Efficacy of Teaching Chemistry with Computer-Based Laboratory Simulations (CBLs) as Opposed to Traditional Methods in Acquisition of Scientific Inquiry Skills in Bomet County

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Abstract

The aim of this research was to examine the efficacy of teaching chemistry with computer-based laboratory simulations (CBLs) as opposed to conventional methods for acquiring scientific inquiry skills in Bomet County. This study utilized quasi-experimental research design and applying Solomon-Four Non-Equivalent Groups Design. Four secondary schools in Bomet County were purposively sampled on the basis of availability of computers and a total of 369 participants were surveyed. Random sampling assigned four schools to control and treatment groups. All groups learned the same chemistry (electro-chemistry). Experimental groups used CBLs whereas control groups used teacher demonstrations and lecture. Before using CBLs, groups II and I were pre-tested. After 4 weeks, all 4 groups were post-tested using the Students' Chemistry Achievement Test (SCAT), which was pilot-tested to establish its reliability. ANCOVA, one-way ANOVA, and t-test were used to analyse data at a 0.05 significance level. Results revealed that Computer based laboratory simulation was more effective and efficient method as opposed to traditional method. CBLs had significant influence on achievement in chemistry. It assisted in improving students' creativity and innovativeness compared to traditional teacher centered instructions. CBLs method of teaching chemistry assisted students to manipulate data in chemistry practical. Computer simulations allowed students to view and participate in real-world experiences. CBLs were characterized by ease, exciting and clearer teaching strategy as compared with traditional method. Simulations as an investigative tool increased motivation and curiosity among learners. Consequently, the study recommends that secondary schools should adopt the use CBLs in teaching of chemistry alongside traditional methods. Also, teacher education in university should restructure their curriculum to include the use CBLs in teachers training. This will improve the application CBLs in secondary schools.

Keywords: Electro-chemistry, conventional teaching methods, computer-based laboratory simulations, scientific inquiry skills

INTRODUCTION

The science influences a nation and her citizens through the creation of fundamental human desires to political, educational, social, technological, and economic progression (Hodson, 2003; Mensah, 2019). The means by which scientists take while conducting scientific inquiry informs the society on the usefulness of science (Dani, 2009; Bonney *et al.*, 2009).

Because modern knowledge-based economies rely significantly on technology clear understanding of chemistry and technology, as well as stronger technical problem-solving abilities, would assist workers to face the difficulties and expectations of the workplace (Effandi & Zanaton, 2006; Porter *et al.,* 2007; Turiman *et al.,* 2012). Moreover, a contemporary knowledge-based economy can first thrive if its workforce has improved degree of technical abilities and understanding (Asunda, 2012; Wieman & Perkins, 2005). The Information Technology (IT) transformation has been brought about by technological advancement (Krymov *et al.,* 2019; Martynov *et al.,* 2019). It is obvious that any society that abandons this change risks exclusion from the global family (SMASSE, 2004). Consequently, for a country's national development objective to be achieved, its citizens must be scientifically and technologically literate. Thus, the need to arrange secondary school chemistry tutoring methodologies in accordance with 21st century competencies (Pacific Policy Research Center, 2010). Problem solving and critical thinking, communication and cooperation, creativity and innovativeness, technology, information, and media, as well as life and career skills, are examples of twenty-first-century skills (Kay & Greenhill, 2011; Papanastasiou *et al.,* 2019; Sang *et al.,* 2018).

According to Alebiosu (2003), the teaching techniques used by a teacher in any particular circumstance are determined by elements such as classroom learning environment, teaching objectives, teacher and student characteristics, and the demands and nature of the topic. Clearly, the traditional educator as knowledge provider or textbook-guided classroom failed to provide the anticipated result of critical thinking scholars. The use of inquiry techniques in the classroom to shift the attention of the learner from teacher-dominated to learner-centered is a widely lauded strategy (Ryder, 2001).

The science instruction in Kenyan secondary schools has been unsuccessful. Learners typically do not acquire scientific skills and also, they don't understand the aim and significance of science in society (Kiboss, 2002). Inquiry-based learning approach improves science education by involving learners in authentic investigations, thus attaining a more genuine perception of scientific endeavor and further enabling motivating and a more learner-centered environment, while also being utilized to support teaching (Markic & Abels, 2014).

