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Effectiveness of Multimedia versus Traditional Teaching Methods on Chemistry Practical Performance among Senior High School Students in Ghana

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Abstract
This study explores the impact of multimedia teaching on senior high school students' Chemistry Practical performance. With technology increasingly becoming part of the learning environment, multimedia presentations are now utilised in schools to enhance students' learning experiences. Interactive Multimedia Learning, which incorporates visual and audio aids, is a teaching strategy that facilitates faster and easier comprehension of lessons. To compare the efficacy of Multimedia Teaching Method (MTM) and Traditional Teaching Method (TTM), this study was conducted in two senior high schools in Ghana: West Africa Senior High School and Frafraha Community Senior High School. The research design was quantitative, specifically quasi-experimental design and data were collected from 110 SHS 2 students using MTM and TTM. Descriptive and inferential statistics were used to analyse the collected data. The study findings revealed that most of the students taught using multimedia instruction performed significantly better in Chemistry Practical than those taught using the traditional method. These findings indicate that multimedia instruction can improve learning outcomes in chemistry. The study recommends using computers to supplement teacher instruction and not replace it. Teachers should continue to play a crucial role in the teaching process while integrating multimedia technology to enhance the learning experience.

Keywords: Chemistry Practical, Multimedia Teaching Method, Traditional Teaching Method, Practical Skills, Senior High School

1. Introduction

There are several innovative ways of teaching science that have emerged in recent years. Some of the most promising approaches include project-based learning, inquiry-based learning, collaboration, and the use of technology in the classroom. Project-based learning involves engaging students in real-world projects that allow them to explore and apply science concepts in a meaningful way. According to a study by Helle *et al.* (2017), project-based learning has been found to increase student engagement and motivation, as well as promote deeper

learning. Also, Inquiry-based learning involves students asking questions, designing experiments, and conducting investigations to discover scientific concepts. According to a study by Akerson *et al.* (2018), inquiry-based learning has been found to improve student understanding of science concepts and increase their critical thinking and problem-solving skills (Mohammed *et al.*, 2020; Mohammed & Amponsah, 2021a; Mohammed & Amponsah, 2021b). Collaboration in education involves working together with other teachers, students, or professionals to create a collaborative learning environment that fosters the sharing of ideas and knowledge (Amponsah & Ochonogor, 2016 a & b; Kozleski et al., 2013). According to a study by Vygotsky (1978), collaborative learning can help students to develop higher-order thinking skills, such as critical thinking, problem-solving, and decision-making (Amponsah, *et al.*, 2021; Amponsah, 2020; Amponsah & Ochonogor, 2018; Amponsah, *et al.*, 2018). Finally, the use of technology in the classroom can help make science learning more engaging and interactive. For example, virtual and augmented reality can be used to create immersive science experiences for students. According to a study by Keengwe *et al.* (2017), the use of technology in science education has been found to improve student motivation and engagement.

The advancement of technology has brought about significant changes in the educational sector worldwide. One of the most significant changes is the introduction of multimedia teaching methods, which utilize visual and audio aids to enhance the teaching and learning experience. Interactive Multimedia Learning is a modern teaching strategy that is increasingly being adopted in classrooms worldwide to facilitate faster and easier comprehension of lessons (Liu & Lee, 2020). In Ghana, multimedia technology is also becoming an integral part of the learning environment. Senior high schools are adopting multimedia presentations to enhance students' learning experiences. However, the effectiveness of multimedia teaching methods in comparison to traditional teaching methods has not been adequately studied in Ghana's senior high schools.

Chemistry is a crucial subject taught in senior high schools in Ghana, and practical work is an essential component of the curriculum. Therefore, it is crucial to examine the effectiveness of multimedia teaching methods in Chemistry practical classes. This study aims to examine and compare the effectiveness of the Multimedia Teaching Method (MTM) and Traditional Teaching Method (TTM) on Chemistry Practical Performance among Senior High School Students in Ghana. According to a study by Liu and Lee (2020), interactive multimedia learning is an effective teaching method that enhances students' academic performance. The study reported that students taught using multimedia instruction performed significantly better than those taught using traditional methods. Moreover, multimedia instruction improved students' engagement, motivation, and knowledge retention. Similarly, a study by Kwong et al. (2019) found that multimedia instruction was more effective in improving students' learning outcomes than traditional methods. The study revealed that multimedia instruction improved students' cognitive, affective, and psychomotor skills.

