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EFFECTS OF COMPUTER SIMULATION, COLLABORATIVE PROBLEM-SOLVING AND CONCEPT MAPPING ON STUDENTS' COGNITIVE ACHIEVEMENT IN CHEMISTRY

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ABSTRACT

This study investigated the effects of computer simulation, collaborative problem-solving and concept mapping on students' cognitive achievement in chemistry in Jalingo Education Zone, Taraba State Nigeria. Quasi-experimental design was used for the study. The population consisted of all secondary school two students. A total of 229 students were sampled using multiple stage sampling technique. Four intact classes were randomly selected from four co-educational secondary schools and assigned to three experimental groups and one control group. Redox Reaction Achievement Test (RRAT) was used for data collection with the reliability index of 0.88 using the Kuder-Richardson's formula-20 (K-R20). The data collected were analyzed using descriptive analysis (mean & standard deviation) and inferential statistics (t-test analysis, one-way analysis of variance-ANOVA) followed by multiple comparison analysis- Scheffe post-hoc analysis) tested at 0.05 level of significance. The findings revealed that the experimental groups taught with computer simulation, collaborative problem solving and concept mapping had better results (achievement) than the control group that used the convention method. The three experimental groups (computer simulation, collaborative problem solving and concept mapping) do not differ significantly from each other in terms of students' achievement. Also, *there is a significant effect of the experimental and control methods of instruction on students' cognitive achievement; in favour of the experimental groups that showed superiority over the control group. And, there is a significant difference in chemistry achievement among students taught with experimental and control groups; in favour of the experimental groups. Based on the findings, it was concluded that the three innovative instructional strategies (mostly collaborative problem solving) can be used for chemistry instructions; since they are useful facility for improving students' academic performance and promoting meaningful learning/developing the 21st century skills (problem solving, critical thinking, collaboration, and creative and computer skills) in students. Therefore, it was recommended that chemistry pre-and in-service teachers should be trained on the use of these innovative instructional strategies (computer simulation, collaborative problem solving and concept mapping) with classroom enabling environments for easy adoption; and also integrated into chemistry curriculum in secondary schools.*

Keywords: Computer Simulation, Collaborative Problem-Solving, Collaborative Concept Mapping, Cognitive achievement.

Introduction

Science education is essential as it is of immense value in the student's individual life and his life in society and the great value of science is that it has introduced us to new ways of thinking and reasoning (Jack, Danjuma, & Adul-Kadir, 2017). Teaching is effective when the approach used brings about a desirable change in the behaviour of the learner. If learning strategies and students' achievement have to improve, then the students have to be introduced to more, effective, efficient and appropriate teaching approaches. Teaching Chemistry can only be result-oriented when students are willing and the teachers are favourably disposed to using appropriate methods and resources in teaching the students. With the current increase in scientific knowledge the world over, much demand is placed, and emphasis is laid on the teacher, the learner, the curriculum and the environment in the whole process of teaching and learning of science generally and chemistry in particular. Despite the importance of Chemistry to mankind most students emerge from the introductory courses with very limited understanding of the subject (Kamisah & Nur, 2013; Woldeamanuel, Atagana & Engida, 2014), and the performance of the subject remains low; which may have resulted from the lack of understanding and difficulties of students in some chemistry concepts as reported by the Chief Examiner, (WAEC, 2020). Chemistry had been regarded by most researchers (Jack, 2014a; Jack et al. 2017; Kamisah and Nur, 2013; Woldeamanuel et al. 2014) as a difficult subject for students due to the abstract nature of many chemical concepts, the difficulty language of chemistry, lack of teaching aids, and poor teaching styles; hence students developing poor understanding and misunderstanding of chemistry concepts. Also, from investigations of these educators (Gongden, 2016; Jack et al. 2017), stipulated that students' poor problem solving ability, conceptual or learning difficulties and misconceptions in chemistry is a likelihood of a deficiency in instructional strategies used in the chemistry classrooms.

