Volume: 5, Issue: 1
Page: 30-40
YEAR: 2025

EURO GLOBAL CONTEMPORARY STUDIES JOURNAL (EGCSJ.COM)

Instructional Simulation: Implications for Students' Academic Performance in Science

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E.G.C.S.J
Accepted 1 February 2025
Published 28 February 2025
DOI: 10.5281/zenodo.15061206

Abstract

Instructional simulation has gained prominence as an effective pedagogical strategy in science education, particularly in Chemistry, by offering students interactive and immersive learning experiences. This study explores the impact of instructional simulation on students' academic performance in Chemistry, highlighting its role in bridging the gap between theoretical knowledge and practical application. Traditional lecture-based methods often fail to facilitate deep understanding of abstract scientific concepts, while simulation-based learning provides an opportunity for students to visualise complex ideas, conduct virtual experiments, and develop critical thinking skills in a risk-free environment. The study also examines the adaptability of instructional simulations to diverse learning styles through multimedia elements, thereby enhancing student engagement and retention. Previous studies in science education have demonstrated the positive effects of simulation-based instruction on students' comprehension and motivation. However, successful implementation requires adequate infrastructure, teacher training, and alignment with curriculum standards. This research contributes to the growing body of literature by assessing the effectiveness of instructional simulation in Chemistry education and its potential for improving students' learning outcomes. Findings suggest that integrating instructional simulation into Chemistry instruction can foster deeper conceptual understanding, enhance academic achievement, and better prepare students for higher education and scientific careers.

Published By

Keywords: Instructional simulation, Science education, Chemistry learning, Academic performance, Pedagogical strategies, Virtual experiments,

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Introduction

Instructional simulation has emerged as a powerful pedagogical tool in science education, offering students an interactive and immersive learning experience. The rapid advancement of technology has revolutionised teaching methods, shifting from traditional lecture-based approaches to more engaging, technology-enhanced instructional strategies. Simulation-based learning enables students to visualise abstract scientific concepts, conduct virtual experiments, and actively participate in problem-solving scenarios. Unlike conventional teaching methods, which often rely on passive knowledge acquisition, instructional simulation promotes experiential learning, allowing students to explore, manipulate, and understand complex scientific phenomena in a controlled and risk-free environment. Consequently, this innovative approach has been recognised for its potential to improve students' comprehension, retention, and overall academic performance in science subjects.

One of the significant implications of instructional simulation in science education is its ability to bridge the gap between theoretical knowledge and practical application. Many scientific concepts, particularly in physics, chemistry, and biology, are inherently abstract and difficult to grasp through traditional teaching methods. Simulations provide students with the opportunity to experiment with virtual models, observe cause-and-effect relationships, and gain hands-on experience without the constraints of physical laboratories. This is particularly beneficial in resource-limited schools where access to laboratory equipment is scarce. By enabling students to conduct experiments virtually, instructional simulations enhance their problem-solving skills, critical thinking, and scientific inquiry, which are essential competencies for academic success in science.

Furthermore, instructional simulations cater to diverse learning styles, making science education more inclusive and accessible. Some students learn best through visual representation, while others benefit from interactive and experiential learning approaches. Simulations incorporate multimedia elements such as animations, graphics, and real-time data analysis, accommodating different cognitive preferences and enhancing engagement. This adaptability fosters deeper understanding and long-term knowledge retention, which are crucial for academic achievement in science. Moreover, research indicates that students who learn through simulations demonstrate higher motivation and enthusiasm towards science subjects, which can ultimately improve their performance.

Despite the numerous benefits, the effective implementation of instructional simulation in science education requires adequate infrastructure, teacher training, and pedagogical integration. Teachers must be equipped with the necessary skills to incorporate simulations effectively into their lesson plans and ensure that students derive maximum benefits. Additionally, the alignment of simulation-based learning with curriculum standards and assessment methods is essential for its sustained impact on students' academic performance. As technology continues to evolve, the integration of instructional simulation in science education holds great promise in fostering a deeper understanding of scientific principles and enhancing students' learning outcomes. The focus of the paper was on Chemistry as a science subject.