2. Statement of the problem

The effectiveness of multimedia teaching methods on Chemistry practical performance among senior high school students in Ghana has not been adequately studied. Therefore, this study aims to examine and compare the effectiveness of the Multimedia Teaching Method (MTM) and Traditional Teaching Method (TTM) on Chemistry Practical Performance among Senior High School Students in Ghana. The study aims to address the knowledge gap on the effectiveness of multimedia teaching methods in comparison to traditional teaching methods in Chemistry practical classes in senior high schools in Ghana. The introduction highlights the increasing adoption of multimedia teaching methods worldwide and in Ghana, and the need to examine their effectiveness in the Ghanaian context. Chemistry is identified as a critical subject with practical work as a significant component of the curriculum, making it essential to assess the effectiveness of teaching methods in this subject area. The study cites previous research by Liu and Lee (2020) and Kwong *et al.* (2019) to support the hypothesis that multimedia instruction can improve students' academic performance and skills.

Several investigations have been conducted on the effectiveness of multimedia teaching methods in improving senior high school students' academic achievement in Ghana. A study by Adu-Gyamfi et al. (2021) found that the use of multimedia instruction significantly improved senior high school students' performance in science subjects. This study reported that students taught using multimedia instruction performed better than those taught using

traditional methods. Asiedu-Addo *et al.* (2021) investigated the effects of multimedia instruction on senior high school students' academic achievement in physics and found that students taught using multimedia instruction performed significantly better than those taught using traditional methods. In another study by Boateng et al. (2021), the effectiveness of multimedia instruction on senior high school students' academic achievement in mathematics was examined. The study revealed that multimedia instruction significantly improved students' academic achievement in mathematics compared to traditional methods. Similarly, Nkrumah et al. (2020) investigated the effects of multimedia instruction on senior high school students' academic achievement in biology and found that multimedia instruction significantly improved students' academic achievement compared to traditional methods. Finally, Osei-Tutu et al. (2021) conducted a study to examine the effects of multimedia instruction on senior high school students' academic achievement in the English language. The study found that multimedia instruction significantly improved students' academic achievement in the English language compared to traditional methods.

As technology has become more prevalent, students have become more interested in using multimedia tools in their learning, leading to an increased push for teachers to incorporate these tools into their teaching methods (Ercan, 2014). Traditional teaching methods, such as lectures where students passively listen to the teacher, are no longer as effective as they once were due to the growing use of technology. By using multimedia, teachers can enhance the higher-order thinking skills of their students.

However, since the introduction of the Senior High School programme in Ghana in 1991, reports from the West African Examination Council have consistently shown poor performance in science subjects, particularly chemistry (WAEC, 1994-1996, 2002-2005, 2010). The Chief Examiners attribute the poor performance in chemistry to the lack of attention given to weaknesses in the subject by schools, which is reflected in students' poor performance in the practical paper. The decline in students' interest and achievement in practical chemistry is a growing concern for chemistry educators in Ghana (Ugwu, 2013). Tamakloe, Atta, and Amedahe (2005) argue that a teacher should understand their students' capabilities and adjust their teaching methods accordingly, rather than sticking to traditional methods that may not be effective for all learners. Therefore, a professional chemistry teacher should make use of available resources, such as multimedia, to enhance the teaching and learning process. Finding suitable methods to address the current mass failure rates in science subjects, including chemistry, is crucial to halt the decline in students' interest and performance in these subjects (Sola and Ojo, 2007). Given that there is not enough insight into the usefulness and the approach of multimedia techniques in enhancing teaching and learning, this study intends to contribute to the literature by examining the extent to which multimedia techniques influence students learning experiences in Chemistry.

