THE EFFECT OF VIRTUAL LABORATORY ON STUDENT TEACHERS' ACHIEVEMENT IN INTEGRATED SCIENCE IN BAGABAGA COLLEGE OF EDUCATION, TAMALE, GHANA

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ABSTRACT

The purpose of this study was to determine the effect of Virtual Laboratory (VL) on student teachers' achievement in Integrated Science in Bagabaga College of Education, Tamale. The study employed an action research design. The accessible population was all the level 100 student teachers of Bagabaga College of Education, Tamale. Purposive sampling technique was used to select 70 student teachers as the sample for the study. The instruments that were used to collect data were pre and post-tests. The pre-test and post-test for both the cognitive achievement test and test of practical skills were analysed statistically using paired t-test. Results from the study showed that for the cognitive achievement test, the mean score of the post-test (17.96) was significantly greater than the mean pre-test score (8.53). ($t(69) = 23.30$, $P < 0.05$), indicating that the VL had a positive effect on the cognitive achievement of student teachers before and after the implementation of the intervention. There was also a significant difference between the practical skills of student teachers before and after the intervention with ($t(69) = 11.93$, $p < 0.05$). The findings of the study strongly suggest that the sampled students' performance has improved in Integrated Science through VL. Furthermore, the VL improved student teachers' practical skills. Based on these findings, it is recommended that tutors should be encouraged through capacity building and provision of resources to integrate VL in their teaching of Integrated Science in the College of Education.

Keywords: Virtual Laboratory, Practical skills, Cognitive achievement, Student teachers, Integrated science, Information and communication technology.

INTRODUCTION

The use of information and communication technology (ICT) in the classroom for science education has increased dramatically in recent years and has proven to be a very effective tool in a variety of situations.

The use of technology in science classes offers many opportunities for educational development for instance students can collaborate with their classmates on meaningful activities; Effective technology can also enhance and enrich learning in interactive environments, which encourages creativity through e-learning applications in various modes such as visualization, simulation and modeling (Manner, 2003; Repnik & Grubelnik, 2010). Virtual Laboratory (VL) provides visual context for numerous abstract concepts and offers remarkable visualization and graphical analysis skills (Wieman & Perkins, 2005).

A number of studies on the effectiveness of virtual environments on student performance in science showed that such environments improved student performance and that there were significant differences between the performance of students taught in virtual environments and those taught in conventional ones. (Efe & Efe, 2012; Falode, 2014). Liao (2007) found out that

Computer Instruction (C.I.) had a positive effect on individuals by comparing 52 research studies carried out in Taiwan in his meta-analysis study. Akpan, et. al. (2016) looked at virtual instructional instructions and their effects on school performance. However, their work has been carried out on distance students and also in Nigeria. Faour and Ayoubi (2018) also did similar work on the effect of using the Virtual Laboratory. However, their work was also limited to 10th grade students in Lebanon. Anekwe (2017) dealt with learning in the virtual classroom. This was done to determine the impact of virtual learning on student academic performance. The study was carried out in Nigeria and at their universities. From the above literature, it can be stated that:
1. Some work on learning in the virtual laboratory has been carried out
2. No study was carried out in the Ghanaian context at the College of Education level on virtual laboratory learning.
3. Most of the work on learning in the virtual laboratory was not done in the integrated science, but in the elective science subjects.
These three results form the basis for the knowledge gap that this study seeks to fill

Statement of the Problem

Integrated Science, which is studied at the basic level, prepares students for science disciplines at secondary schools and university levels in Ghana. But student underperformance in science in the West African Secondary School Certificate Examination (WASSCE; WAEC, 2015, 2016) has raised many problems. Educational actors and the general public across the country have raised many questions about student achievement in integrated science and the methods of teaching and learning science. Student teachers in most Colleges of Education in Ghana are no exception to this problem because of their weak foundation in Integrated Science. The abstract nature of content delivered to students in their secondary schools affected most student teachers' performance in Integrated Science at the College level (Institute of Education UCC, 2015). A series of observations made during integrated science lessons at the Bagabaga College of Education (BACE) revealed that most student teachers' performance in integrated science lessons was not encouraging. The majority of student teachers performed poorly in weekly quizzes. Evidence from the Chief Examiner's Report (Institute of Education, UCC 2018) showed that out of 276 candidates, who sat for Integrated Science paper at the Bagabaga College of Education, Tamale, 226 candidates scored below 40 marks out of 60 marks and this supported the observation made during the researcher's lessons. Many things could be done to raise the standard of student teachers in the colleges of Education in Ghana with regard to their achievements in Integrated Science. It was based on this that VL was used to teach student teachers the concepts in the Integrated Science so as to access its effect on their cognitive and practical skills achievement.