Over the years, traditional teaching method was a common mode of instruction delivery since there were no available facilities for effectiveness in demonstrating chemistry concepts at disposal; and this mode of instruction is teacher-activity-centred where learners are inactive or passive recipients seems to encourage more of rote learning (Jack & Sheriff, 2020). As noted by Jack and Sheriff (2020), the mode of instruction delivery has taken a quantum leap with emergence of computer technologies in teaching and learning; which is student-activity-centred where learners are active recipients and encourages more of meaningful learning using computer-assisted instruction (a new approach in the field of education that comprises the use of computer technologies in instructional delivery) and one of such type is computer simulation. Computer Simulation is a strategy for using computer software or power-point projector to model the operation of "real-world" processes, systems, or events (Fishwick, 2014); and it plays an important role in the teaching and learning of scientific/chemical and concepts. Several studies in the literature (Arıcı & Yılmaz, 2020; Candida, Jose & Armando, 2013; Guy & Lowness- Jackson, 2015; Ibrahim, Ibrahim, Aminu & Abubakar, 2017; Jack & Aji, 2021; Jack & Gamnjoh, 2020a & 2020b; John, Robert & Israel, 2013; Kabigting, 2021; Kibirige & Tsamago, 2019; Kumar, 2018; Mihindo, Wachanga, & Anditi, 2017; Okwuduba, Offiah, & Madichie, 2018; Philip, Du Toit, & Van Breda, 2023; Ouyang et al. 2021; Topuz, 2018; Wen, Liu, Chang, Chang, Chang, Chiang, ... & Hwang, 2020; Udo & Etiobun, 2011; Yıldız, 2019) also revealed that using the computer simulation had positive and strongly significant effects on students' academic achievement.

There is also computer supported collaborative learning (CSCL) which focuses on the collaborating groups' meaning-making practices with the design and support of technological artifacts to mediate interactions and communications (Hmelo-Silver & DeSimone, 2013; Xu, Wang & Wang, 2023). In cultivating critical thinking in curriculum teaching, this can start with a problem, and one of the most popular critical thinking instructional approaches is problem-based learning (Liu et al., 2020); which can be used as a group collaboration which is progressive active learning and can help improve students' critical thinking and problem-solving skills. Collaborative problem-solving (CPS), as one of the main CSCL modes, has been widely used in schools to improve student learning and performance and critical thinking (Kapur, 2011; Ouyang et al. 2021). And, as noted by Xu et al. (2023), CPS has been widely embraced in the classroom instruction of critical thinking, which is regarded as the core of curriculum reform based on key competencies in the field of education as well as a key competence for learners in the 21st century. CPS is defined as a group of learners building mutual understandings of a shared problem, pooling together their expertise, skills, and efforts, and come up with a final solution for the problem (Fiore et al., 2017). CPS typically situates learning in solving

real-world authentic, ill-structured problems, encourages students to create group knowledge, and develops responsibilities, self-regulation, collaboration and problem-solving skills for learning (Hmelo-Silver & DeSimone, 2013). Problem solving skills refer to the ability of an individual to find meaningful solutions to solve problems using effective and timely strategies (Karabacak, Nalbant, & Topçuoglu, 2015). Problem solving is a systematic approach in conceptualizing and understanding a given problem, designing strategies to solve the problem, and evaluating the strategies implemented. In science education, "the term 'problem solving" refers to mathematical tasks that have the potential to provide intellectual challenges for enhancing students' scientific understanding and development. Such tasks can promote students' conceptual understanding, foster their ability to reason and communicate mathematically, and capture their interests and curiosity. Problem solving has become an important component of science education; hence science teachers are considered shifting of emphasis from teaching problem solving to teaching through problem solving in a collaborative classroom or laboratory environments as applicable in this current study.

The CPS has been widely used in schools both at primary, secondary and tertiary levels, and informal learning to improve students' learning quality (Avry et al., 2020; Chang et al., 2017). However, little attention has been paid to the impact of collaborative problem-solving on critical thinking and students' conceptual understanding. Therefore, the best approach for developing and enhancing critical thinking throughout collaborative problem-solving is to examine how to implement critical thinking instruction; however, this issue is still unexplored, which means that many teachers are incapable of better instructing critical thinking as noted by these educators (Leng & Lu, 2020; Niu et al., 2013). CPS is the organic integration of collaborative learning and problem-based learning, which takes learners as the center of the learning process and uses problems with poor structure in real-world situations as the starting point for the learning process (Liang et al., 2017). Students learn the knowledge needed to solve problems in a collaborative group, reach a consensus on problems in the field, and form solutions through social cooperation methods, such as dialogue, interpretation, questioning, debate, negotiation, and reflection, thus promoting the development of learners' domain knowledge and critical thinking (Liang et al., 2017). CPS can also be seen as a complex, multidimensional, and multilevel practice that needs students' coordination of the social, cognitive, metacognitive, and behavioral activities in a temporal fashion (Fiore et al., 2017). CPS is a joint and shared activity where small groups execute several steps to transform a current problem state into a desired goal state (Hesse et al., 2015). It is considered one of the critical and necessary skills used in education and the workforce (Andrews-Todd & Forsyth, 2020). Hence, the students in each group should participate in the social practices and interact with each other to jointly solve problems (Hakkarainen et al., 2013); use cognitive engagement to solve the ill-structured problems usually needs students' exploration and understanding of the problem, proposition, and justification of the solutions, and the sustained development of new ideas and artifacts in the groups (Hakkarainen et al., 2013); and the students need to take actions to externalize their knowledge in artifacts (e.g., concept map, writing document) and refer to peers' behavior to coordinate their group activity and optimize the knowledge artifacts (Stahl, 2017). Moreover, to succeed in the group collaboration, students need to negotiate what to achieve as a group, plan, and implement problem-solving strategies, and monitor and reflect on the working progress (Järvelä & Hadwin, 2013; Winne et al., 2013). Research about CPS in a technology-supported learning environment has been well documented (Du, Dai, Tang, Hung, Li, & Zheng, 2022). Chang et al. (2017) analyzed how students solved a physics problem using individual-based and collaborative simulations, and the result indicated that students using the collaborative simulations demonstrated a higher level of engagement in the CPS activity. Gu and Cai (2019) found that integrating semantic diagram tools in CPS helped students achieve a greater depth of understanding of the domain knowledge. There are also very few studies in literature (Avry et al. 2020; Fiore et al. 2017; Hakkarainen et al. 2013; Hmelo-Silver & DeSimone, 2013) that revealed that used CPS and attested that using the instructional strategy had positive and strongly significant effects on students' achievement. The research conducted by Unal and Cakir (2021) also concluded that CPS supported by web 2.0 technologies has a positive effect on student achievements.