However, the effectiveness of multimedia teaching methods in Ghana's senior high schools remains largely unexplored when it comes to chemistry. Therefore, this study seeks to bridge the knowledge gap by examining and comparing the effectiveness of the Multimedia Teaching Method (MTM) and Traditional Teaching Method (TTM) on Chemistry Practical Performance among Senior High School Students in Ghana.

3. Literature Review

Several theoretical frameworks can be used when incorporating multimedia as a teaching strategy in chemistry. But in this research, two theoretical frameworks were used. These are the Dual Coding Theory and Constructivism.

Dual Coding Theory (DCT) suggests that learning is more effective when verbal and visual information are presented simultaneously (Paivio, 1991). When using multimedia in chemistry instruction, DCT suggests that instructors should strive to present both verbal and visual information in a coordinated and integrated manner (Mayer, 2009). This can be done by using techniques such as text and image pairing, animation, and diagrams (Mayer & Moreno, 2003). According to Dual Coding Theory, instructors should strive to present both verbal and visual information in a coordinated and integrated manner when using multimedia in chemistry instruction (Mayer, 2009; Mayer & Moreno, 2003). Some studies were conducted using the DCT and the results indicated that it enhanced active learning in students. For instance, a systematic review examined the effectiveness of active learning in undergraduate chemistry classrooms, including the use of DCT-based strategies. Gormally and

Brickman (2019) found that active learning approaches, including those that incorporated DCT-based strategies, were generally more effective than traditional lecture-based approaches at improving students' conceptual understanding and problem-solving skills. Also, a study investigated the effects of dual coding on students' motivation, engagement, and learning in a flipped classroom setting (Yeo & Lin (2020)). The authors found that students who received dual-coded materials (i.e., materials that included both verbal and visual information) had higher levels of motivation and engagement, and performed better on assessments, compared to those who received materials with only verbal or only visual information. Finally and not least, in a study, Gire and Vazquez-Abad (2021) used a DCT-based approach to develop an active learning module for organic chemistry. The module was designed to help students develop a better understanding of chemical reactions by engaging them in activities that required them to interpret visual representations of reaction mechanisms.

Constructivism suggests that learners actively construct their knowledge and understanding through interactions with the environment (Jonassen & Land, 2012). When using multimedia in chemistry instruction, constructivism suggests that instructors should strive to create authentic learning environments that allow students to engage with and manipulate the material in meaningful ways (Jonassen, 1994). This can be done by using techniques such as simulations, virtual labs, and interactive videos (Mayer, 2009). According to Constructivism, instructors should strive to create authentic learning environments that allow students to engage with and manipulate the material in meaningful ways when using multimedia in chemistry instruction (Jonassen, 1994; Mayer, 2009). Similarly, here are some recent studies in chemistry education that have used constructivism as a theoretical framework for teaching: This study explored how a constructivist approach to laboratory work in a general chemistry course impacted student engagement. The authors found that when students were allowed to engage in independent inquiry and meaningful problem-solving, their engagement increased (Kelleher & Shachar, 2021). Again, Tandoc and Lagarto (2020) investigated how a constructivist learning environment could be used to address student misconceptions about chemical equilibrium. The authors found that when students were allowed to construct their understanding through inquiry-based activities, their understanding of chemical equilibrium improved. Also, Tare and Kumar (2019) used a constructivist approach to teaching chemical bonding in a high school chemistry class. The authors found that when students were allowed to engage in collaborative activities that required them to construct their understanding, their understanding of chemical bonding improved. These examples show that DCT and constructive help improve learner performance in chemistry based on the research conducted in these areas.

4. Materials and Methods

4.1. Research design

A quasi-experimental design is a research approach that involves the manipulation of an independent variable but lacks random assignment of participants to experimental and control groups. Quasi-experimental designs are commonly used when true experimental designs are not feasible or ethical. According to Creswell (2014), a quasi-experimental design "attempts to create groups that are equivalent to each other, but the assignment of participants to the groups is not done randomly" (p. 194). In this study, a quasi-experimental design was employed. This was to determine the effect of multimedia instructional techniques on science process skills and enhancement of two of the experimental groups and on the science process skills. Specifically, we utilised a pre-test, post-test non-equivalent control group research design involving three groups (two groups served as experimental while one group was the control). Video-based and internet-based multimedia techniques were used on the experimental groups. The experimental groups, A and B, and the control group (all intact classes) were randomly drawn from the three SHS 2 science classes in the selected Schools, namely: science A, science B, and Science C respectively. The experimental groups received different treatments from different research assistants. The students in the control group were taught in a conventional classroom arrangement, where there was no use of multimedia instructional strategy.

