Forum for Education Studies 2023; 1(1): 308.
Original Research Article

The effect of e-learning-assisted instruction on students' achievement in chemistry

Juliana Nkiru Nnoli*, Felicity Uju Onwudinjo

Department of Chemistry, Nwafor Orizu College of Education Nsugbe, Ukwu-Abwa 432108, Anambra, Nigeria

*** Corresponding author:** Juliana Nkiru Nnoli, nkejul@yahoo.com

ARTICLE INFO

Received: 9 November 2023
Accepted: 20 November 2023
Available online: 28 December 2023

doi: 10.59400/fes.v1i1.308

ABSTRACT: This study investigates the impact of e-learning on students' achievement in chemistry, guided by three research questions and one hypothesis. Using a quasi-experimental pretest-posttest design with a non-randomized control group, 21 Senior Secondary School Two (SS2) chemistry students from four coeducational schools in Nnewi North were randomly selected. Data collection involved a Chemistry Achievement Test (CAT) sourced from WAEC past questions, a Computer Assisted Instructional Package (CAIP), YouTube, and the Chemistry Performance Test (CHEMPET). Instrument reliability, verified through Cronbach alpha procedures, yielded a value of 0.83. Analysis of the data, employing mean, standard deviations, and a significance level of 0.05 in the t-test for the hypothesis, revealed that students using e-learning performed better on post-tests and knowledge retention exams. Notably, female students outperformed males in e-learning-supported teaching. The study underscores the significant difference in performance between male and female pupils exposed to e-learning. Recommendations emphasize the importance of supporting educational computer programs like e-learning for effective teaching and learning of chemistry, calling on curriculum designers, policymakers, and educators to integrate such practical approaches.

KEYWORDS: e-learning assisted instruction; chemistry; students' achievement; learning chemistry

1. Introduction

The term "education" refers to a deliberate, conscious, or unconscious psychological, social, scientific, and philosophical process that aims to maximize societal growth as well as the greatest possible development for each person[1]. Chazan[2] concurs that education is an intentional endeavor aimed at accomplishing specific objectives, particularly the dissemination of information. According to the American Heritage Dictionary[3], the academic study of the procedures and activities used in teaching and learning, along with the social structures engaged in these procedures. The essential and sufficient conditions of education are defined by Peters[4] as the transfer of information and understanding in a way that is ethically acceptable and in line with the interests of the students. Ensuring that pupils meet the specified learning objectives is a constant goal in education.

In education, the reciprocal relationship between learning and teaching is pivotal. Instructors employ diverse pedagogies to cultivate active learners[5,6]. Education's primary goal is to motivate individuals, providing tools for intellectual development, workforce readiness, societal contribution, personal fulfillment, and knowledge application[7]. This paper asserts that learners' acquisition of chemical knowledge, mastery of scientific methods, and adoption of scientific values can notably contribute to entrepreneurial education. Ultimately, this synergy is envisioned to propel Nigeria's industrial and sustainable development, emphasizing the transformative power of education in shaping individuals and fostering societal progress.

The following are only a few of the numerous obstacles that face teaching children fundamental chemical knowledge and abilities in schools: One of the most challenging issues facing Nigerian chemistry education is a manpower deficit. There is a great need for skilled workers in chemistry, particularly at the secondary school level, yet few of them are seen in the classroom because most of them would rather work for businesses, oil firms, or other more promising fields. The success of any educational program is greatly enhanced by teachers who possess both vocational qualifications and subject-matter competence[8]. Developing scientifically literate people who are highly competent in logical thought and behavior is the main objective of science education[9]. This aligns with the goals of scientific education, which include enabling students to investigate and examine their surroundings and provide an explanation for basic natural events. cultivate scientific attitudes such as objectivity, curiosity, and critical thinking; use science's knowledge and skills to solve real-world issues; build self-reliance and confidence via science's problem-solving exercises; and much more.