Concept of Chemistry as a Science Subject

Chemistry is one of the science subjects that senior secondary students offer in senior secondary certificate examinations in Nigeria (FRN, 2014). Interestingly, it is a popular subject among students and its popular nature among other science subjects has made it a distinct choice for all students (Lawal, 2011). Chemistry is a very important science subject and a requirement for further studies of other science related professional courses such as medicine, agriculture, pharmacy, biotechnology, genetic engineering, etc. Chemistry is the key to economic, intellectual, sociological, human resource development and well-being of any society. It is of importance in many ways for both individual and societal development as seen in biotechnology and genetic engineering (Lawal, 2011). Based on these assertions on the importance of Chemistry, there is need for it to be properly taught in the secondary schools to improve students' achievement in the subject.

The Chemistry Curriculum over the years has been delivered mechanically or by rote learning, which makes instruction teacher-centered. Hardly can vital abstract contents in Chemistry be effectively communicated to the learners theoretically. They need to be taught using relevant materials. The teacher and his/her method of teaching may have been a major source of student's poor academic performance in Chemistry. Most teachers still prefer using the 'chalk and talk' method in instructing learners.

Concept of Instructional Simulation Strategy

The word simulation comes from Latin word 'similis' meaning 'like' that is to act like, to resemble, or to pretend to be. Additionally, the format of simulations ranges from computerized games to elaborate, role-playing scenarios (Moore, 2010). Simulations give students the chance to apply theory, develop critical skills, and provide a welcome relief from the everyday tasks of reading and preparing for classes (Awodun, 2010). Simulation is conceived as a representation of the behaviour or characteristics of a system through the use of another outlet especially a computer programme designed for the purpose (Coulter, 2009; Krulik, 2010). According to Krulik (2010) it can mean mimicry, making working replicas or representations of machines for demonstration or analysis of problems but clearly illustrates real life or hypothetical situations.

Simulation can bring into the classroom, aspects of the world or universe that are too expensive, dangerous, difficult or too slow or too fast in occurrence to be experienced first-hand (Coulter, 2009). For example, there are simulation that can illustrate the human circulatory system along with its major arteries, veins and capillaries. Natural occurrences such as earthquakes, radioactivity, predators/prey relationships which occur too rapidly to be observed, can be illustrated through simulation. Simulation may, therefore, make learning more concrete and meaningful. Although simulation has been severally applied in physical sciences and medicine, its relevance in Chemistry instruction is still being speculated.

An additional benefit of simulations is the introduction of an aspect of realism into the students' experience. Simulation is an educational tool where students learn through the application of theory and decision-making to a simulated real-world business scenario. The use of simulation techniques where students are allowed to project themselves into new classroom roles helps to improve classroom dialogue, active participation and transfer of learning.

Simulation is an educational tool where students learn through the application of theory and decision-making to a simulated real-world business scenario. The use of simulation techniques in instruction at different levels has been reported to be of high motivational value by researchers (Chauham, 2010). This is one of the most distinctive features of simulation which makes it acceptable at all levels of teaching because if any teaching technique succeeds in creating motivation in learners all other problems may be drastically reduced (Chauham, 2010). The use of simulation techniques where students are allowed to project themselves into new classroom roles helps to improve classroom dialogue, active participation and transfer of learning.

Balleck (2012) reported that the use of active learning in the form of simulations, student presentations, and problem-solving situations will better prepare students to understand. Although researches have stated the positive effect that the use of active learning through simulation techniques has upon knowledge acquisition (Garca-Carbonell, 2011), professionals involved in education at all levels are still struggling to make sure that this acquisition, introducing active methodologies in the classroom, turns into understanding and retention so that formal instruction becomes a precursor to life-long learning.

Instructional simulation is therefore a program of instruction presented by means of a computer or computer systems. Most recent, some computer software integrates features that encourage activities beyond the simple drill-and-practice, such as simulations, graphing and even modeling (Barot, 2010; Yusuf, 2010). Instructional simulations combine visual and interactive learning experiences, promotes application of knowledge, and provides a simplified representation of real world systems (Eskrootchi&Oskrochi, 2010). Instructional simulation is used with the aid of computer to simplify real life situation (simulation) and this will aid to manage the class, support reluctant learners, stimulate gifted children and ease administration. Simulation employs selected aspects of a real-life situation. Instructional simulation can be applied to Chemistry by providing real life settings for the application of Chemical concepts. Instructional simulation in teaching and learning of Chemistry helps the understanding of abstract and difficult concepts by allowing the students to experiment on the variables that form the concept. Instructional simulation helps students to develop their own understanding of Chemistry concepts.