Another innovative instructional strategy which seems to be an answer to a purposeful and meaningful understanding of difficult concepts in chemistry to enhance students' achievement is concept mapping which can also be carried out in a collaborative classroom learning environments. Concept mapping is an approach for teaching of chemistry that aims at enhancing understanding rather than promoting memorizing and juggling of facts (Jack 2019). An effective way of dealing with problem is for the teacher to provide a bridge between the unfamiliar concepts and the knowledge which students already have. This is based on the premise that new concepts do not exist in isolation but depend upon others for meaning (Jack, 2019). The use of this tool as technique in teaching abstract concepts in chemistry may be observed as a paradigm shift. One big advantage of using concept maps is that during its formulation process, it consolidates a concrete and precise understanding of the meanings and inter-relations of concepts (Jack, 2013). Thus, it makes learning an active process, not a passive one. In educational settings, concept mapping exercises have been used to encourage students to actively construct an understanding of concepts and relationships within domains of interest. It was designed to support the learner's effort by externalizing concepts and propositions known to the student, making them visually apparent to facilitate their connection with newly acquired concepts. Concept maps have been used by teachers to assess students' understanding, by students to compare their knowledge and collaboratively renew their understanding, and by experts as a vehicle for modelling and sharing their knowledge. In other word, Concept maps are graphical tools for organizing and representing knowledge. Concept mapping has been adequately advocated in literature as a strategy for meaningful learning of abstract concepts and assists learners into learning about conceptual changes. Some studies which the researcher had worked on previously have found the use of concept mapping very effective in science teaching and learning difficult concepts in chemistry (Jack, 2013; Jack, 2014b; Jack, 2019; Jack & Suleiman, 2020); which learning environments were mostly not in a collaborative class or lab. Concept mapping can also be carried in a collaborative learning environments as applicable in this present study. Collaborative concept mapping (CCM) is a combination of two well-researched learning strategies: concept mapping and collaborative learning; and evidence suggests that the synergistic effects of both strategies is effective for supporting the acquisition and retention of knowledge (Wong, 2021). CCM also refers to the process of constructing a concept map with two or more individuals. It is well-rooted in research on both concept mapping and collaborative learning. In the last decade, the field has observed an increase in the interest and use of collaborative concept mapping to support the acquisition of retention of learning. Several studies (Ajayi, Achor & Agogo, 2017; Githae, Keraro, & Wachanga, 2015; Kipkemoi, Mukwa, & Too, 2019; Kyado, Abah & Samba, 2019; Sunday, Olaoye, & Audu, 2021; Terhemba, Okwara, & Jirgb, 2021) have found the use of CCM to very effective in science teaching and learning of some difficult concepts in the sciences, though very few in chemistry in improvement on students' achievement.