Purpose of the Study

The purpose of this study was to determine the effect of VL on student teachers' achievement in Integrated Science in Bagabaga College of Education, Tamale.

Objectives of the Study

The objectives of the study were to:

1. Determine the effect of the use of VL on student teachers' cognitive achievement in Integrated Science
2. Determine the effect of using VL on student teachers' practical skills in Integrated Science lessons

Research Questions

Two research questions were formulated to guide the study

1. What is the effect of using VL on student teachers' cognitive achievement in Integrated Science?
2. What is the effect of using VL on student teachers' practical skills in Integrated Science?

Null Hypotheses

The following null hypotheses were tested;

1. Ho1: There is no statistically significant difference between the cognitive achievement of students on the pre-intervention test and the post-intervention test.
2. Ho2: There is no statistically significant difference between the practical skills of students before and after the implementation of the intervention.

Literature Review

Effect of VL on Students Cognitive and Practical Skills Achievement in Integrated Science

A laboratory refers to experiences in school settings where students interact with devices and materials or secondary data sources to observe and understand nature (Hofstein & Kind, 2012). A virtual laboratory is defined as an electronic workspace for remote collaboration and experimentation in research or other creative activities in order to generate and deliver results using distributed information and communication technologies. Furthermore, virtual learning environments offer an emphasis on authentic scientific experiences because students can revise their original predictions for experiments by way of instant feedback from data manipulations, form more accurate mental models of phenomena, and can even use these virtual simulations as a practice to prepare them conceptually for complex hands-on experiments (Zacharia, 2007). Virtual laboratories are essentially simulated experiments performed with computer software and offer numerous benefits for both student learning and the logistics of the educational experience.

Technologies can be used to perform time-consuming tasks like collecting and analyzing data. This gives students more time to observe, reflect, and construct conceptual knowledge; perform, interpret and report more accurate and relevant data; and focus on student collaboration, developing a community of practice, and engaging in reasoning (Hofstein & Kind, 2012)

Hofstein and Kind (2012) note some improvements in the conceptual understanding of science through the integration of information and communication technologies (ICT) into the laboratory, but the level at which ICT is used in different school laboratories varies. They suspect that ICT will be used to achieve a better synthesis between laboratory work and computational simulations and conclude that this is an area that requires more research into its educational effectiveness.

Yu, Brown, and Billet, (2005) constructed a system that makes use of the instant feedback function by providing an intelligent tutor agent who gives students advice on how to correct their mistakes while conducting a virtual experiment. Of course, virtual experiments are repeatable inside and outside the classroom, a feature that serves to prepare students for starting a hands-on experiment and allows them to review an experiment after it has been carried out (Cobb, Heaney, Corcoran & Henderson-Begg, 2009; Reising, 2010). While some virtual laboratories are designed to incorporate student collaboration (Cobb et al., 2009), others are focused on training individuals in the skills and concepts of a particular experiment.

The types of laboratories intended to enable student collaboration to excel in imitating a true scientific experience of not only investigation but also the building community of practice. Indeed, one of the most important features of web materials necessary to improve learner outcomes is a high degree of interaction, which can be accomplished asynchronously and synchronously (Chandra & Fisher, 2009). Virtual laboratories on the other hand focus on the individual, have the advantages of enabling shy students to find more voice (Dede, 1999) and reducing the peer pressure from both fellow students and teachers, thus allowing users to feel more comfortable about making and learning from mistakes (Yu, et. al 2005). These advantages might be applied to online experimentation that includes collaboration, as well, because there is a degree of anonymity. However, disadvantages of utilizing virtual laboratories include the use of idealized data, lack of collaboration, and the absence of interaction with real equipment (Hofstein & Lunetta, 2004; Nedic, Machotka, & Nafalski, 2003).