4.2. Study population

The study was Targeted at chemistry students in senior secondary schools. Specifically, the study population of comprised all SHS 2 Chemistry students in the selected Schools.

4.3. Sample and sampling techniques

The study randomly selected WASS and Frafraha Community from a pool of schools in two municipalities in Greater Accra. It was conducted at West Africa Senior High School in La-Nkwantanang-Madina Municipality and Frafraha Community Senior High School in the Adentan Municipality. The study included a total of 107 senior high school students who were taking elective chemistry courses, with 50 students from West Africa Senior High School and 57 students from Frafraha Community Senior High School.

4.4. Instrumentation

The instruments for the data collection were structured as follows.

The qualitative Analysis Concepts Achievement Test (QACAT)-was meant to assess students' performance (conceptual understanding) in the qualitative analysis aspect of practical chemistry. The test item prepared contained thirty (30) multiple-choice items. QACAT was used for both the pre-test and post-test. The study was pilot tested in two senior high schools that did not take part in the study. The items in the instrument were adapted from a collection of WAEC question papers (2018-2020).

Science Process Skills Acquisition Test (SPSAT) also was used to assess students' science process skills acquisition in the quantitative analysis aspect of chemistry practical. A total of sixteen (16) items are contained in the instrument. Each item answered correctly attracts 2 marks. Thus the total number of marks for this instrument is 32 marks. Quantitative analysis items were adopted from alternative to chemistry practical past questions from WAEC (2018-2020).

This instrument was given to two chemistry teachers in a senior high school in the municipality to examine QACAT for coverage, clarity or non-ambiguity, relevance, and to the level of the students' knowledge based on the research questions and hypotheses. As a result of the validation done by the experts, the instrument was scaled down to 30 items.

SPSAT: The instrument was also given to two chemistry teachers in a college of education to assess the instrument for coverage, clarity and non-ambiguity, relevance, and to the level of the students' knowledge. Any item rejected by two out of the three as not meeting the criteria stated was dropped, corrected, or modified.

A test is said to be reliable if repeated measurements using the test gives the same results (Muhammed,2014). To establish the degree of reliability of the instruments, the Qualitative Analysis Concepts Achievement Test (QACAT) and Science Process Skills Acquisition Test (SPSAT), SHS2 chemistry students of the selected schools. The two instruments were administered to them. The reliability coefficient of QACAT was calculated using the test, retest method. The scores of the two tests were correlated using Pearson product-moment correlation analysis and a reliability coefficient of 0.88 was obtained.

QACAT and SPSAT as pre-test were administered to all the members of the groups used for the study by the research assistants at the beginning of the exercise. The two tests were administered during the second week of the first semester. The QACAT test lasted for 45 minutes while the SPSAT test lasted for one hour. The same method of administration used for the pre-test was also used for the post-test at the end of six weeks. The pre-test items were randomly rearranged to get the post-tests.

QACAT-The items in the qualitative analysis achievement test were scored using the marking scheme prepared by the researcher. Each question was assigned one mark giving a maximum of 30 marks. The raw scores were converted to 100 percent.

SPSAT-The items in the science process skills acquisition test were scored using the marking scheme prepared by the researcher. A total of sixteen items are contained in the instruments. Each item answered correctly attracts two marks giving a maximum of 32 marks. The raw scores were also converted to 100 percent.

Three assistants were trained for this work. All three research assistants are chemistry teachers with B.Sc. (Ed) degrees in Chemistry. They have an interest in chemistry education research. The research assistants were trained and randomly assigned to the experimental groups and control groups.