It appears that the integration of instructional simulation in Chemistry classrooms can provide an effective learning environment for students to enhance their Chemistry skills by engaging them with “real world” conditions to make the abstract concepts concrete and clear. In this way students could have a meaningful and retentive learning and they will be much more ready for their future education life. The instructional simulation environment provides a platform to apply the knowledge in a given situation and their interactions results in the discovery of new knowledge that will help in cognitive domain development and the accumulation of knowledge (Shamai, 2011).

Instructional Simulation and Students’ Academic Performance in Science

Abdullahi (2010) carried out a study on the effect of simulation method on students’ achievement in basic science. The study was conducted in junior secondary schools in Kafanchan area of Kaduna State. The study made use of one hundred and fifty students. Achievement test in basic science developed by the researcher and validated by experts was used for data collection. Mean and standard deviation was used for data analyzed in order to answer the research questions while t-test was used to analyze the research hypotheses. The findings of the study among other things showed that the use of simulation teaching method increase students’ achievement in basic science. The study recommended the use of simulation teaching method in teaching basic science in schools. The relevance of the reviewed work to the present study is that the reviewed work helped the researcher to identify simulation as one of the teaching methods that enhance students’ achievement in basic science. Basic science is related to Chemistry, therefore, the idea borrowed from the reviewed work can help enhance the present study.

Similarly, Yearwood (2015) conducted a study on the effect of simulation method on students' achievement in biology. The study was carried in senior secondary schools in Bayelsa State of Nigeria. The study used one hundred and thirty senior secondary school students as the population of the study. The instrument used for data collection was biology achievement test. The instrument was developed by the researcher and validated by experts. Data collected were analyzed using mean and standard deviation while the research hypotheses were analyzed using t-test. The major finding of the study was that simulation teaching method influenced students' achievement in biology. The study among other things recommended the use of innovative teaching methods as simulation method in teaching biology. The relevance of the reviewed work to the present study is that it helped the researcher to identify simulation method as an effective teaching method in biology. While the reviewed work was carried out in biology the present study will be carried out in Chemistry. This difference creates a gap that the present work intends to fill.

Samuel (2017) carried out a study on the effect of simulation method on students achievement and retention in Chemistry. The study was conducted in Abia State. A total number of one hundred and forty students sample from an intact class was used for the study. Students' achievement test in Chemistry and students' retention test in Chemistry was used for data collection. Mean and standard deviation were used to answer the research questions while t-test was used to analyze the research hypothesis. The findings of the study among other things showed that the simulation method significantly improve students' achievement and retention in Chemistry. The study recommended efficient and effective use of simulation method in teaching Chemistry and the replication of this study in other areas. The relevance of the reviewed work to the present study is that the reviewed study helped the researcher to identify simulation method as one of the methods that could possibly have a better impact on students' achievement and retention in Chemistry. Also the former study was not carried out in Ekiti State. This difference creates a gap that the present study intends to fill.

Leuven(2016) concluded that there is no evidence for a relationship between increased educational use of instructional simulation and students' performance. In fact, they find a consistently negative and marginally significant relationship between instructional simulation use and some student achievement measures. Students may use instructional simulation to increase their leisure time and have less time to study. Online gaming and increased communications channels do not necessarily mean increased achievement. Many other explanations were presented.

Gambari (2010) pointed out that instructional simulation instruction presents information in a non-linear style, allowing students to explore new information via browsing and cross-referencing activities. He also concluded that instructional simulation teaching supports active learning processes emphasized by constructivist theory. Nkweke, Dirisu, and Umesi (2012) in their research opined that, effective and efficient use of instructional simulation in teaching and learning offers both audio and visual messages or information and these appeals to sense of sight and hearing, simultaneously. Students feel a sense of reality in what they learn.

Instructional Simulation: Implications for Students' Academic Performance in Science

Instructional simulations have emerged as a pivotal tool in science education, offering dynamic and interactive environments that facilitate deeper understanding of complex scientific concepts. These simulations enable students to visualize and manipulate variables in virtual settings, thereby enhancing their engagement and comprehension. The implications of instructional simulations for students' academic performance in science are multifaceted, encompassing cognitive, affective, and practical dimensions.