Waight and Abd-El-Khalick (2007) added that true investigation in virtual experiments can also be compromised due to the perceived authority of the technology. Winnet al. (2006) suggest that such technological tools can benefit students with more prior knowledge. Ultimately, many of these disadvantages can be avoided by applying good design principles for the implementation of virtual laboratories (Annetta, Klesath & Meyer, 2009; Toth, Morrow, & Ludvico, 2009). Proponents of hands-on labs emphasize design skills (Ma & Nickerson, 2006) and the importance of making and learning from mistakes (Toth, Morrow & Ludvico, 2009), while proponents of virtual and remote labs focus on the benefits gained through conceptual understanding (Marbach-Ad, Rotbain & Stavy, 2008; Toth, Morrow & Ludvico, 2009). VL has the advantage of increased safety since there is no exposure to potentially harmful substances or equipment and the time for actually completing the laboratory assignment is reduced (Toth & Morrow, 2012). They are also necessary to perform complex simulations of known theories that would otherwise not be demonstrable (Singh, 2012).

According to Tatli and Ayas (2013), VL is one of the solutions of teaching technology, which is very important in chemistry class, provides students with meaningful virtual experiences, and presents important concepts, principles, and processes through it give students the opportunity to repeat a wrong experiment or to deepen the intended experience. The philosophy of VL depends on many principles (Mahdi, 2008; Salem, 2009)) including the following:

a) Exceeded the true reality: The VL was created as an alternative to reality due to the difficulty of access to it or to its gravity. For example, three-dimensional science virtual labs seek to build the worlds from symbols; in order to simulate reality, or the establishment of worlds fantasy digital creature and multimedia which takes the learner to practice experiences that, are difficult for him to do in the real world, like a prowling the outer space or wandering around inside the nuclear reactor.
b) Individual learning and learner freedom: as each learner depend on its self, according to his possessions from the preparations, capabilities and its needs from required variables, that are leading in terms of interest of learning more than instruction, and attention of training to produce knowledge rather than receive it.
c) Continuity of instruction: by providing lifelong learning, which is an urgent necessity that can’t be dispensed under the dictates of the times of the new requirements and variables, as it allows anyone to join him at the time that he deems appropriate to his circumstances; to develop acquaintances constantly in order to yield the best

instructional outcomes and the cognitive best results, that lead to the formation of a learner who has the ability to take responsibility.

d) Remove the temporal and spatial barriers in the traditional instructional systems and emphasize the continuity of lifelong learning, diversity of methods, means, and breadth of instruction for all.

Objectives of the VL (Bose,2013) include:

i. To provide remote access to Labs in various disciplines of science. These VL would cater to students at the undergraduate level, postgraduate level as well as to scientific research.
ii. To enthuse students to conduct experiments by arousing their curiosity. This would help them in learning basic and advanced concepts through remote experimentation.
iii. To share costly equipment and resources, which are otherwise available to a limited number of users due to constraints on time and geographical distances.
iv. To provide a complete Learning Management System around the VL where the students can avail of various tools for learning, including additional web resources, video lectures, animated Demonstrations, and self-evaluation.

Some researchers have argued that conducting experiments in a virtual environment is more effective than conducting experiments in real laboratories (Bayrak, Kanli & Kandilingec, 2007; Pyatt & Sims, 2012; Swan & ODonnell, 2009; Tatli & Ayas, 2012). Studies have shown that in traditional learning settings there are always inconsistencies between student predictions and observations (Josephsen & Kristensen, 2006; Kerr, Rynarson & Kerr, 2004). Such environments turn students into passive learners and cause them not to express their opinions directly (Sheppard, 2006). In contrast, virtual learning environments enable learners to repeat the events several times without hesitation, or zoom in and out, and watch the experimental process in slow motion (Tuyuz, 2010). On the effect of using virtual experiments on students' practical skills, many studies showed that virtual experiments helped students to gain better practical skills, which was reflected in their performance in the real lab (Alneyadi, 2019; Radhamani et al., 2014; Yang & Heh, 2007). Gorghiu et al. (2009) carried out a study to explore the impact of VL software on teaching "acid-base and neutral solutions" to seventh-grade students. The results showed that VL software impacted the students' satisfaction and efficiency and enabled them to better understand abstract concepts, and that it was also very helpful in hypothesis verification and increasing motivation. In addition, the students used VLs to improve their skills in a risk-free practice environment. In most studies, it is clear that VL has a positive influence on student performance and attitudes towards science, as well as improving student learning (Gorghiu et al., 2009; Rauwerda et al., 2006).

Conceptual Framework
The Conceptual framework is represented diagrammatically in Fig.1.