5. Results

Table 1: Summary of Participants in the Study

School	Class	Boys (%)	Girls (%)	Total
West Africa Senior High School	2 Science A	23 (43.39)	30 (56.60)	53
Frafraha Community Senior High	2 Science A	25 (43.86)	32 (56.14)	57
Total		48 (43.64)	62 (56.36)	110

Source: Field Data 2019

1. Research question 1: To what extent does the use of the multimedia approach in teaching chemistry practicals improve the achievement scores of senior high school students compared to the traditional approach in selected schools in Medina – Adentan Metropolis?

Tables 2 and 3 provide a comparison of the means and standard deviations between the control and experimental groups in both the pre-test and post-test, with each group comprising 53 and 57 respondents, respectively. These tables offer a clear depiction of the performance differences between the two groups, both before and after the intervention, in terms of academic achievement scores in Chemistry practical work.

Table 2: Comparison of Mean Scores on Pre-test of Control Group and Experimental Group.

Type of Test	Name of Group	N	Mean	Std. Deviation	Std. Error Mean
Pre-test	Control Group	53	12.38	2.46	0.32
Pre-test	Exp. Group	57	12.58	2.98	0.40

Source: Field Data 2019

Table 2 presents the pre-test mean scores for the control and experimental groups as 12.38 and 12.58, respectively, with corresponding standard deviations of 2.46 and 2.98. Group statistics revealed that the control and experimental groups had a mean difference of only 0.18 points in the pre-test, indicating that they were homogeneous at the start of the study.

Table 3: Comparison of Mean Score on Post-test of Control Group and Experimental Group

Type of Test	Name of Group	N	Mean	Std. Deviation	Std. Error Mean
Post-test	Control Group	53	20.36	4.45	0.59
Post-test	Exp. Group	57	23.32	3.17	0.43

Source: Field Data 2019

Table 3 in the post-test indicates a marginal difference of 2.95 points between the means, suggesting that the use of multimedia in teaching Chemistry did lead to a slight improvement in students' academic achievement. Therefore, it can be inferred that multimedia has a limited impact on the academic performance of students in Chemistry.

Research question 2: How do the academic achievement scores of Senior High School students taught practical work in chemistry using multimedia compare to those taught using traditional methods?

The findings were validated using the data in Tables 4 and 5. According to Table 5's statistics, there is a .19-point difference in the pre-test mean scores of the Control and Experimental groups. Their ratings for standard deviation also vary.

Table 4: Comparison of Mean Scores of Pre-test and Post-test Scores based on Group

Type of Test	Group	N	Mean	Std. Deviation
Pre-Test	Experimental	57	12.58	2.98
	Control	53	12.38	2.46
Post-Test	Experimental	57	23.32	3.17
	Control	53	20.36	4.45

Source: Field Data 2019

Table 5: Independent Sample T-test by Groups: T-test for Equality of Means

Type of Test	Variance(V)	T	Df	Sig. 2-tailed	Mean Difference
Pre-Test	Equal V Assumed	-0.383	108	0.703	-0.19
	Equal V not Assumed	-0.379	101.214	0.705	-0.19
Post-Test	Equal V Assumed	-3.974	108	0.000	-2.95
	Equal V not Assumed	-4.022	101.264	0.000	-2.95

Source: Field Data 2019

Nevertheless, at level.05., there was no difference between the Control and Experimental groups in the pre-test. The t (-.382), df (108), and (p=.703) in Table 5 are negative. Once more, Table 5's data shows that there is a 2.95-point difference in the post-test mean scores between the Control and Experimental groups. Their ratings for standard deviation also vary. In the pre-test, the computed t-values resulted in a t-value of (-.382), a df (108), and a sig. value of p=.703. The pre-test results show that there was no discernible difference between the experimental and control groups. However, at.05 levels of significance, there was no difference between the Control and Experimental groups in the post-test. The t (-3.974), df (108), and (p=.000) are shown in Table 6. The experimental group's performance was superior to the control group's performance when the t-values for the post-test were computed, as shown by the independent student t-test. The difference between the two means was statistically significant at 0.05 levels, as evidenced by the t (-3.974) df (108) and the significant value of p =.000 in Table 6. Therefore, at the 0.05 level, the claim that "There is no statistically significant difference between the academic achievement scores of students taught chemistry practical using multimedia approach and those taught using the traditional approach" is rejected. It follows that there was a notable academic achievement gap between students who received multimedia teaching and those who did not in the study of photosynthesis. This suggests that the intervention did enhance the students' performance, leading to the conclusion that the usage of multimedia in the classroom had a negligible impact on the academic performance of Chemistry students. According to a study of the data acquired, students who were taught practical work in chemistry using a multimedia method had much higher academic performance scores than students who were taught using a traditional technique.

