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Influence of Computer-Based Laboratory Simulations (CBLS) as a teaching Method on Secondary Schools Students' Attitudes and Performance towards Chemistry in Bomet County

Chepkorir Salome

Department of Curriculum and Instruction, School of Education, University of Eldoret, P. o. Box 1125, Eldoret, Kenya

Abstract

Chemistry education in secondary schools is a critical component of fostering scientific literacy and equipping students with the knowledge and skills necessary for their academic and future career pursuits as well as addressing the nation's developmental challenges. However, the subject has often been perceived as challenging by students, leading to disinterest and negative attitudes towards learning chemistry. Computer-Based Laboratory Simulations (CBLS) leverages technology to create virtual laboratory environments, allowing students to conduct experiments, analyze data, and explore chemical phenomena in a safe and interactive manner. By offering an alternative to traditional hands-on laboratory experiences, CBLS aims to make chemistry more accessible, captivating, and relevant for students. This research objective was to examine the effect of CBLS as a teaching method on students' attitudes and performance in chemistry in secondary schools within Bomet County, Kenya. The aim of this study is to investigate the potential of CBLS in enhancing students' engagement, attitudes, and academic achievements in the subject of chemistry. Constructivist theory by Jean Piaget guided the study. The study adopted positivism Philosophical paradigm and employed Quasi-Experimental Research Design. Solomon-Four Non-equivalent Groups Design was applied. The research took place in Bomet County, located in the southern part of the former Rift Valley Province of Kenya. The study involved a target population of 687 Form four students and 4 teachers from public secondary schools in Bomet County. The final sample size consisted of 369 participants, including 4 teachers who underwent interviews, 205 students who completed a questionnaire, and 160 students who participated in an experimental test. To select the 4 schools, a purposive sampling method was used based on the availability of computers. The schools were then randomly assigned to either the treatment group or the control group using a simple random sampling procedure. All the student groups were taught the same chemistry content, focusing on electro-chemistry. However, the experimental groups received instruction through CBLs, while the control groups were taught using regular teaching methods (RTM), which involved teacher demonstrations and lectures. Before implementing the CBLs treatment, a pre-test for both the control group II and experimental group I to measure their initial knowledge levels and establish a baseline was conducted. After four weeks of the study, all four groups underwent a post-test using the Students' Chemistry Achievement Test (SCAT). The SCAT had been previously validated by education experts and pilot tested to ensure its reliability. The data collected from the pre-test and post-test scores were subjected to statistical analysis using one-way ANOVA. CBLs had significant influence on attitude of students which enhanced performance in chemistry ($P<0.05$). The study concluded that CBLS had significant influence on achievement in chemistry since it assisted the learner to develop inquiry skills than RTM. The study recommended that schools should foster a positive and supportive learning environment that encourages students to embrace CBLS and develop a favorable

attitude towards technology-based learning. This can be achieved through collaborative group activities, interactive learning experiences, and continuous Teacher Training as well as address technological barriers in secondary schools in Bomet County.

Keywords: Students, chemistry, CBLS, performance, attitude, secondary schools, teaching

Correspondence: salomechepkorir@gmail.com

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Introduction

Chemistry is a science subject which is very crucial in Kenyan Secondary Curriculum (Chepkorir et al., 2014). It Is a fundamental subject for the synthetic industry, chemical engineering, agricultural science, textile technology, medical sciences, pharmacy, printing technology, to reference just a few (Dani, 2009). Excellent performance of chemistry in secondary schools is vital for individual students' personal growth and future opportunities. Additionally, it aligns with the achievement of SDGs and supports Kenya's national developmental priorities, contributing to the country's overall progress and prosperity (Mwangi & Mwangi, 2016). A scientifically literate populace is essential for driving innovation, research, and technological advancement in a country. Fostering excellence in chemistry education is essential for building a scientifically literate and innovative nation that can address global challenges and contribute to sustainable development (Zuin et al., 2021). However, the subject of chemistry has often been perceived as challenging and majority of learners have phobia for chemistry and thus seeing it as difficult to comprehend, a fact that is attributed to the subject's abstract nature and the technique (lecture approach) being applied by utmost number of the teachers in chemistry, in Kenya. Learners' anxiety for chemistry may be attributed to learner's perception of the complex nature of chemistry (Dani, 2009). Learners' anxiety for chemistry education progresses to interest loss in the sciences (Hu-Au & Okita, 2021). Effective teaching methodologies that increase learning must be devised and applied in the teaching of chemistry in order for good outcomes to be achieved.