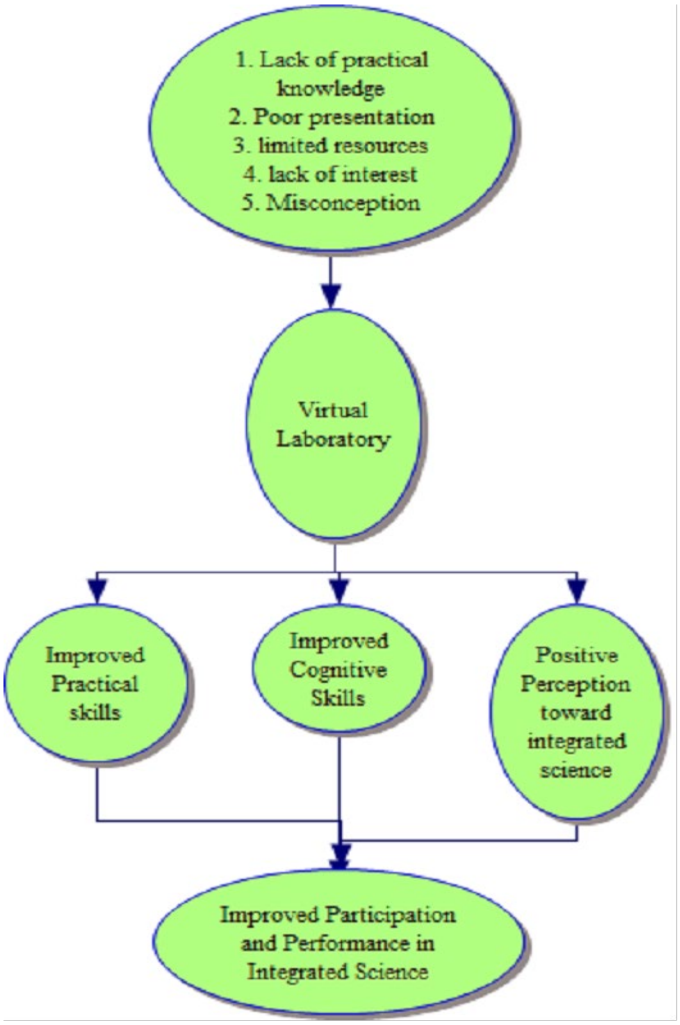

Figure 1: Conceptual framework

Fig. 1 showed the relationship of variables determining the effects of VL on student teachers' achievement in Integrated Science. The learning outcomes are influenced by various factors. They include the lack of practical skills, poor presentation, limited resources, lack of interest, and misconception as shown in the figure. These are extraneous variables that needed to be controlled. The independent variable is the VL as the teaching approach and the dependent variable is the improved participation and performance in Integrated Science. In this study, any difference found in the academic performance of the student teachers could therefore be attributed to the mode of instruction employed thus the use of VL.

Methodology

Research Design

Action research design was used to achieve the research objectives and to address the research problem to improve student teachers' participation and achievement in Integrated Science. Action research was used to bring about innovative teaching and learning in Integrated Science at Bagabaga College of Education, Tamale. The interventions were to help the student teachers to overcome the learning difficulties they had in the Integrated Science. Action Research would help the Researcher to manipulate the interventions to bring the desired learning outcomes in student teachers.

Population

The target population was all first-year student teachers and the accessible population was 70 level 100 student teachers of the 2019/2020 academic year of Bagabaga College of Education, Tamale.

Sample and Sampling Procedure

The purposive sampling technique was used to select B.E.d 1C student teachers as the sample for the study. This sample size was 70 student teachers who were assigned to the researcher to teach. All the students were used because the researcher handled them in the first semester of the 2019/2020 academic year. The researcher chose this intact class because it was the class that had difficulty in participation and performance in Integrated Science.

Instrumentation

The instrument used for the study were pre-test and post-test which were used to collect data on student teachers' cognitive achievement in integrated science. The test items were two sets of ten multiple-choice questions each, one for pre-test and the other for post-test of student teachers' cognitive achievement in Integrated Science. A practical test was used to determine the student teachers' practical skills before and after the intervention. Two sets of tests of five practical questions were also used to determine their level of performance in the practical skills before and after the intervention. The content areas of the test covered part of the second-semester course outline on introduction to Integrated Science 2 for level 100. Some of the content areas tested were the concept of energy, how to teach energy at the basic school, basic electronics, and practical electronics components and simple electric circuits.