The academic performance in chemistry in Taraba State, Nigeria is still raising a serious concern to educators and researchers with WAEC results reflecting percentage of "A-C6" 32.7%, 51.6%, 47% and 39.8% in 2019, 2020, 2021, and 2022 respectively (Taraba State Ministry of Education Resource Center, 2022). In Taraba State, the fundamental challenge facing the teaching/learning of chemistry as a

science subject in secondary schools is how to enhance students' conceptual understanding as well as affective characteristics associated with teaching/learning process. The challenge has impeded students' attainment of meaningful learning. Based on this challenge, the present study was designed to determine the effect of innovative, effective and efficient instructional strategies in a collaborative class and lab environment. Also, in order to bridge the gap in literature in the study area (Taraba State) in the use of the three experimental instructional strategies (computer simulation, collaborative and problem solving and concept mapping) in teaching some chemistry concepts such as chemical (redox) reactions which is perceived as difficult by students (Jack, 2014a; Jack et al. 2017). Worried by the poor performance of students in chemistry, this study therefore aimed to ascertain if there would be an improvement on students' conceptual understanding and cognitive achievement using the aforementioned innovative instructional strategies.

In order to achieve the purpose of the study, these research questions were raised as a guide and answered.

i. Does experimental group one (EG1) give a better result than control?
ii. Does experimental group two (EG2) give a better result than control?
iii. Does experimental group three (EG3) give a better result than control?
iv. Does the three experimental groups differ significantly from each other?
v. Is there any effect of the experimental and control methods of instruction on students' cognitive achievement?
vi. Is there any significant difference in chemistry achievement among students taught with experimental groups and control?

Research Method

The design used for this study was quasi experimental design; using pretest and posttest. The pretest score constituted the covariant to determine the initial equivalence before the posttest. The design consisted of four instructional groups (computer simulation, collaborative problem-solving, concept mapping and conventional teaching method). The independent variable was the instructional strategies while the dependent variables were immediate achievement of chemical knowledge.

The population of the study comprised 1940 Secondary school two (SS2) students offering chemistry of 2021/2022 academic session in all the 40 public schools Jalingo Education Zone, Taraba State, Nigeria. The sample consists of 229 students from four intact chemistry classes purposively selected from four schools in the zone. The sample was divided into three experimental groups (EG1, EG2 & EG3) that used computer simulation, collaborative problem solving and concept mapping respectively and one control group taught chemistry concepts (redox reactions) using the conventional method. The redox reactions comprises of subtopics combination and decomposition, displacement reactions (single & double), combustion reaction, and disproportionation; majoring more on calculation of oxidation number, oxidizing and reducing agent and balancing of redox equation which was taught for 4 weeks using three double periods of 90 minutes per week. The lesson plans for the experimental groups (computer simulation, collaborative problem-solving and concept mapping) and that for the control group (conventional teaching method) were prepared on the Chemistry topics of senior secondary schools syllabus/scheme of work. The topics are contained in the recent senior secondary school education curriculum approved for use in senior secondary schools in Nigeria by (NERDC).

To determine the extent to which the instrument can measure the achievement of SS2 students in Chemistry, the RRAT was scrutinized by preparing test blue print and by process of face and content validation of three experts; and the corrections and suggestions arising from the experts were used to review the instrument before use. The items constructed in RRAT have a table of specification that measured the six objectives in the cognitive domains (knowledge, comprehension, application, analysis, synthesis, evaluation). The data collection tool was Redox Reaction Achievement Test (RRAT) made up of 30 multiple choice questions. Psychometric and item analysis of RRAT selected 30 out of 40 initial questions. Kuder-Richardson (K-20) was used to estimate the reliability index of 0.88 for the RRAT.

The three experimental groups were exposed to treatment using computer simulation, collaborative problem-solving and concept mapping; while the control (contrast) group was taught using the conventional teaching method. The pre-test was administered on experimental and control groups at the first week of the study. The reason was because the result of the pre-test was used to ascertain students' entry behaviour on the topics to be taught. Six weeks was used for the study after the training of the research assistants because of the number of the selected topics from chemistry syllabus on chemical reactions or redox reaction concepts. The first week was for the administration of pretest, the 2nd to 5th week for treatment, and the last week of the sixth week was used for administering the post-test was administered to the three groups in the experimental group and the contrast (control) group with the intention of estimating the understanding of the knowledge chemistry concepts taught after that period of treatment to ascertain their cognitive achievement.

To control experimenter's biases, the students' regular chemistry teachers in the four schools were sampled to teach both the experimental and control groups. To control teacher variable, sets of lesson plans on computer simulation, collaborative problem-solving and concept mapping; while the control group was taught using the conventional teaching method were prepared for the teachers to use during chemistry lesson instructions. The contents of the lesson plans were extensively discussed and training was adequately carried out with the teachers; who were advised to adhere to them with proper mentoring and supervision. Teachers were also taught how to administer the pretest and posttest using the RRAT.

At the end of every two week's instruction a post achievement test of 30 items was administered to both the experimental and control groups. The students test scores were averaged at the end of the 6 weeks of instruction to present a single test score. Two weeks after the post test, a follow-up test (retention test) using the same instrument was administered to the three groups in the experimental group and the contrast (control) group with the intention of estimating the retention of the knowledge taught after that period of treatment.