Within natural science, chemistry examines the makeup, structure, and transformations of matter[10]. In the Nigerian education system, chemistry is one of the science courses offered to senior secondary school students. It is a crucial subject needed as a prerequisite for science-related courses like chemical engineering, pharmacy, and medicine, to name a few. Students are encouraged to pursue science-related courses in Nigeria since there is a stronger focus on science and technical advancement. On the other hand, it is well known that chemistry is a subject that many secondary school students in Nigeria fail. According to Blakemore et al.[11], studies have revealed the most challenging chemistry topics, which include organic chemistry, acids, bases, and salts; chemical kinetics; equilibrium chemical; bonding structure; periodicity; and atomic structure, in descending order of difficulty. Danso[12] posits that the reasons behind students' difficulties in grasping these challenging subjects are broad and abstract, the vocabulary is complex, and the teachers have not provided students with relatable real-world examples.

According to Lawal et al.'s[13] comment, low performance in chemistry can frequently be linked to low practical work scores. Traditional teacher-driven learning methods are becoming more participatory, self-directed, and adaptable to the students' requirements, interests, styles, and skills due to the increasing integration and usage of e-learning. Recently, it has evolved into a venue for engaging pupils in hands-on learning. Dahiru[14] drew attention to the research on the trend of low student accomplishment in chemistry, explicitly linking it to a lack of instructional resources in schools due to inadequate budgets. Principals have a significant issue since they cannot supply instructors with sufficient teaching resources.

Millions of videos have been categorized as instructional on the website; many of them have been submitted by educators, students, and researchers[15]. It is also an internet platform for public communication. All registrants can submit and view videos on the website for free. Anyone can see the uploaded movies as well. The films range in quality from beginner to highly polished, including instructional videos. Due to its popularity, e-learning has emerged as one of the most popular websites and vast educational material resources. E-learning should be utilized in e-learning as it may be a terrific learning tool that genuinely benefits students. It is not only intended for digital amusement. They are often utilized to present and clarify a few new ideas to the class while also showing material or, at the very least, recommending certain websites. Students can watch e-learning on demand or at their convenience. The student can watch these videos as many times as they like, which will aid in the learner's achievement of learning objectives as a result of various learning processes that are indicated in the learner's cognitive mental activity and measured by the level at which he performs when asked to take a standardized examination[9].

Functional groups and hydrocarbons were selected for the study on the effect of e-learning-assisted instruction in chemistry due to their foundational importance and real-world applications. These concepts are fundamental in organic chemistry, influencing the properties of molecules[16]. The subjects also have practical relevance in pharmaceuticals, polymers, and energy production, enhancing their significance in daily life. Moreover, students often struggle with the abstract nature of these topics, making them suitable for assessing the efficacy of e-learning in overcoming comprehension challenges[17]. The visual and interactive nature of e-learning aligns well with these subjects, allowing for dynamic presentations and virtual manipulations[18]. Overall, investigating the impact of e-learning on functional groups and hydrocarbons provides insights into optimizing technology integration in chemistry education, addressing foundational concepts with broad implications.

2. Statement of the problem

There are many topics in chemistry that appear abstract and might be challenging to explain during education. Because most instructors no longer employ visual aids as teaching resources, educators are pressured to find new and creative ways to bring abstract concepts to life. These directly impact learning outcomes and provide several obstacles to the teaching and learning process. The teaching profession offers many options to improve students' academic performance. While many instructional materials are simple for students to understand, others need additional strategies to ensure that significant learning goals and objectives are fulfilled. However, when used skillfully in instructional delivery, mobile and stationary visual aids can improve teaching quality.

The motivation for studying the effect of e-learning-assisted instruction on students' achievement in chemistry stems from the evolving landscape of education and the increasing integration of technology. As noted by Azonuche[19], traditional teaching methods may not fully engage students, especially in complex subjects like chemistry. E-learning offers a promising avenue to enhance learning experiences, providing interactive and multimedia resources that cater to diverse learning styles[20]. However, despite the potential benefits, there is a noticeable gap in understanding how effectively e-learning impacts academic achievement in chemistry specifically. Previous research by Raja and Najmonnisa[21] suggests that the effectiveness of technology-enhanced learning is contingent on various factors, including the nature of the subject and the design of the instructional materials. Consequently, a focused investigation into the influence of e-learning on chemistry education is warranted to fill this gap. Therefore, the main goal of this study was to ascertain how students' performance in secondary school chemistry classes was impacted by e-learning-supported instruction.