In recent years, educators and researchers have been exploring innovative teaching methods to enhance students' attitudes and academic performance in chemistry (Sugano & Nabua, 2020; Folounrunso & Sunday, 2017). One such instructional approach gaining popularity is the use of Computer-Based Laboratory Simulations (CBLS). CBLS leverages technology to create virtual laboratory environments, allowing students to conduct experiments, manipulate variables, and observe chemical phenomena in a controlled and interactive manner (Sari et al., 2019; Ranjan, 2017). The use of computers in education has become unavoidable as an outcome of the fast growth of information and communication technologies. Using technology in education offers students with a more conducive learning environment, fosters interest and a learning-centered culture, and aids in increasing students' motivation. Technological instruments, notably computers, started to be employed in educational settings to create audio visual resources for instance, animation and simulation, leading to the creation of computer-based training methodologies (Haleem et al., 2022).

CBL is a contemporary technique of science instruction in a laboratory, with learners doing experiments that collect and transfer data straight to a computer (Trelease, 2016). A computer is employed as an instrument of laboratory transforming it into a powerful resource for measuring the tangible world. This is achieved by attaching some of the sensors to it and utilizing the computer's capacity for running the sensor data. This enables students to learn the numerous options that measure a wide range of phenomena in an innovative and subsidiary manner (Kiboss, 2005). The computer can then assist students in measuring, recording, and graphing values including location, force, light acceleration, speed, pressure, temperature, heart rate, response time, muscle signals, brain waves and numerous other occurrences. These measurements can be stored, studied more, or printed. CBLS make it simple for learners to conduct experiments and view facts presented as a histogram, line graph, or bar graph,

either individually or collectively (Kynigos & Argyris, 2004). CBLS has the ability to shift the focus of teaching laboratories away from mundane mechanical operations such as transcribing temperatures from thermometers or charting data and toward more creative components of science such as analysis, hypothesis, and experimentation (Hannel & Cuevas, 2018). Computer-simulated training allows learners to watch and participate with real-world experiences. Students can use problem-based simulations to test new models, monitor experiments, and increase their intuitive grasp of complicated processes (Daulay et al., 2020). Simulations may also be beneficial for imitating laboratories that would be impossible, impractical, costly, or too hazardous to perform in the real world (Vagale et al., 2022). Simulations can help with conceptual shift (Windschitl, 2000), give learners open-ended experiences (Sadler *et al.,* 1999), and deliver instruments for scientific inquiry (Stieff, 2003). Kiboss *et al.* (2002) observed that using CBI simulation to teach challenging concepts in Geography, Physics, Mathematics, and Biology was effective.

KNEC (2021; 2022) reports indicate that learners have been answering practical questions theoretically and performing poorly in questions that require use of process skills. Although the persistent poor results in questions that require process skills may be caused by many factors, non-use or ineffective use of the laboratory is the main cause since the science laboratory is the main environment where practical knowledge and specifically process skills are supposed to be acquired through practical activities. Consequently, there is reason to suggest that the laboratory either is being ineffectively used hence contributing to the poor results. Poor performance in chemistry among secondary school students as reflected in KCSE results has been a concern to educationists in Bomet County. The traditional approach to teaching chemistry often relies on theoretical lectures and limited opportunities for hands-on laboratory experiences, which may lead to challenges in fostering students' positive attitudes towards the subject and may not fully support their academic performance. To address these concerns, there is a need to explore alternative teaching methods that can enhance students' attitudes towards chemistry and improve their academic performance. CBLS is a means to bridge the gap between theory and practice, providing students with interactive and engaging virtual laboratory experiences. However, while there is growing interest in integrating CBLS into the chemistry curriculum, there remains a gap in empirical evidence on its effectiveness in enhancing students' attitudes towards chemistry and its impact on academic performance. Therefore, this study aims to investigate the influence of Computer-Based Laboratory Simulations (CBLS) as a teaching method on secondary schools' students' attitudes and performance towards Chemistry in Bomet County