The data collected was analyzed using descriptive analysis (mean & standard deviation) and inferential statistics (t-test analysis, one-way analysis of variance (ANOVA) followed by multiple comparison analysis- Scheffe post-hoc analysis).

Presentation of Results

Answering research question one (RQI): Does EG1 give a better result than control?

Table 1 was used to answer research question one.

Table 1: Pre-and post-test Mean achievement scores for EG1 and control groups

GROUP	N	Pretest Mean	Std deviation	Posttest Mean	Std deviation	Mean gain
EG1	52	10.67	1.451	23.79	1.601	13.12
CTRL	50	10.24	1.364	12.04	1.665	1.80

In comparing experimental group one (EGI) with the control group as presented in Table 1, EG1 had pretest mean achievement scores of 10.67 and posttest achievement scores of 23.79 with a mean gain of 13.12. While for the control group had pretest mean achievement scores of 10.24and posttest achievement scores of 12.04 with a mean gain of 1.80. From the mean gain differences (EG1, M=13.12; CTRL, M=1.80); EG1 gave a better result than the control group. Lead Answering research question two (RQ2): Does EG2 give a better result than control?

Table 2 was used to answer research question two.

Table 2: Pre-and post-test Mean achievement scores for EG2 and control groups

GROUP	N	Pretest Mean	Std deviation	Posttest Mean	Std deviation	Mean gain
EG2	77	10.58	1.427	24.78	2.069	14.20
CTRL	50	10.24	1.364	12.04	1.665	1.80

In comparing experimental group two (EG2) with the control group as presented in Table 2, EG2 had pretest mean achievement scores of 10.58 and posttest achievement scores of 24.78 with a mean gain of 14.20. While for the control group had pretest mean achievement scores of 10.24and posttest achievement scores of 12.04 with a mean gain of 1.80. From the mean achievement gain differences (EG1, M=14.20; CTRL, M=1.80); EG2 gave a better result than the control group.

Answering research question three (RQ3): Does EG3 give a better result than control?

Table 3 was used to answer research question three.

Table 3: Pre-and post-test Mean achievement scores for EG3 and control groups

GROUP	N	Pretest Mean	Std deviation	Posttest Mean	Std deviation	Mean gain
EG3	50	10.62	1.292	21.48	1.644	10.86
CTRL	50	10.24	1.364	12.04	1.665	1.80

In comparing experimental group three (EG3) with the control group as presented in Table 3, EG3 had pretest mean achievement scores of 10.62 and posttest achievement scores of 21.48with a mean gain of 10.86. While for the control group had pretest mean achievement scores of 10.24and posttest achievement scores of 12.04 with a mean gain of 1.80. From the mean achievement gain differences (EG1, M=10.62; CTRL, M=1.80); EG2 gave a better result than the control group.

Answering research question four (RQ4): Does the three experimental groups differ significantly from each other?

Table 4 and 5 were used to answer research question four.

Table 4: Comparison of pre and posttest achievement means of experimental groups

GROUP	N	Pretest Mean	Std deviation	Posttest Mean	Std deviation	Mean gain
EG1	52	10.67	1.451	23.79	1.601	13.12
EG2	77	10.58	1.427	24.78	2.069	14.20
EG3	50	10.62	1.292	21.48	1.644	10.86

Table 4 shows the achievement mean gains of EG1, EG2 and EG3 to be 13.12, 14.20 and 10.86. The results shows that EG2 has the highest mean gain followed by EG1 and lastly EG3. In order to verify if the three experimental groups differ significantly from each other, a t – test comparison of posttest achievement means of experimental groups was conducted and is presented on Table 5.

Table 5: t – test comparison of posttest achievement means of experimental groups

POSTEST

Group	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum	Test of Homogeneity of variances Levene Statistic	df	Sig.
EG1	52	23.7885	1.60069	.22198	23.3428	24.2341	20.00	20.00			
EG2	77	24.7792	2.06871	.23575	24.3097	25.2488	19.00	19.00	2.361	3 175	.072
EG3	50	21.4800	1.64429	.23254	21.0127	21.9473	18.00	18.00		179	
Total	179	23.3492	5.23709	.34608	22.8884	23.8101	10.00	10.00			

Table 5 presents a t – test comparison of posttest achievement means of experimental groups (EG1, EG2 & EG3). The t-test comparison results shows that t=2.361, df=175, p-value=0.72 (p>0.05), not significant. Hence, the three experimental groups (that used computer simulation, collaborative and concept mapping) do not differ significantly from each other in their achievement mean scores.