The inquiry approach, while praised by science instructors, is yet to be prevalent in the classroom, and is frequently misused. This might be as an effect of several factors, including amount of classroom period, lack of effective ways for learners to conduct independent inquiries, the challenge of abstract concepts' incorporation with inquiry, and inadequate teacher experience and expertise. One of the electronic systems that is being incorporated into the classroom to support in the process of learning is the computer (Jethro *et al.,* 2012; Odera, 2011; Akungu, 2014). One such area includes computer simulations that have been utilized in learning and training of numerous subjects, such as physics, accounting, medicine and mechanics, with promising results (Omwenga, 2005).

Computer technology has progressed to the era that it can considerably ease the application of inquiry learning on a variety of levels, as well as give new tools for depicting the nature of science in the science rooms (Asch *et al.,* 2018). This utilization of technology in provision of new teaching techniques and objectives in science has enormous potential for enhancing scientific learning in the science room, as long as the inherent limits of acquisition are acknowledged and technology is utilized as a tool rather than as a foundation (Wu, et al, 2013; McFarlane, 2013).

Chemistry is a science subject which is very crucial in Kenyan Secondary Curriculum (Abungu *et al.,* 2014; Mwangi & Mwangi, 2016; Njeri, 2022).). 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; Oludipe & Awokoya, 2010; García-González *et al.,* 2019). "As vital as the subject is and despite of the urge of governments to encourage chemistry instruction, learners still shun the subject" (Jegede, 2003). It has been shown that, 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 (Chebii, 2011; Keter, 2013; Birgen, 2013). Learners' anxiety for chemistry may be attributed to learner's perceived complex nature of chemistry (Dani, 2009; Kolil *et al.,* 2020; Flaherty, 2020). Scholars' anxiety for chemistry education progresses to interest loss in the sciences (Potvin & Hasni,2014).

Literature available indicates that most of the learners in Kenyan secondary contain insufficient information and comprehension of chemistry principles and ideas (SMASSE, 2001). Therefore, the topic electro-chemistry has continually been problematic to grasp by learners or to teach by instructors. In accordance to a SMASSE baseline review 58% and 62% of the teachers and learners interrogated illustrates the electro-chemistry as complex to teach by instructors and learners to grasp, respectively (SMASSE, 2005). This goes in line with the KNEC report which shows the dismal performance on electro-chemistry questions by candidates (KNEC, 2018).

While the incorporation of such a teaching/learning technique may help in chemistry teaching, much has not been done in investigating the effectiveness of Computer-Based Laboratory Simulations (CBLs) use in the tutoring of secondary school chemistry particularly the topic electro-chemistry that has been considered difficult by students who learn it. The utilization of proper teaching equipment and methods is vital to the effectiveness of chemistry teaching and learning. There is still considerable work to be accomplished in terms of making the most use of current educational tools (Bello, 2011). The current investigation attempts to examine the efficacy of teaching chemistry with computer-based laboratory simulations (CBLs) as opposed to conventional methods for acquiring scientific inquiry skills in Bomet County.

METHODOLOGY

The study was carried out in Bomet County, which is located in Kenya's former Rift Valley Province. Bomet County is bounded to the south east, south, and south west by Kericho County, to the North West by Nyamira County, and to the east by Nakuru County (Korir, 2018; Kimutai, 2021). The County has a total land area of 2,037.4 Km^2, of which 1,716.6 Km^2 is arable and suitable for farming (Simuli, 2017). Because of familiarity and ease of access, the location was chosen for research. The design of a quasi-experimental pre-test post-test control group was used where CBLs and Traditional approach formed the independent variables. The quasi-experimental design which implies partly experimental employed experimental approach as well as the use of survey questionnaires and interviews. A target population of 687 Form four students and 4 teachers from public secondary schools in Bomet County was used. A sample size of 369 participants which entailed 4 teachers subjected to interview, 205 students who responded to the questionnaire and 160 students who did experimental test. Four (4) secondary schools in Bomet County were purposively sampled based on computer availability. The study had 369 individuals in total. By using simple random sampling procedure, the four learning institutions were assigned to treatment and control groups.