Methodology

The study utilized the positivism philosophical paradigm and employed a Quasi-Experimental Research Design. This quantitative research method involves manipulating independent variables without random participant assignment to groups. It aims to compare two groups with different treatments to establish cause and effect relationships. The design involved an experimental approach along with the use of survey questionnaires and interviews. An experimental design is a robust approach used to investigate hypotheses and draw meaningful connections between dependent and independent variables (Creswell, 2013).

The target population for the study comprised all form four students in secondary schools in Bomet County, Kenya. The total number of Form four learners in selected schools was 687 and 4 Chemistry teachers from public Secondary Schools in Bomet County. In this study, the sample size comprised the sample for experimental group which had 80 students while the control group had 80 students and 4 Chemistry teachers. The sample also consisted of sample of 205 students which represent 30% of 687 total number of Chemistry students in the four schools who filled the questionnaire. This was obtained based on Mugenda and Mugenda (2003) concept of picking 30% where there was target population of 100 to 1000 respondents. This made a total sample size of 369 respondents.

Purposive sampling was adopted to select the four secondary schools, 4 chemistry teachers for interview and 40 Chemistry students based on the topic electrochemistry covered in form four. The data collection instrument chosen for this study was the Students Chemistry Achievement Tests (SCAT), which was developed and used to determine the mean achievement score in Chemistry. The assessment consisted of twelve structured questions related to electro-chemistry, a topic taught in Form four, as per the secondary school syllabus-volume two (KIE, 2002). This topic was chosen due to its reputation as one of the most challenging in chemistry (KNEC,

2022), and its suitability for computer-based laboratory simulations (CBLS) as a teaching technique. The question format, with short responses, was modeled after the KNEC chemistry paper one, which is commonly used at the secondary school level in Kenya (KNEC, 2005). The test questions were designed based on Bloom's taxonomy of educational aims in the cognitive domain (Bloom, 1956) and assessed the cognitive levels of knowledge, understanding, and application.

Formal teacher semi-structured interviews were carried out to obtain data on their reactions to the usage of CBLS. A pilot study was done to help guarantee the instrument's validity and reliability, particularly the questionnaire. The reliability of the tool was determined by disbursing it to the same subjects twice and determining the Cronbach coefficient between the results.

The achievement tests were administered before, to the experimental and control groups which were taught using CBLS and traditional method, respectively. Then similar exams were administered after students had been taught using the two methods and results were recorded and then analysed.

The data obtained from the questionnaire and chemistry achievement test were processed using SPSS version 21.0. Descriptive statistics, such as mean and standard deviation, were employed to present the impact of computer-based laboratory simulations on chemistry achievement. In addition, one way Analysis of Variance (ANOVA) was applied to evaluate the data obtained from the chemistry achievement test. Furthermore, the qualitative data gathered through interview schedules underwent content analysis to quantify and analyze the presence and relationship of certain themes. This method provided a systematic approach to interpret and draw insights from the qualitative information collected during the interviews.

Results and discussion

Response Rate

A response rate of 86.5% was obtained where 173 copies of 200 questionnaire were returned. This enabled the research to proceed with data analysis because over 80% response rate is excellent for analysis according to Mugenda and Mugenda (2003).