Answering research question five (RQ5): Is there any significant effect in the posttest achievement means of the experimental and control groups' method of instruction on students' cognitive achievement?

Tables 6 and 7 were used to answer research question five.

Table 6: ANOVA Comparison effects of post – test scores of experimental and control groups'

POSTEST

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	5529.051	3	1843.017	572.508	.000*
Within Groups	724.320	225	3.219		
Total	6253.371	228			

*P<0.005, Significant

The ANOVA comparison effects of post – test scores of experimental and control groups on Table 6 shows F-value=572.506, and P-value= .000. Hence, there is a significant effect (p=0.000< 0.005) of instructional strategies used in the experimental and control groups. To verify if there is an equality of the posttest achievement means, robust tests on Table 7 was used.

Table 7: Robust Tests of Equality of posttest achievement means

Robust Tests of Equality of Means

POSTEST

	Statistic[a]	df1	df2	Sig.
Welch	611.802	3	120.994	.000
Brown-Forsythe	607.417	3	223.838	.000

a. Asymptotically F distributed.

Table 7 result also shows that there is a significant effect on the posttest achievement means (p<0.05).

Answering research question six (RQ6): Is there any significant difference in the posttest achievement means of the experimental and control groups' method of instruction on students' cognitive achievement?

Tables 8 and 9 and Figure 1 were used to answer research question six.

Mean plots

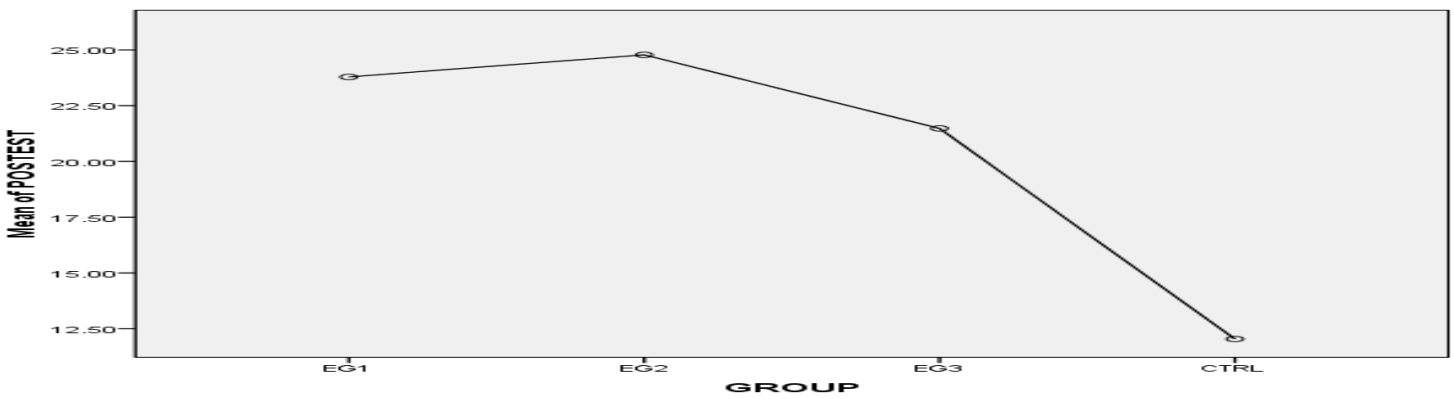


Figure 1- Comparison of posttest achievement means of experimental and control groups

Figure 1 shows the achievement means plot for the experimental and control groups with EG2 having the highest mean (24.78) followed by EG1 (23.79), and EG3 (21.48). All the experimental groups scored higher marks (achievement means) than the control group that had (12.04). To finally verify where the mean difference is significant at the 0.05 level, a post hoc multiple comparisons was used as presented in Table 8.

Table 8: Post – hoc tests multiple comparisons to compare the effect of experimental and control groups.

POSTEST Tukey HSD

					95% Confidence Interval	
(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
EG1	EG2	-.99076*	.32205	.013	-1.8243	-.1572
	EG3	2.30846*	.35538	.000	1.3886	3.2283
	CTRL	11.74846*	.35538	.000	10.8286	12.6683
EG2	EG1	.99076*	.32205	.013	.1572	1.8243
	EG3	3.29922*	.32587	.000	2.4558	4.1427
	CTRL	12.73922*	.32587	.000	11.8958	13.5827
EG3	EG1	-2.30846*	.35538	.000	-3.2283	-1.3886
	EG2	-3.29922*	.32587	.000	-4.1427	-2.4558
	CTRL	9.44000*	.35884	.000	8.5112	10.3688
CTRL	EG1	-11.74846*	.35538	.000	-12.6683	-10.8286
	EG2	-12.73922*	.32587	.000	-13.5827	-11.8958
	EG3	-9.44000*	.35884	.000	-10.3688	-8.5112

*. The mean difference is significant at the 0.05 level.