Questionnaires and interview schedules were utilised to obtain information from students and chemistry teachers. Formal teacher semi-structured interviews were carried out to obtain data on their reactions to the usage of CBLs to supplement classroom instruction and their perspective of what was actually happening in the chemistry classroom while the students utilized the CBLs software to learn electro-chemistry. Pilot testing was carried out on the instruments to evaluate their dependability. To guarantee uniformity in the teaching technique across all control and experimental groups, instructional steps were followed in accordance with the planned lesson. Cronbach's alpha coefficient of 0.756 was achieved for the content validity of the questionnaire items. Data was analysed using inferential statistics and analysis of Covariance (ANCOVA) to compare computer-based laboratory simulations and traditional teaching techniques at a 5% significant level. ANCOVA was used to determine significant differences in mean test scores between schools sampled (post-test and pre-test). Descriptive statistics were utilised to show the effect of computer-based laboratory simulation on chemical achievement. Analysis of Variance (ANOVA) statistics were used to determine if CBLs influenced the development of inquiry skills. Standard deviations, means, and frequencies were used to analyse the collected data in tables. Data was represented using line graphs, pie chart and bar graphs.

RESULTS AND DISCUSSIONS

CBLs versus Traditional Methods of Teaching on Effectiveness in Teaching Chemistry in Secondary Schools

Computer- based laboratory simulation was assessed on the effectiveness in chemistry teaching as compared with traditional methods. Mean, standard deviation and ANOVA analysis were conducted on questionnaires. ANCOVA was conducted to establish whether there was a significant change in test results in between the experimental (CBLs) and control groups (traditional method).

The results from questionnaire provided descriptive analysis as well as test if CBLs had significant impact on achievement of chemistry based on its effectiveness. However, ANCOVA results assisted in provision of comparison results of CBLs and traditional teaching style at five percent significant level. The discussions were made based on the results obtained. Interview results were also used to confirm the response from the student questionnaire using content analysis.

Results from Questionnaire

Students' questionnaires analysed using the 5-point Likert scale established the mean and standard deviation of comparison between CBLs and traditional teaching method in teaching science in secondary schools. The descriptive results of computer-based laboratory simulation are presented in Table 1 below.

Table 1 presents results for CBLs in comparison with traditional methods of teaching chemistry based on effectiveness in teaching this subject. Computer- based simulation was found to improve understanding of chemistry concepts as compared with traditional teaching methods (mean of 4.1734). However, the variation on improvement of understanding was minimal (standard deviation of .72656). This means that CBLs approach was better in knowledge acquisition as compared with the traditional methods of teaching chemistry.

Vanosdall *et al.* (2007) found that use of CBLs technique resulted in greater accomplishment in studying of mixtures and solutions in chemistry other than those tutored using traditional methods. This affirms that CBLs is not a replacement but can

be incorporated in different areas in chemistry. The results converge in applicability in teaching abstract topics, also, the current study found that CBLs assists in simulating electro-chemistry besides other topics in chemistry.

Table 1: CBLs and Effectiveness of Teaching Chemistry

	N	Minimum	Maximum	Mean	Std. Deviation
Computer based laboratory simulation improve student understanding more than the traditional teaching method	173	2.00	5.00	4.1734	.72656
Computer based simulation improved innovativeness than traditional methods	173	2.00	5.00	3.8671	.63768
The new computer-based simulation provides added information as compared to traditional methods	173	2.00	5.00	3.9422	.67092
Computer based simulation improved students' attitude to chemistry	173	3.00	5.00	3.8786	.60257
Computer based simulation assisted in manipulation of data	173	2.00	5.00	3.9249	.62887
It assisted student to research unlike traditional method	173	2.00	5.00	4.3295	.64798

Source: Field Data (2020)

According to the results from table 1, CBLs improved innovativeness among the learners as compared to traditional methods (mean of 3.871). Its variation was, however, low on innovativeness improvement (standard deviation of .63768). Therefore, CBLs assisted learners to be more creative and innovative in chemistry than the traditional methods that over depends on teacher expertise and teaching skills, CBLs gives students an opportunity to practice critical thinking skills in a controlled environment.

New CBLs positively added more information compared to traditional methods of teaching chemistry as indicated by the analysis (mean of 3.9422). The variation was also low on ability of CBLs to additional information (standard deviation of .67092). This implies that majority of the students preferred CBLs approach since it provided more information than traditional methods of teaching chemistry.

Sola and Ojo (2007) focusing on effects of project inquiry on teaching methods on senior secondary students' achievement in separation of mixtures, investigated the impact of inquiry-based teaching models on success of students. According to the findings of this investigation, inquiry approaches of tutoring were extremely helpful in increasing students' success and skill advancement. This finding concurs with the current study which adopts CBLs approach as a strategy which has impacted positively on learners understanding of electro-chemistry.