Reliability

Cronbach Alpha was used to test the reliability of questionnaire. The alpha co-efficient ranges from 0 to 1 and was used to elaborate the reliability of components extracted from items with two alternative responses; a value greater than 0.7 indicates that the questionnaire is reliable. Table 1 shows the results.

Table 1: Reliability of Instrument

Details	Cronbach Alpha	Item
Computer based laboratory simulation and Students' Attitudes	.780	6
Achievement in Chemistry	.801	4
Aggregate Average	**.791**	

Source: Researcher (2020)

Computer based laboratory simulation in relation to student attitudes was also reliable with Cronbach alpha Co-efficient of 0.780. while achievement in chemistry was also reliable with four questions with 0.801 as Cronbach alpha Co-efficient. According to Jones & Rattray (2010) a threshold of Cronbach alpha above 0.7 is termed as reliable. Hence, all the questions for each objective were reliable with aggregate Cronbach alpha co-efficient of 0.791.

Demographic feature of the respondents

Demographic information provided in table 2 provided insights into the diverse characteristics of the student population, such as gender, age and the type of school.

According to the findings presented in table 2 above, majority of students were boys (53.76%) while 46.24% of them were girls. Also, majority of students were between the ages of 15-16 years and finally, type of school was distributed evenly.

Table 2: Demographic features of the respondents

		Frequency	Percent
Gender	Males	93	53.76
	Females	80	46.24
Ages	13-14 years	3	1.7
	15-16 years	108	62.4
	17-18 years	62	35.8
	Total	173	100.0
Type of School	A	39	22.5
	B	51	29.5
	C	43	24.9
	D	40	23.1
	Total	173	100.0

Note*: A- boys experimental group (CBLS), B- girls experimental group (CBLS), C- boys control group (traditional) and D- girls control group (traditional)*

Computer-based laboratory simulation and Students' Attitudes

The student's questionnaire used the Likert scale to extract mean and standard deviation based on the response of students. The obtained mean and standard deviations are summarized in Table 3.

Table 3: CBLS Teaching methods and students' attitudes

	N	Minimum	Maximum	Mean	Std. Deviation
The chemistry lessons via new technology were innovative and improves creativity	173	1.00	5.00	3.89	1.01418
Chemistry lessons taught by the teacher were easy	173	1.00	5.00	2.0983	1.23733
Chemistry lessons via new technology were friendly	173	1.00	5.00	4.2890	.84064
Chemistry lessons taught by the teacher were interesting	173	1.00	5.00	2.5087	1.31015
I like chemistry lessons taught with the use of new technology	173	1.00	5.00	4.0116	1.05096
The chemistry lessons taught via the new technology were meaningful	173	1.00	5.00	4.4220	.93447

Source: Field Data (2020)

Table 3 illustrates the outcomes of investigation into the relationship between CBLS and students' attitudes. From these results, chemistry lessons taught using new technology were innovative and creative in tone to some extent (mean of 3.8902). The variation was low on innovative and creative (standard deviation of 1.01418). Therefore, according to the established findings CBLS encouraged students to be innovative and creative in learning electro-chemistry. The same findings were reported by Sola and Ojo (2007) while investigating the impact of inquiry-based laboratory teaching approaches, that inquiry approaches of teaching were extremely helpful in increasing student accomplishment and skill development. They claimed that student achievement and analytical skills had either been elevated or considerably improved.

The students liked electro-chemistry lessons taught with the use of new technology (CBLS) to great extent (mean of 4.0116). The variation was low on the interest in chemistry lessons taught using CBLS (standard deviation of 1.05096). Therefore, computer-based laboratory simulation was liked by students in electro-chemistry lessons. This study adds to previous research that shows that using computers boosts good student attitudes and improves students' perceptions of science and mathematics (Thomas, 2001).

Chemistry lessons taught applying the new technology were more meaningful (mean of 4.4220).