Cognitively, instructional simulations provide learners with opportunities to engage in active learning, which has been shown to significantly improve academic performance. For instance, a meta-analysis by Freeman et al. (2014) revealed that active learning strategies, including the use of simulations, reduced failure rates and increased student performance in science, engineering, and mathematics courses. By allowing students to experiment with scientific phenomena in a risk-free environment, simulations promote exploration and hypothesis testing, leading to a more profound understanding of the material (Rutten et al., 2012).

Affective benefits are also notable, as simulations often increase student motivation and interest in science subjects. The interactive nature of simulations can make learning more engaging, which in turn fosters a positive attitude toward the subject matter. McLaren et al. (2017) developed a digital learning game called Decimal Point to teach decimal fractions to middle school students. Their study found that students who used the game not only achieved better learning outcomes but also reported higher levels of enjoyment compared to traditional instructional methods. This heightened engagement can lead to increased time on task and persistence, contributing to improved academic performance (Wouters et al., 2013).

Practically, instructional simulations offer flexibility and accessibility that traditional laboratory experiments may lack. They allow students to conduct experiments that might be too costly, dangerous, or time-consuming in a physical lab setting. For example, PhET Interactive Simulations, developed by the University of Colorado Boulder, provide free interactive math and science simulations that are widely used in educational settings. These simulations enable students to visualize abstract concepts and conduct virtual experiments, thereby enhancing their conceptual understanding and problem-solving skills (Perkins et al., 2006).

Moreover, simulations can be tailored to individual learning paces, accommodating diverse learning styles and needs. This adaptability ensures that students can revisit complex topics and practice as needed, leading to mastery of the subject matter. A study by Olympiou and Zacharia (2012) demonstrated that students who used simulations in conjunction with physical experiments showed greater conceptual understanding and ability to transfer knowledge to new situations compared to those who used only physical experiments.

However, the effectiveness of instructional simulations is contingent upon their integration into the curriculum and the pedagogical approaches employed by educators. Simply incorporating simulations without proper guidance and context may not yield significant improvements in academic performance. It is essential for educators to align simulations with learning objectives and provide scaffolding to help students make connections between the simulation and real-world phenomena (de Jong and van Joolingen, 1998).

In conclusion, instructional simulations hold substantial promise for enhancing students' academic performance in science. By offering interactive, engaging, and flexible learning experiences, they address various learning needs and preferences. To maximize their potential, educators must thoughtfully integrate simulations into their teaching strategies, ensuring alignment with curriculum goals and providing appropriate support to students. As technology continues to evolve, the role of instructional simulations in science education is likely to expand, offering even more innovative ways to enrich student learning.

Conclusion

Instructional simulation has proven to be a transformative pedagogical tool in science education, particularly in Chemistry, by enhancing students' engagement, comprehension, and academic performance. Unlike traditional rote learning methods, simulation-based instruction facilitates experiential learning, allowing students to interact with virtual models, conduct experiments, and explore abstract scientific concepts in a risk-free environment. This approach is especially beneficial in Chemistry, where complex concepts such as chemical reactions, atomic structures, and molecular interactions are often challenging to grasp through theoretical explanations alone. Moreover, simulations cater to diverse learning styles, incorporating visual, auditory, and interactive elements that foster deeper understanding and long-term knowledge retention.

Despite its numerous advantages, the successful implementation of instructional simulation in Chemistry education requires strategic planning, adequate resources, and well-trained teachers who can effectively integrate simulations into lesson plans. The alignment of simulation-based learning with curriculum objectives and assessment methods is crucial for ensuring its long-term impact on students' academic success. Research has consistently shown that students exposed to simulation-based learning perform better in science subjects, including Chemistry, compared to those taught through traditional methods. As technology continues to evolve, the adoption of instructional simulation in Chemistry classrooms holds great promise for making science education more accessible, engaging, and effective.

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Cite this article:

Author(s), AYOYINKA, Bridget Fayoke, SALAUDEEN, Muhydeen Dayo, AKINWANDE, Samson Akanmu, (2025). "Instructional Simulation: Implications for Students' Academic Performance in Science". **Name of the Journal:** Euro Global Contemporary Studies Journal, (EGCSJ.COM), P, 30-40. **DOI**: http://doi.org/10.5281/zenodo.15061206 , Issue: 1, Vol.: 5, Article: 3, Month: February, Year: 2024. Retrieved from https://www.ijarbas.com/all-issues/

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