The results also reveal that computer-based laboratory simulation improved student's attitude towards chemistry (mean of 3.8786). The variation was low in improvement of the attitude in chemistry (standard deviation of .60257). Therefore, students like chemistry as a subject since computer-based laboratory could motivate them to learn. Science-related attitudes tend to influence students' involvement in science as a subject

as well as their performance in science (Linn & Hsi, 2000). Other studies have found that a good attitude toward science influences student performance and, as a result, enrolment in this field.

As per the obtained results, computer-based simulation assisted in manipulation of data to a great extend (mean of 3.9249). Its variation on manipulation of data was found to be low (standard deviation of .62887). Based on visualization and ability to bring out concepts clearly, information is easily passed on to the students through computer simulations. CBLs allow learners to interact with computers and reduce the otherwise dangerous aspect of chemistry. Learners in treatment group could observe and discover scientific concepts that were not possible to manipulate by learners using traditional methods. This means that CBLs facilitates acquisition of scientific skills more as compared to traditional methods.

Finally, computer-based laboratory simulation as a technique was found to assist the students in doing more research unlike traditional method (4.3295). However, it had low variation on assisting student in research work (standard deviation of .64798). The results revealed, therefore, that computer-based laboratory simulation techniques were crucial in developing interest in science. According to the conclusions of this research, CBLs are extremely helpful in improving learners' achievement and inspiration to study science, as well as the growth of scientific process abilities (Sola and Ojo, 2007).

Results obtained from ANOVA

The Results obtained from ANOVA compared traditional method and computer-based laboratory simulation based on the achievement made by students in chemistry. The ANOVA used f-test at 5 percent significant level to establish the relationship with achievement and the results presented in table 2.

Table 2: ANOVA relationship CBLs and Chemistry achievement

			Sum of Squares	Df	Mean Square	F	Sig.
Chemistry achievement * CBLs	Between Groups	(Combined)	9.297	11	.845	4.201	.000
	Within Groups		32.391	161	.201		
	Total		41.688	172			

Source: Field Data (2020)

The results of ANOVA analysis presented in Table 2 reveal that there existed significant relationship between the adoption of computer-based laboratory simulation and science achievement ($F=4.201$, $P=.000<.05$). Therefore, it implies that as the schools intensified the use of CBLs in chemistry, there was noteworthy increase in performance of learners.

Experimental Results

The descriptive results were based on the experimental design, in which the experimental group was educated using computer-based laboratory simulations (CBLs) and the control group was educated using the traditional technique.

Table 3 represents experimental design results where the change in marks between post-test and pre-test were revealed. Experimental group representing CBLs method is seen to have the highest changes in marks of an average positive change of 11.862% (Mean of 11.862). Traditional method had, however, lower than average positive change of 4.532% (Mean of 4.537).

Table 3: Descriptive Statistics for CBLs versus Traditional Methods

Tradition Method versus CBLs Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Experimental Group (CBLs)	11.862[a]	.312	11.245	12.479
Control Group (Traditional)	4.537[a]	.312	3.920	5.154

a. Covariates appearing in the model are evaluated at the following values: Pre-test = 43.8356.
Dependent Variable: Change in Marks

Source: Field Data (2020)

CBLs showed improvement of 7.330% than traditional method of teaching chemistry. The technique has been thought to be able to generate inspiration among secondary school learners since it piques their interest in the step to gaining scientific information and abilities (Gibson & Chase, 2002).

Experimental ANCOVA Results

ANCOVA was used in this study to examine comparison between CBLs and traditional methods based on pre-test done by learners from both control and experimental groups respectively. The results were tested based on significances of 5 percent and these are summarized in Table 4.

Table 4: ANCOVA relationship Traditional method and CBLs method

Source	Type III SumDf of Squares		Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2260.015[a]	2	1130.008	137.027	.000	.636
Intercept	1020.254	1	1020.254	123.718	.000	.441
Pre	99.850	1	99.850	12.108	.001	.072
Tradition/CBLs	2145.211	1	2145.211	260.133	.000	.624
Error	1294.715	157	8.247			
Total	14311.490	160				
Corrected Total	3554.730	159				

a. R Squared = .636 (Adjusted R Squared = .631)
Dependent Variable: % Change in Marks

Source: Field Data (2020)

The results presented in Table 4 indicates that there was a significant difference in change in marks [F (1, 157) =260.133, P=.000<.05] between computer-based laboratory simulation and traditional method of teaching chemistry while adjusting for pre-test. This implies that computer-based laboratory simulation increased significantly the achievement of students after adopting it as opposed to the control group who used traditional method of teaching chemistry. Further, the partial Eta Squared value of 0.624 reveals a strong significant difference in between CBLs and traditional techniques of teaching this subject. Computer-based laboratory simulation had some impact on test taken by the students. This indicates that CBLs should be adopted to supplement traditional methods in chemistry based on significant improvement in achievement of this subject as compared to traditional method.