Its variation was low on meaningfulness of chemistry lessons using new technology (standard deviation of .93447). Therefore, computer-based laboratory simulations were more meaningful. These results concur with Chumba et al. (2020) where there existed positive relationship between the attitude and CBLS approach. This is because student found a sense of belonging and meaningfulness when computer-based learning was adopted.

Results Based on Interview Schedules

Interview results in response to the question "*What is the attitude of students towards chemistry when computer-based laboratory simulation was used*?" revealed that CBLS had assisted learners to develop positive attitude towards the learning of chemistry. The outcomes from teachers in all the schools indicated that students developed positive response towards electro-chemistry that had been for a long time recording low performance. This new technique assisted students to participate actively in the lesson and access information easily.

In response to the question "*What is the teachers' attitude towards the use of computers in chemistry?"* there was a positive attitude among the teachers' interviewed. Teacher from school A and C agreed that CBLS method had assisted in supplementing chemistry demonstration and sometimes in chemistry lessons. Teacher from school B added that, "CBLS motivated me to hold more practical lessons with the students other than providing theoretical concepts". The response was also similar with that of teacher from school D who integrated the learning process with CBLS. Simulations provide benefits over undertaking risky, difficult, or impossible tests in terms of time, security, expense, and motivation (Jegede, 2003).

Concerning the question "*What is the effect of CBLS on participation of students in Chemistry?"* the teacher responses showed overwhelming positive impact on participation of students in chemistry lessons. The response from teacher from school B was, "CBLS increased participation, creativity and innovation in chemistry practical and lessons". This confirms results from Thomas (2001) showing an interactive learning environment with animations and simulations for abstract topics, in which students become actively involved in their learning, allows students to more readily create and grasp complex concepts. Since CBLS is not only interactive but also ensure safety of the students who are learning using the approach. Adoption of CBLS in electro-chemistry will facilitate acquisition of scientific inquiry skills.

The results towards this instructional strategy of this study, therefore, reveal that computer-based laboratory simulation has significant impact on the attitude of students towards chemistry both in theory and practical form. These findings are similar to those of Chumba et al. (2020), where computer simulations in Physics were found to lead to significant positive influence on the students' attitude towards physics. However, the present study focused on student's attitude towards chemistry as a subject. This has led to students developing interest in chemistry practical and theory learning, increase in creativity and innovation as well as high student participation in electro-chemistry lessons when computer simulations are used.

Achievement in Chemistry

Results obtained from Questionnaire

Students' questionnaire was used to obtain the mean and standard deviation from the Likert scale. These descriptive statistics of students was utilized in examining the achievement in chemistry subject among the secondary schools. The student questionnaire analysis was presented in Table 4.

Table 4: Achievement in Chemistry

	N	Minimum	Maximum	Mean	Std. Deviation
There is an improvement in chemistry practical when computer simulation is applied	173	2.00	5.00	4.1214	.69236
Students' science skills improved drastically on utilization of computer simulation method	173	2.00	5.00	3.9538	.64533
Performance in chemistry improved when the teacher incorporated computer simulation method	173	2.00	5.00	4.1387	.64100
Student attitudes towards chemistry improved through introduction of computer simulation method	173	3.00	5.00	4.2486	.67476

Source: Field Data (2020)

Table 4 relates to descriptive results on achievement in chemistry. The results showed an improvement in chemistry practical lesson while using CBLS application (mean of 4.1214). It was revealed that the use of CBLS approach enhanced student's performance in chemistry. Others have observed a similar occurrence in which the instructor places less focus on remembering material and more emphasis on inquiry and hands-on activities through which students get a better understanding and appreciation of the nature of science (Coller, 2004). As a result, when students are actively participating in the teaching process, their enthusiasm to learn improves.

According to the results from table 4, students' science skills improved drastically on utilization of computer simulation method to some extent (mean of 4.1387). The variation in students' science skills was also low after utilization of CBLS (standard deviation of .64100). This implied that computer-based laboratory simulation improved acquisition of scientific inquiry skills. Sola and Ojo (2007), in their study of the impact of inquiry-based teaching approaches, explained a similar occurrence. According to the findings of this study, inquiry-based teaching strategies are particularly successful in promoting students' accomplishment and skill development in chemistry. They indicated that student achievement and analytical skills had either been elevated or significantly improved.