Pre-Intervention

The pre-intervention involved the administration of the pre-test. The test was administered to the target population to assess their cognitive performance and practical skills in Integrated Science. The purpose of the pre-test was to ascertain the present level of achievement of student teachers in their cognitive and practical skills. All the scripts were marked, recorded and the scores were collated for further processing.

Intervention

The intervention consisted of concrete measures put in place to help solve a research problem. The intervention process involved the use of the VL to teach Integrated Science in BACE. A virtual laboratory is a computer-based activity where students interact with an experimental apparatus or other activity via a computer interface. VL is a collection of interactive computer simulations for teaching and learning sciences. VL simulates a virtual operating system, the computer screen, Science laboratories, exploiting the potential offered by modern media technology key feature technical interaction and direct and plausible manipulation of objects and parameters. VL could be run online or downloaded for free from the company's website. The computer simulations helped student teachers to learn in an animated, interactive, and game-like environment by means of investigation. Student teachers are able to quickly replicate experiments and quickly investigate the impact of many different parameters embedded in the simulation. VL were used to aid in the introduction of topic, to develop concepts or skills during lectures, to reinforce ideas in laboratory activities in class, and to provide a final review and reflection of student teachers work

Post-Intervention

The post-test on their cognitive and practical skills achievement in Integrated Science was administered to student teachers after the intervention to see if there was an impact of the use of VL on their cognitive achievement and practical skills in Integrated Science.

Data Analysis

Descriptive and inferential statistics of the Statistical Package for Social Science (SPSS) version 16.0 for windows 2007 were used to analyse the data collected. All the test scripts for both the cognitive achievement test and the practical tests were scored, each expressed as a percentage, and the results of the analysis were presented as bar charts. Paired Samples t-test was conducted to determine whether there was any statistically significant difference between pre-test and post-test mean scores. This was to establish whether the performance of students was a result of the instructional method used in the study.

Results and Discussion

The results of the study were presented and analysed in accordance with the research questions.

Research Question 1

What is the effect of using VL on students' cognitive achievement in Integrated Science?

The data from the pre-test and post-test were analysed and the outcome of the analysis were used to answer the research question on

