequate computing resources in schools, ensuring both students and chemistry teachers have access to the tools necessary for integrating simulations into the curriculum seamlessly. By embracing these recommendations, educational institutions can foster a more dynamic and effective learning environment conducive to student success in chemical bonding and beyond.

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