Performance in chemistry improved to a great extent when the teacher incorporated computer-based laboratory simulation method (mean of 4.1387). CBLS not only improved practical lessons but also enhanced performance in chemistry. This is in line with Omwenga (2005), who observed that CBLS learning environments supports a disciplined inquiry skills and problem solving, implying that the use of technology fosters students' interactions among themselves and with curriculum material in order for inquiry to take place. Computers in education promote critical and higher order thinking skills in students.

Students' attitudes towards chemistry as subject improved through introduction of computer simulation method to a greater extent (mean of 4.2486). CBL's variation on students' attitude towards chemistry is low (standard deviation of .67476). Therefore, computer-based laboratory simulation improves significantly the attitude of students towards chemistry. The opinions of the students show a highly favorable attitude towards the subject and that the CBLS program was helpful in promoting the students' view of the chemistry classroom environment. This study adds to previous research that computers improves students' attitudes and changes their perceptions of science and mathematics (Kiboss, 2002 & Wekesa, 2003). The students are able to positively contribute, collaborate and inquire resulting to improvement of attitude towards chemistry subject.

Results obtained from ANOVA

Results obtained from ANOVA were analysed on the relationship of student's attitude using computer-based laboratory simulation and results presented in Table 5.

Table 5: ANOVA relationship student's attitude and Chemistry achievement

			Sum of Squares	Df	Mean Square	F	Sig.
Chemistry achievement * Student's attitude	Between Groups	(Combined)	6.898	13	.531	2.425	.005
	Within Groups		34.790	159	.219		
	Total		41.688	172			

Source: Field Data (2020)

Table 4 revealed that students' attitude following the results of computer-based laboratory simulation developed favourably. The attitude of the learner had significant outcome on achievement in chemistry according to the results obtained from ANOVA (F=2.425, P=.005<.05). Therefore, the positive attitude developed among students while adopting CBLS enabled them to achieve better results in chemistry. This concurred with Evans et al. (2008) who examined the use of computer-simulated activity used in pre-lab to mentally prepare students for real-world acid-base titration lab activities. As a consequence of their research, they came to the conclusion that the experimental group of pupils had a positive attitude toward learning. Aldrich (2004)

discovered that CBLS helped students enhance their motivation, achieve more, and create positive attitudes in learning sciences.

Conclusion and recommendations

Results revealed that computer-based laboratory simulation assisted in improvement of student's attitude which had significant effect on Chemistry achievement. CBLS assisted students to develop positive attitude towards electro-chemistry. Furthermore, by allowing students to explore the simulated world and conduct simulated experiments at their own leisure, computer simulations boosted students' excitement and motivation. Also, computer-based laboratory simulation teaching strategy had significant effect on chemistry achievement. This implies that CBLS teaching strategy had positive significant influence on performance of Chemistry. The study on CBLS revealed that the new technology increased the skills of innovation and creativity among the science students. Chemistry lessons taught by the teacher were found to be abstract as compared with CBLS which was friendly. CBLS made chemistry lessons enjoyable and meaningful. Finally, CBLS impacted positively on the attitude of students towards chemistry. The findings revealed that subjects taught by regular modes were boring, appeared lost or directionless in the absence of teacher leadership, lacked autonomy and self-confidence. The study recommendeds that schools should foster a positive and supportive learning environment that encourages students to embrace CBLS and develop a favorable attitude towards technology-based learning. This can be achieved through collaborative group activities, interactive learning experiences, and continuous Teacher Training as well as address technological barriers in secondary schools in Bomet County. Also, a comparative study involving the rural and urban school settings to establish the findings concerning socio-cultural regions on implementation of CBLS.

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