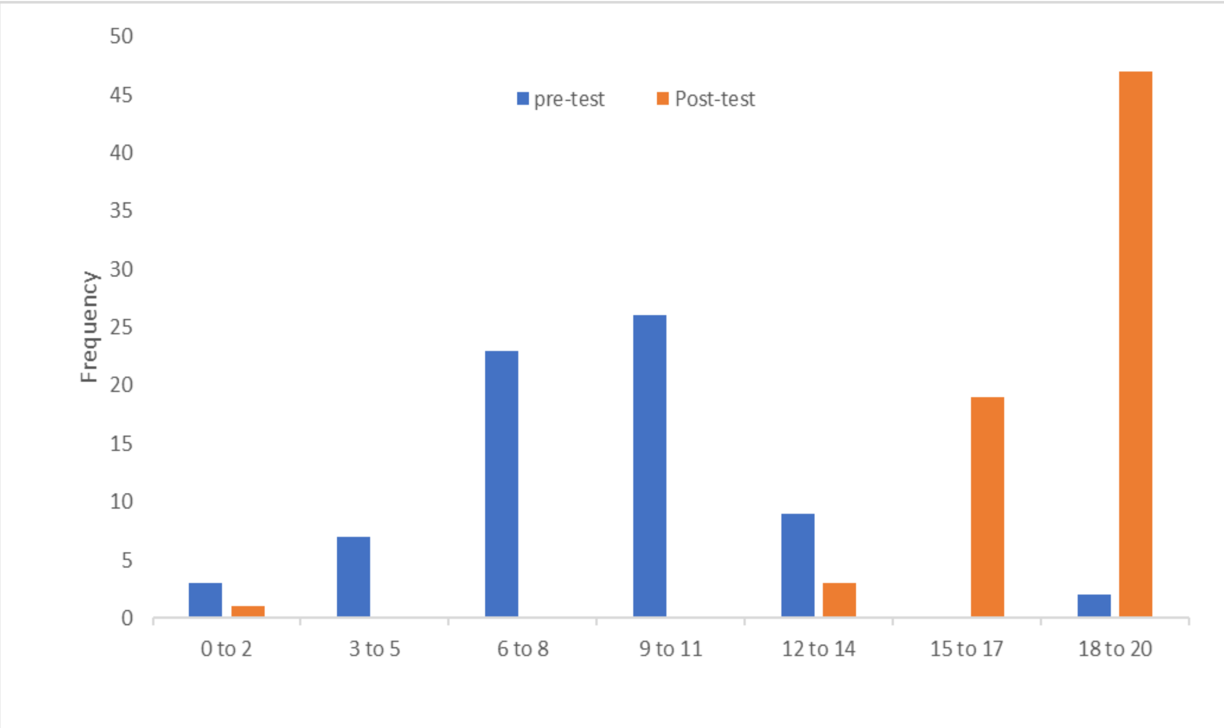

Figure 2: Percentage distribution of pre-test and post-test scores of student teachers' cognitive achievement

From Fig 2, it was revealed that most of the student teachers performed poorly in the pre-test which indicates that they lack the basic knowledge and understanding about the concept of Integrated Science such that; they performed poorly in the exercises. It could be seen those 3 students representing 4% had marks between 0 and 2. While 10% of students had marks between 3 and 5. Some 33% of students scored between 6 and 8, whereas 37% of students had marks between 9 and 11. Some 13% of students scored between 12 and 14 marks. None of the students had scores between 15 and 17. Two (2) Students (3%) scored between 18 and 20 marks. The distribution of post-test scores of students in the same group is displayed in fig. 2. It was observed from fig. 2 that there was a remarkable improvement in the scores of the students after the intervention. The scores obtained by students in the post-intervention test on their cognitive achievement showed that one student scored below 2 marks. None scored between 3-15 through 9-11 marks. Only 3 students (4%) scored between 12 and 14 marks. The rest scored above 15 marks representing 94%. The results suggested that a good number of the student teachers overcame their difficulties in understanding the concepts of integrated science taught the VL was used in teaching them the concepts.

Testing for Null Hypothesis One

H_{o1}: There is no statistically significant difference between the cognitive achievement of students on the pre-intervention test and the post-intervention test.

Table 1 showed the mean score and standard deviations of sample's score on the pre-test and post-test respectively.

Table 1: Distribution of descriptive statistics on the samples scores in cognitive achievement tests

Cognitive tests	Mean scores	N	Standard Deviation
Pre-test	**8.53**	**70**	**2.784**
Post-test	**17.86**	**70**	**3.480**

The mean of the post-test was higher than the mean sore of the pre-test. The standard deviation of the pre-test (2.784) indicated a more cluster of the pre-test scores around the mean scores than those of the post-test. This suggested that the intervention improved student teachers' cognitive achievement on the concept taught.

Table 1, showed the mean, standard deviation, t- statistics, degree of freedom, and p-value for pre-test and post-test for cognitive achievement test.

Table 2: Results of paired t-Test analysis on the sample's means scores for cognitive achievement tests

Compared Cognitive Tests	Mean	Standard Deviation	t Stat	Degree of Freedom (df)	P(T<=t) two-tail
Pre-test Post-test	9.429	3.378	23.358	69	1.75×10^{-34}

There was a significant difference in the scores for post-test (M=17.96, SD=2.78) and pre-test (M=8.53, SD=3.48); (t (69) = 23.36, p< 0.05).

This implied that there was a statistically significant difference between the cognitive achievement of students on the pre-intervention test and the post-intervention test. Therefore, the null hypothesis of no difference was rejected. This suggest that VL had positive effect on student teachers' cognitive achievement in Integrated Science.

Research Question 2, What is the effect of using VL on students' practical skills in integrated science?

The data from the pre-test and post-test on student teachers' practical skills were analysed and the outcome of the analysis was used to answer the research question one