Table 8 shows the post – hoc test to compare the effect of experimental and control groups. The result presented compared achievement mean test scores of students in the three experimental groups (computer simulation, collaborative problem solving and concept mapping) and the control group (conventional method) which indicated a significant difference among the groups. The multiple comparisons result shows that all the posttest achievement have mean difference that is significant at the 0.05 level (P < 0.05). The post hoc analysis using Scheffe test shown in Table 8 helped to determine the direction of the noticed significance indicated; and all the students in the experimental groups significantly outscored those in the control group; and the mean difference is significant at the 0.05 level. Hence, there is a significant difference in the posttest achievement means of the experimental and control methods of instruction on students' cognitive achievement.

Table 9: Posttest Means for groups in homogeneous subsets

Tukey HSD POSTTEST

		Subset for alpha = 0.05			
GROUP	N	1	2	3	4
CTRL	50	12.0400			
EG3	50		21.4800		
EG1	52			23.7885	
EG2	77				24.7792
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Table 9 presents the means that are listed under each subset, which comprise a set of means for groups in homogeneous subsets; and in this case all the subsets are not significantly different from each other. This shows that within the subset (each group) there is no significant difference (p=1.00>0.005); while between the subsets (between groups) there is a significant difference (p=btw 0.000-0.013<0.05) as shown in Table 8. This confirms that there is a significant difference in the posttest achievement means of the experimental and control methods of instruction on students' cognitive achievement; with an initial equivalence of subsets within the groups.

Discussion of Findings

The key findings:

1. The experimental group one (EG1) that used computer simulation had better achievement than the control group that used the convention method.
2. The experimental group two (EG2) that used collaborative problem solving had better result in terms of their cognitive achievement than the control group that used the conventional method.
3. The experimental group three (EG3) that used collaborative concept mapping had better achievement than the control group that used the convention method.
4. The three experimental groups (computer simulation, collaborative problem solving and concept mapping) do not differ significantly from each other in terms of students' achievement.
5. There is a significant effect of the experimental and control methods of instruction on students' cognitive achievement; in favour of the experimental groups that showed superiority over the control group.
6. There is a significant difference in chemistry achievement among students taught with experimental and control groups; in favour of the experimental groups.

On the effectiveness of computer simulation, its supported by several studies in the literature (Arıcı & Yılmaz, 2020; Candida et al. 2013; Guy & Lowness- Jackson, 2015; Ibrahim et al. 2017; Jack & Aji, 2021; Jack & Gamnjoh, 2020a & 2020b; John, Robert & Israel, 2013; Kabigting, 2021; Kibirige & Tsamago, 2019; Kumar, 2018; Mihindo, Wachanga, & Anditi, 2017; Okwuduba, Offiah, & Madichie, 2018; Philip, Du Toit, & Van Breda, 2023; Ouyang et al. 2021; Topuz, 2018; Wen et al. 2020; Udo & Etiobun, 2011; Yıldız, 2019) that also revealed that using the computer simulation had positive and strongly significant effects on students' academic achievement. This would have resulted to development of creative, critical thinking, collaborative and computer skills; hence the resultant effect of the experimental group that used computer simulations having second to highest achievement amongst the three experimental groups. And as noted by Lawal (2017), computer simulations are motivating and enhance learning of factual information. It allows for better understanding of processes, improves critical thinking and transferability to other situations. Also, as noted in Jack and Gamnjoh (2020), computer simulation promotes application of knowledge, and provides a simplified representation of real-world systems, facilitates learning through representation and practice in a repeatable, focused environment. These substantiate claims would have led to the students' taught in the experimental group that used computer simulations, having better results than their counterparts in control group that used conventional teaching method that was teacher-activity centred.

On the effectiveness of collaborative problem solving (CPS) the students in the each group that used this strategy, participated in the social practices and interact with each other to jointly solve problems (Hakkarainen et al., 2013); use cognitive engagement to solve the ill-structured problems usually needs students' exploration and understanding of the problem, proposition, and justification of the solutions, and the sustained development of new ideas and artifacts in the groups (Hakkarainen et al., 2013); and the students need to take actions to externalize their knowledge in artifacts (e.g., concept map, writing document) and refer to peers' behavior to coordinate their group activity and optimize the knowledge artifacts (Stahl, 2017). This must have resulted to development of creative, critical thinking, collaborative and problem solving skills; hence the resultant effect of the experimental group that used CPS having the highest achievement amongst the three experimental groups. Moreover, the collaboration in problem solving helped the group to succeed, where the students need to negotiate what to achieve as a group, plan, and implement problem-solving strategies, monitor and reflect on the working progress (Järvelä & Hadwin, 2013; Winne et al., 2013). There are some studies in literature (Avry et al. 2020; Fiore et al. 2017; Hakkarainen et al. 2013; Hmelo-Silver & DeSimone, 2013) that revealed that CPS instructional strategy had positive and strongly significant effects on students' achievement. Gu and Cai (2019) found that integrating semantic diagram tools in CPS helped students achieve a greater depth of understanding of the domain knowledge. The research conducted by Unal and Cakir (2021) also concluded that CPS supported by web 2.0 technologies has a positive effect on student achievements.