3. Purpose of the study

Therefore, the main goal of this study was to ascertain how students' performance in secondary school chemistry classes was impacted by e-learning-supported instruction. In particular, the goal of the study is to ascertain:

1) Ascertain whether there is a notable disparity in the academic performance of students in chemistry when instructed on the functional group through e-learning as opposed to those taught through an improved conventional teaching approach.
2) Determine whether there are significant variations in students' academic performance when they are instructed in the concept of hydrocarbons through e-learning compared to those instructed through an improved conventional teaching approach.
3) Identify any significant disparities in the academic accomplishments between male and female students who have been instructed in the functional group through e-learning.

4. Research questions

1) Does the academic performance of students in chemistry differ significantly when learning about functional groups through e-learning compared to an enhanced conventional approach?
2) Are there notable differences in students' academic performance in the concept of hydrocarbons through e-learning compared to an improved conventional teaching method?
3) Are there significant disparities in academic achievements between male and female students instructed in the functional group through e-learning?

Research hypothesis

There is no significant difference in the mean achievement scores of male and female students taught the functional group using e-learning.

5. Methods

A quasi-experimental, pre-test, post-test, non-equivalent, non-randomized control group design was used in the study. Quasi-experimental refers to a research design that shares similarities with experimental designs but lacks the random assignment of participants to treatment and control groups[22]. Unlike true experimental designs, where participants are randomly assigned, quasi-experimental designs involve the use of naturally occurring groups or non-randomized allocations[23]. A 2 × 2 factorial design is used in the design. The two treatment levels in this study are conventional instruction (control group) and cooperative e-learning-assisted instruction (experimental group 1), as well as the two gender levels (male and female). The study's sites were selected as public secondary schools in the Nnewi North Local Government Area of Anambra State. All eight secondary school pupils in the Nnewi North local government district made up the study's population. The selection of the Nnewi North Local Government Area in Anambra State as the geographical area for the study stems from strategic considerations. This specific choice was driven by factors such as the accessibility of schools, cooperation from educational authorities, and the researcher's familiarity with the region.

The sample included (twenty-one) 21 Senior Secondary School Two (SS2) chemistry students randomly drawn from four co-educational schools. The research instrument used for the study was the Chemistry Achievement Test (CAT). It consisted of 20 items of multiple-choice test questions for section A. Section B consists of 5 items. The instruments for this research were the treatment instrument "Computer Assisted Instructional Package (CAIP)" and YouTube and the test instrument, "Chemistry Performance Test (CHEMPET)". The treatment instrument, Computer Assisted Instructional Package (CAIP) on Chemistry, was a self-instructional, interactive package lasting 1.5 h for an average student. It had two lessons divided into sections. The bundle covers the themes of functional groups and introduction to hydrocarbons found in Nigeria's senior school chemistry curriculum. It was created by the researchers using YouTube and Flash, which is written in hypertext with the help of a qualified programs developer. Using Cronbach alpha methods, a reliability coefficient of 0.83 was determined.

The CHEMPET exam consisted of ten open-ended items derived from previous chemistry problems from the West African Examination Council's (WAEC) Senior Secondary Certificate Examination. A table of specifications encompassing the six levels of the cognitive domain of learning served as the basis for the test's content. Two chemistry professors and a psychology department specialist verified the face and content validity of the instrument, and their suggestions and critiques helped to make the final edition of the instrument better. The CAT was used as a pre-test for the experimental and control groups.

Next, using a web browser (Firefox or Explorer), the students in the first experimental group experienced e-learning installed on desktop computers, and the students in the second experimental group experienced identical content while working on desktop computers in groups of four. Other programs, such as games and internet access, were turned off. The e-learning format was taught to the experimental group of students under the instructor's guidance for a sufficient amount of time for them to become acquainted with the navigation buttons and utilize the package on their own. They were also urged to take as many notes as possible in case they needed them for the post-test. Students in the control group learned the same material as the experimental groups, but using a traditional teaching approach. They received their education in a traditional classroom setting. The overhead projector, charts, and chalkboard were the teaching aids in the classroom. Every group received therapy for a total of five weeks. Following the therapy, the CAT—reorganized as a post-test—was administered to the two groups.