Figure 1 revealed the existence of significant difference between male and female students who used CBLs over traditional method as well as the female students.

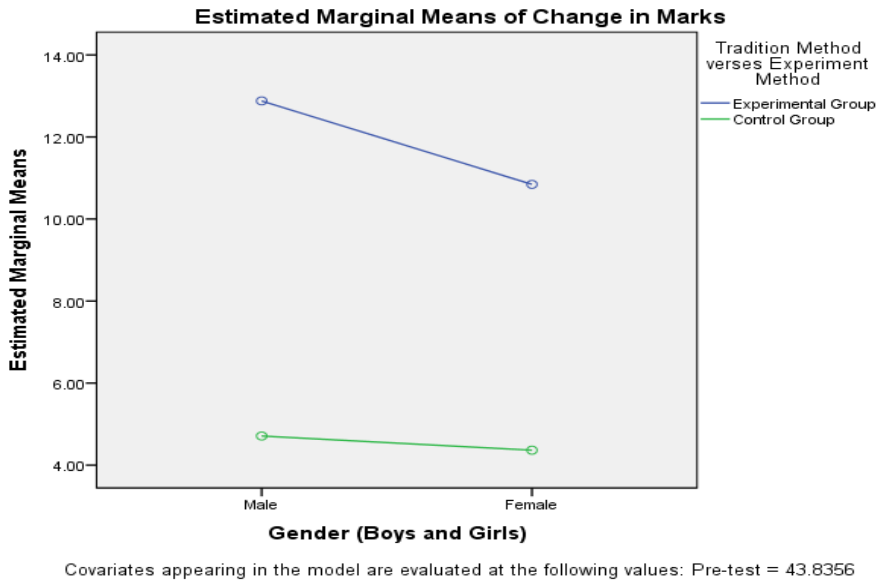

Figure 1: Experimental Group (CBLs) versus Control Group (Traditional)
Source: Field Data (2020)

The figure 1 revealed a larger marginal difference between control groups (traditional method) with experimental groups (CBLs method) with CBLs being the effective teaching method of electro-chemistry. Using computer technology allows scholars to participate actively in the process of learning, knowledge creation, improve problem-solving abilities, and explore alternate answers (Özmen, 2008).

Results Based on Interview Schedules

Interview responses to "compare the traditional method and computer-based laboratory simulation on effectiveness in teaching chemistry?" showed that majority 80% of teachers proposed that integrating the two methods of teaching chemistry would benefit the student. "CBLs is more efficient in teaching than traditional demonstration methodology since it assists all students to participate in process of learning" was response from teacher from school A. Teacher from school B argued that, "Despite us embracing technology there is need for a teacher to facilitate, group students, provide order and provide solution that CBLs cannot provide. Hence both are effective when they are integrated together rather than using traditional method or computer-based laboratory simulation separately".

As for teacher from school C, "Computer-based laboratory simulation has made students to be proactive towards electro-chemistry lessons. However, the technology has reduced teaching roles to facilitating. Therefore, traditional methods of teaching chemistry have only been modified to accommodate the computer technology". Teacher from school D alluded that, "Students have improved in chemistry lessons as well as practical lessons since the computer-based laboratory has assisted in providing information". This is reinforced by Freedman (1997), who discovered that positive attitude toward science is associated with performance in laboratory practical. However, a chemistry teacher who practices teacher-based teaching method, with no hands-on exercises and lack of practicals usually reduces scholars' enthusiasm in chemistry classes.

In response to the question "Compare the students who used and those who never used the new technology, do you think the students who used CBLs learnt any better?" Teacher from school A responded that, "Students who used CBLs were better in acquisition of scientific knowledge, skills and developed positive attitude towards chemistry". Teacher from school B commented that, "Students who have been passed through CBLs were better in level of intellectual understanding on different paradigm given by the teacher as well as computer simulations". While teacher from school C responded that, "Scholars taught using CBLs were better than those who depended on traditional teaching method". However, teacher from school D alluded that, "Performance of students have significantly improved in chemistry since the introduction of CBLs". All teachers seem to approve the use of CBLs in Kenya's secondary school education system.