On the effectiveness of collaborative concept mapping (CCM), its supported by several studies (Ajayi, Achor & Agogo, 2017; Githae, Keraro, & Wachanga, 2015; Kipkemoi, Mukwa, & Too, 2019; Kyado, Abah & Samba, 2019; Sunday, Olaoye, & Audu, 2021; Terhemba, Okwara, & Jirgb, 2021; Wong, 2021) that found the use of CCM to very effective in science teaching and learning of some difficult concepts in the sciences, though very few in chemistry in improvement on students' achievement. Hence, conceptual understanding which have emerged in recent discoveries as the critical factor contributing to the continued inertia in performance in chemistry could also be minimized using collaborative concept mapping which helped in minimizing students' misconceptions of chemistry concepts which they initially perceived as difficult. And as noted by Jack (2022) in order to overcome students' misconceptions, a forum for students to confront their misconceptions should be provided; and the students should be helped to reconstruct and internalize their knowledge, based on scientific models. Jack (2022) also opined that the key to students' academic success is ensuring that students are constructing or reconstructing a correct framework for their new knowledge; one way of establishing this framework is to have students create "concept maps" which can also be achieved in collaborative classroom environments. Conceptual understanding as opined by Woldeamanuel, Abate, and Berhane, (2020) requires clarification of misconceptions and offers the potential to engaging students in meaningful teaching-learning process. And, as noted by Jack (2022) meaningful learning occurs when complex ideas and information are combined with students' own experiences and prior knowledge to form personal and unique

understandings; and concept maps are one of the most important teaching and learning tool that helps in promoting meaningful learning. These substantiate claims would have led to the students' taught in the experimental group that used collaborative concept mapping, having better results than their counterparts in control group that used the conventional teaching method.

It therefore follows that the degree of achievement earned by students in the various instructional groups may be hinged on the effectiveness of the methods. This is because all experimental groups (computer simulation, collaborative problem solving and concept mapping) were taught in collaborative class environments. And students seem to learn best when they are actively involved in the process as applicable in the three experimental groups; though the collaborative problem solving had the highest achievement means followed by computer simulation and lastly concept mapping. This attests to earlier that, regardless of the subject matter, students working in small groups tend to learn more of what is taught and retain it longer than when the same content is presented in other instructional formats. Students who work in collaborative groups also appear more satisfied with their classes. In as such, other innovative instructional strategies should be applied in collaborative classroom enabling environment during chemistry lessons. And, as noted by Jack and Sheriff (2020)**,** the traditional classes or conventional mode of instruction that is teacher-activity-centred (where learners are inactive or passive recipients) and seems to encourage more of rote learning (memorization) should be discouraged in chemistry classes in order to promote meaningful learning/development of the 21st century skills and students' academic performance.

Conclusion

It was found that the experimental groups (computer simulation, collaborative problem solving and concept mapping) outperformed the control group (convention method) in achievement; though the students' that were taught with collaborative problem solving had the highest achievement mean scores, followed by computer simulation and lastly collaborative concept mapping. Hence, the study concluded that the three innovative instructional strategies (mostly collaborative problem solving) can be used for chemistry instructions; since they are useful facility for improving students' academic performance and promoting meaningful learning/developing the 21st century skills (problem solving, critical thinking, collaboration, and creative and computer skills) in students. Therefore, the conventional method (lectures, discussions and demonstrations) which remains the most popularly used method in chemistry classes that is teacher-activity centred should be discouraged; and in its stead the use of student-activity-oriented strategies (such as computer simulation, collaborative problem solving and concept mapping) which aid the attainment of certain values such as student-centered learning, active participation thereby enhancing achievement of students in the subject.

Based on the conclusion drawn, the researcher recommended that chemistry pre-service and in-service teachers should be trained on the use of these innovative instructional strategies (computer simulation, collaborative problem solving and concept mapping) with classroom enabling environments for easy adoption; and also integrated into chemistry curriculum in secondary schools.

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