As per the method of data analysis, mean and standard deviation were employed to analyze the average performance and variability among students receiving e-learning-assisted instruction in chemistry. The mean calculated the average scores in post-tests and knowledge retention exams, offering an overview of overall performance. The standard deviation assessed the spread of scores, indicating the level of variability. Additionally, the t-test determined the statistical significance of performance differences between students who received e-learning and those who did not, contributing to the assessment of the instructional method's effectiveness.

6. Results

Research question 1: Does the academic performance of students in chemistry differ significantly when learning about functional groups through e-learning compared to an enhanced conventional approach?

Table 1 below shows that the experimental group's mean was 19.82, while the control group's mean was 8.10. Consequently, the experimental group outperformed the control group.

Table 1. The mean scores and standard deviation in a functional group.

	N	*Mean (X)*	*SD*
Experimental group	11	19.82	4.06
Conventional group	10	8.10	3.81

Research question 2: Are there notable differences in students' academic performance in the concept of hydrocarbons through e-learning compared to an improved conventional teaching method?

Table 2 below shows that the experimental group's mean was 20.63 and the control group's mean was 9.10. Consequently, the experimental group outperformed the control group.

Table 2. The mean scores and standard deviation in hydrocarbons.

	N	*Mean (X)*	*SD*
Experimental group	11	20.63	4.41
Conventional group	10	9.10	3.81

Research question 3: Are there significant disparities in academic achievements between male and female students instructed in the functional group through e-learning?

According to **Table 3** below, the mean for female students was 41.70, whereas the mean for male students was 15.20. As a result, the female students outperformed the male pupils.

Table 3. The mean scores and standard deviation of the functional groups of male and female students.

	N	*Mean (X)*	*SD*
Female	11	41.70	7.73
Male	10	15.20	6.18

Research hypothesis: There is no significant difference in the mean achievement scores of male and female students taught the functional group using e-learning.

Table 4 shows the mean achievement scores of male and female students taught in the functional group using e-learning. Based on the computed *t* value of 8.72–2.093 t-critical, the researcher concludes that there is a significant difference in gender performances and rejects the null hypothesis.

Table 4. Mean achievement scores of male and female students taught in the functional group using e-learning.

	N	*Mean (X)*	*SD*	*DF*	T-CAL	T-CRIT
Female	11	41.7	7.73	19	8.72	2.093
Male	10	15.2	6.18			

7. Discussion

E-learning's favorable impact on the academic performance of chemistry students is underscored by a wealth of research, as evidenced by Collins[24], who emphasizes the consistent enhancement of student achievement through e-learning and instructional media. This finding is in line with the present study's outcome, which also indicates a positive influence on success levels. In contrast, Nuseir et al.[25] observed that traditional classroom instruction alone yielded less significant improvements compared to a hybrid approach combining traditional teaching with specific internet resources. This supports the idea that integrating e-learning with traditional methods can lead to superior academic achievements. Adding to this body of evidence, Burin et al.[26] conducted a related study revealing that students who engaged with e-learning resources exhibited higher comprehension levels in organic chemistry compared to those relying solely on traditional teaching methods. The study underscores the synergistic benefits of blending conventional instruction with technology-assisted learning. Additionally, in a comprehensive meta-analysis, Dahiru[14] found a substantial positive correlation between student involvement in e-learning and academic success in chemistry. These diverse studies collectively affirm that the integration of e-learning significantly contributes to improved chemistry education outcomes, fostering a more engaged and successful student learning experience.