6. Discussion

The study showed that using multimedia and constructivist approaches as an intervention improved students' practical performance in chemistry and resulted in a significant difference in academic achievement scores between students taught with multimedia and those taught with traditional methods (Owusu-Acheaw, 2020). This finding highlights the potential benefits of multimedia in enhancing learning outcomes in chemistry education. One possible reason for the improved performance of students taught with multimedia could be the enhanced visual and auditory stimulation provided by multimedia materials, which may help students to better understand and retain complex chemical concepts (Huang *et al.,* 2021). Additionally, the constructivist approach used in the study may have allowed students to engage in active learning and construct their knowledge, leading to deeper understanding and improved performance (Boud, 2017).

However, it is worth noting that the specific design of the intervention and the characteristics of the study population may limit the generalizability of these findings. For example, the study was conducted with senior high school students from two high schools in Ghana, and it is unclear whether these findings would apply to other populations or educational contexts. Additionally, the study did not investigate the long-term impact of using multimedia on students' learning outcomes, so it is unclear whether the observed improvements in performance

would be sustained over time. Despite these limitations, the results of this study provide valuable insights into the potential benefits of using multimedia and constructivist approaches in chemistry education.

7. Conclusion

In conclusion, the use of multimedia and constructivist approaches in teaching chemistry has the potential to improve students' practical performance and academic achievement scores. The findings of the study "Effectiveness of Multimedia versus Traditional Teaching Methods on Chemistry Practical Performance among Senior High School Students in Ghana" suggest that multimedia can enhance learning outcomes by providing visual and auditory stimulation and by allowing students to engage in active learning and construct their knowledge. However, it is important to consider the specific characteristics of the study population and the design of the intervention when interpreting these findings, and further research is needed to investigate the impact of multimedia and constructivist approaches on a broader range of learning outcomes and educational contexts. Nonetheless, the results of this study provide valuable insights into the potential benefits of using multimedia and constructivist approaches in chemistry education and suggest that educators should consider incorporating these strategies into their teaching practices to enhance student learning outcomes.

8. Recommendations

Based on the findings of the study it is recommended that teachers:

1. Incorporate multimedia materials and constructivist approaches into chemistry education: The study suggests that using multimedia and constructivist approaches can lead to improved performance and academic achievement in chemistry. Therefore, I would recommend that educators consider incorporating these strategies into their teaching practices to enhance students' learning outcomes.
2. Conduct further research to investigate the long-term impact of multimedia on learning outcomes: While the study provides valuable insights into the potential benefits of using multimedia in chemistry education, it did not investigate the long-term impact of these approaches on students' learning outcomes. Therefore, I would recommend that further research be conducted to investigate the sustained impact of using multimedia on students' academic achievement in chemistry.

9. Implications

Based on the findings of the study two possible implications can be drawn are:

1. The potential benefits of multimedia in chemistry education: The study showed that using multimedia in teaching chemistry can have a positive impact on students' practical performance and academic achievement. This finding suggests that educators should consider incorporating multimedia materials into their teaching practices to enhance students' learning outcomes in chemistry.
2. The importance of pedagogical approaches in teaching chemistry: The study also found that a constructivist approach, which emphasizes active learning and student-centered instruction, can enhance students' learning outcomes in chemistry. This finding highlights the importance of pedagogical approaches in teaching chemistry and suggests that educators should consider adopting student-centred instructional approaches in their teaching practices.

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