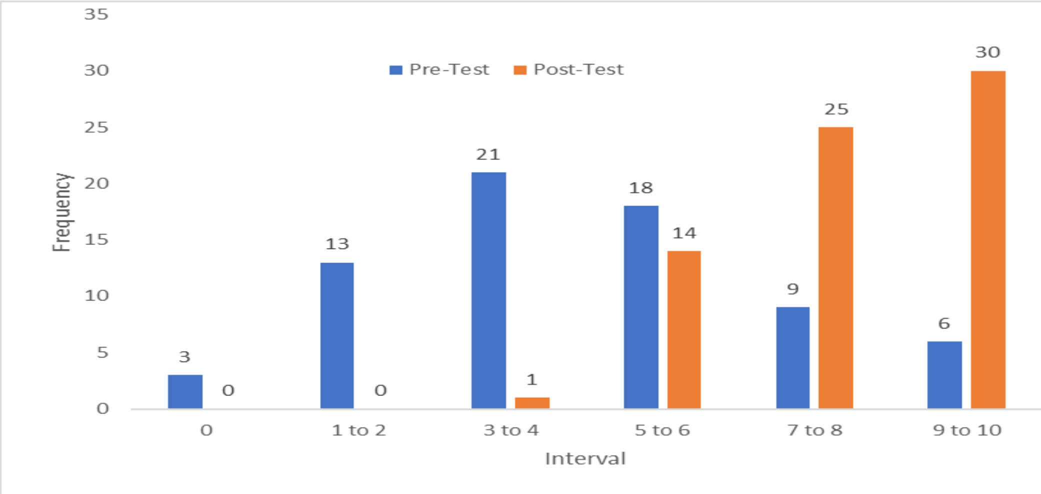

Figure 3: Frequency distribution of pre-test and post-test scores of student teachers' practical skills achievement in Integrated Science

From Figure 3, it was seen that most student teachers performed poorly which indicates that they lack basic practical skills in Integrated Science. From Figure 3, it could be seen that 3 student teachers scored 0 in the pre-test while non-scored 0 in the post-test. thirteen student teachers scored between 1 and 2 marks in the pre-test, while non scored between 1 and 2 marks in the post-test. Twenty-one of the student teachers scored between 3 and 4 marks while in the post-test, 1 student-teacher fell in the range of 3 and 4 marks. Between the range of 5 and 6, 18 student teachers fell in that category in the pre-test while 14 student teachers scored between 5 and 6 in the post-test. Nine student teachers scored between 7 and 8 marks in the pre-test while 25 student teachers scored between 7 and 8 in the post-test. Finally, about 30 student teachers scored between 9 to 10 in the post-test while only 6 student teachers fell in that range in the pre-test.

Testing for Null Hypothesis Two

H_{o2}: There is no statistically significant difference between the practical skills of students before and after the implementation of the intervention.

Table 3 showed the mean scores and standard deviation of pre-test and post-test scores on student teachers' practical skills.

Table 3: Sample descriptive statistics of test scores on practical skills

Practical tests	Mean scores	N	Standard Deviation
Pre- test	**4.43**	**70**	**2.534**
Post- test	**7.89**	**70**	**1.593**

The mean scores of the post-test (7.89) were higher than the mean score of the pre-test (4.43). The standard deviation of the post-test indicated a more cluster of the post-test scores around

the mean. The standard deviation of the post-test is more consistent as compared to the standard deviation of the pre-test.
Table 4 showed the t-test paired two samples for means for practical skills.

Table 4: Results of paired t-Test analysis on the sample's means scores for practical skills

Compared Practical Skills Tests	Mean	Standard Deviation	t Stat	Degree of Freedom (df)	P(T<=t) two-tail
Pre-test Post-test	*3.457*	*2.424*	*11.93*	*69*	*$1.94x10^{-18}$*

There was a significant difference in the practical scores for post-test (M=7.89, SD=1.59) and pre-test (M=4.43, SD=2.53), ($t(69) = 11.93$, $p< .005$). This implied that there was a statistically significant difference between the practical skills of students before and after the implementation of the intervention. Therefore, the null hypothesis of no difference is rejected. This suggests that VL improved student teachers' practical skills in Integrated Science.

CONCLUSIONS

The use of VL improved the student teachers' cognitive achievement and practical skills in Integrated Science lessons. This research has shown that there is great potential in VL as a teaching aid that can turn around learners' poor performance in Integrated Science. Based on the findings of this study it can be recommended that using VL in teaching Integrated Science significantly improved students' cognitive achievement and practical skills. The results showed that the use of VL in the teaching process has a positive impact on the students' knowledge levels.

RECOMMENDATIONS

1. The findings of the study revealed that VL when used in teaching Integrated Science will lead to student teachers' cognitive achievement and practical skills. It is therefore recommended that VL should be used in teaching concepts in integrated science.
2. Due to limited resources available at the Bagabaga College of Education in Ghana, it was recommended that tutors should be encouraged through capacity-building to integrate VL in teaching the practical aspects of the Integrated Science in the College.

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