Enhancing online classrooms with visual aids, such as images, graphics, and engaging films, can significantly elevate the learning experience. Research by Young[27] supports the notion that incorporating multimedia elements into online education enhances engagement and comprehension. Visual aids not only capture students' attention but also cater to diverse learning styles, making educational content more accessible and stimulating[28]. Furthermore, effective teaching strategies play a crucial role in the success of online learning. Instructors can promote a positive learning experience by posing questions, providing prompt answers, and offering clear explanations. This interactive approach, according to Kuit and Osman[29] fosters student engagement and a deeper understanding of the material. Such findings align with the study's conclusion that online learning consistently yields favorable student outcomes. The research also emphasizes the efficacy of online e-learning in teaching chemical concepts. Even when there is a desire to integrate traditional classroom instruction with online materials, the study suggests that students still perform well in understanding chemical ideas through online platforms[30]. This underscores the adaptability and effectiveness of online education, debunking concerns about its compatibility with certain subjects, such as chemistry[31]. Overall, the combination of visual aids and effective teaching methods contributes to the positive impact of online learning on students' academic performance.

The paradoxical relationship between academic performance and self-concept in science, particularly chemistry, among boys and girls is an intriguing aspect of educational psychology. While boys tend to perform on par with girls in science success across many countries, there is a notable difference in their self-concept within the field of chemistry. Research by Jatto[32] suggests that, counterintuitively, girls often exhibit higher confidence in their ability to study the sciences, including chemistry, compared to boys. This phenomenon raises questions about the underlying factors contributing to this disparity. Jatto proposes that socialization processes and classroom experiences may play a pivotal role. Despite having higher self-confidence, Jansen et al.[33] noted that girls may still face challenges such as poor self-esteem and passive-dependent behavior, potentially resulting from societal expectations and gender norms. These factors could influence their perception of chemical ideas positively, creating an environment where they feel more empowered and capable in the study of chemistry[34,35]. These findings challenge traditional stereotypes and underscore the importance of considering not only academic performance but also the psychological aspects of self-concept when addressing gender disparities in STEM fields[36]. It prompts educators and policymakers to delve deeper into the classroom dynamics and societal influences that contribute to shaping students' confidence and perceptions, fostering a more inclusive and equitable learning environment for both boys and girls.

8. Conclusion

Upon introduction to the concepts of organic chemistry, the students experienced an enhanced level of success. Consequently, the research illustrates that the utilization of e-learning contributes to an improvement in students' academic performance. Additionally, the research indicates that students can acquire a better understanding of chemical concepts through the use of online e-learning materials. This holds true despite the acknowledged need and preference for a blend of traditional classroom instruction and online resources such as YouTube videos.

Post-therapy, female students surpassed their male counterparts in mean scores, showcasing a notable performance difference between the genders. Furthermore, the study establishes that, irrespective of the learning environment, a significant disparity in mean scores exists between male and female students' academic performance. The study's limitations include unequal technology access among students, instructor variability, and cultural and linguistic biases. Variations in technology access may affect the uniform impact of e-learning, and differences in instructor proficiency could introduce inconsistency. Cultural and linguistic diversity might not be adequately addressed, and reliance on self-reported measures may introduce response bias.

9. Recommendations

1) Based on the findings, educators should select curricular materials that not only enhance students' skills but also ignite their interest in learning activities. This is particularly crucial given the association between e-learning and differentiated teaching methods, allowing instructors to tailor their approach to individual student needs.
2) In light of the study's results, teachers are encouraged to explore optimal settings that foster student receptivity to e-learning, thereby enhancing the overall learning experience. Considering diverse learning environments can help educators identify approaches that cater to the unique demands of each student, promoting a more engaging and enjoyable learning atmosphere.
3) The study suggests modifying instructional activities to incorporate technology-based learning, such as e-learning, in lieu of traditional chemical practical elements. This adaptation aligns with the positive outcomes observed in the study and underscores the potential benefits of integrating e-learning into the classroom for more effective chemistry education.

Author contributions

Conceptualization, JNN and FUO; methodology, JNN; software, FUO; validation, JNN and FUO; formal analysis, JNN and FUO; investigation, JNN and FUO; resources, JNN and FUO; data curation, JNN and FUO; writing—original draft preparation, JNN and FUO; writing—review and editing, JNN and FUO; visualization, JNN and FUO; supervision, JNN and FUO; project administration, JNN and FUO. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors claim no conflict of interest in the paper.

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