On the question "What are the benefits gained by CBLs as opposed to traditional methods of teaching chemistry?" was responded with numerous benefits like creativity, development of observation skills, increased participation, creativity and innovativeness, analytic skills and manipulation skills. According to teacher from school A, "computer-based laboratory simulation had improved analytical, manipulating and observation skills among the learners especially in areas where normal teaching and experiments cannot be effective."

Teacher from school B mentioned that, "computer-based laboratory simulation has enabled students to gain more knowledge in chemistry both practical as well as theory part". Teacher from school C said that, "Computer simulation assisted the students gain positive attitude towards chemistry. This study adds to previous research that shows that using computers fosters good student attitudes and has a favorable impact on students' perceptions of science and mathematics (Kiboss, 2002). Therefore, it imposes that CBLs is capable in modification and changing of attitude towards chemistry, since it equips the learner with knowledge and skills suitable for improving the subject.

Teacher from school D added that, "students have been more innovative and creative through active participation in CBLs technique of teaching". Creativeness and innovation play an important role in scientific discover which develop positive attitude towards the study of chemistry. From the study all teachers seem to approve the use of CBLs in Kenya's secondary school education system.

Hypothesis Testing

HO_1: There is no significant difference in achievement scores amongst learners taught using CBLs learning method and those that using regular teaching methods (RTM) on achievement of chemistry. The results failed to accept the null hypothesis. Therefore, based on ANCOVA results there existed significant difference between CBLs learning approach and regular teaching method ($P<.05$), where CBLs had better impact on achievement of chemistry in comparison to traditional method.

Okwuduba et *al.* (2018) found similar results where there existed significant difference between computer simulation and traditional method of teaching chemistry. Computer simulation method was better than convention method as presented in the current study. Sreelekha (2018a) also found similar results that computer-based laboratory simulation was better than traditional method of teaching Physics, though the study was not conducted in chemistry.

Radulović *et al.* (2016) found that interactive computer-based simulation and laboratory inquiry-based experiments were effective instructional methods. This also

concurs with Awodun and Oyenyi (2018) findings who reported that computer simulation had significant impact on performance of student in science subjects as compared to traditional methods. From these findings, there was significant improvement in students' achievement in chemistry using computer simulation as opposed to using traditional methods.

Despite the fact that most research has been conducted on physics, chemistry performance has also revealed similar improvement in students' achievement as compared with traditional method. The CBLs method is used to explain teaching strategies based on scientific inquiry (Kahn and O'Rourke, 2005). The methodology is firmly anchored in constructivist tutoring methods. It is student-centred, other than teacher-centred, and allows pupils to participate actively in questioning, exploring, and discovering.

The results revealed that CBLs enhanced creativity and innovativeness as compared with traditional methods of teaching chemistry. This technique assisted students to gain more information. As it was employed for presenting material, tests and assessment, and delivering feedback, CBLs made teaching more successful than traditional teaching methods. It contributed to the personalization of education. It inspired pupils and encouraged them to participate actively in the learning process. It aided in the development of learners' creativity and problem-solving abilities in learning, as well as their identity and self-reliance. CBLs gave students the drawings, graphics, animation, music, and a plethora of resources to allow them progress at their own speed and in accordance with their specific peculiarities. It was used to regulate a variety of variables that have an influence on learning and cannot be handled using standard educational procedures (Ran *et al.*, 2021).

CONCLUSION

CBLs had significant influence on achievement in chemistry. It assisted in improving students' creativity and innovativeness compared to traditional teacher centered instructions. CBLs method of teaching chemistry assisted students to manipulate data in chemistry practical. Computer simulations allowed students to view and participate in real-world experiences. CBLs were characterized by ease, exciting and clearer teaching strategy as compared with traditional method. Simulations as an investigative tool increased motivation and curiosity among learners.

RECOMMENDATIONS

Based on this study, the following recommendations are made;

i. The study recommends that secondary schools should adopt the use CBLs in teaching of chemistry alongside traditional methods.
ii. It also proposed that teacher education in university should restructure their curriculum to include the use CBLs in teachers training. This will improve the application CBLs in secondary schools.
iii. The study also recommends that secondary science instruction should be restructured so as to enable teachers integrate with ease the use of CBLs.
iv. Suggestion for further research should be based on other subjects.

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