EFFECT OF TEACHING WITH PhET SIMULATION ON THE KNOWLEDGE OF HYBRIDIZATION IN THE SHS

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ABSTRACT

The study examined the effect of the usage of PhET simulation to teach hybridization at Collins Senior High school. Quasi-experimental design was adopted for the study. Using the convenient sampling technique, all the 45 SHS 1 science students in one class from the Collins Senior High School were involved in the study. Researcher-made tests was the instrument used in collecting data for the study. The data were analyzed through the computation of frequency counts, percentages, paired sample t-test as well as independent sample t-test. The study demonstrated that the use of the PhET simulation intervention is significant and has a positive effect on students' knowledge and understanding on hybridization. The difference that was found to be statistically significant can be partly attributed to the intervention of the PhET simulation. Again, the use of the PhET simulation intervention was significant and had a positive effect on male students' knowledge and understanding on hybridization as compared with their female counterparts. This may attribute to the fact that males are more technology inclined than females. There is the need for a further investigation to evaluate the degree to which these factors influence post-test results and to also find out the factors accounting for these differences in terms of gender. It is important that the Ministry of Education and the Ghana Education Service ensure that school heads and teachers adopt the use of PhET simulation as a teaching learning resource for teaching hybridization.

Keywords: Hybridization, PhET, Teaching, Simulation.

INTRODUCTION

Quality Chemistry education requires chemistry teachers to have good knowledge about the subject matter to teach students for understanding to enhance practice of what is learnt (Nilsson, 2014). Knowledge is imperative in teaching chemistry as it provides opportunity for wide range learning opportunities for students of chemistry (Voss & Kunter, 2013). Shulman as stated in Trinidad-Velasco (2020) identified three aspects of knowledge critical for teaching any subject, including chemistry, as Content knowledge (CK), pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK). All these three aspects of knowledge are required of chemistry teachers for meaningful delivery of concept.

Chemistry learning blends content and pedagogy for clarity of understanding of what is being taught (Shulman, 1987). PhET encompasses carefully selected analogies, examples, explanations and demonstrations by chemistry teachers to make a topic comprehensible to students. Every chemistry teacher is required to possess skills and knowledge for transforming knowledge in a way that every student or majority of students can understand what is being taught and to apply what has been taught (Driel, 2021). This is what PhET is all about; hence imperative and inevitable to teaching chemistry. Extensive work in PhET simulation have provided justification for instruction; as it led to efficient learning outcomes.

PhET has highly recommended for teaching science subjects, like Chemistry. The reasons being those topics in Chemistry such as hybridization is abstract for understanding at early stages of education (Gess-Newsome, 2015; Joki &Aksela, 2018). Hybridization, an idea that atomic orbitals fuse to form newly hybridized orbitals, which in turn, influences molecular geometry and bonding properties, is regarded as one of the complex and abstract topics in Chemistry (Alabugin, 2007). Hanson, Sam and Antwi (2012) showed that pre-service teachers had gross misconceptions about atomic orbitals and hybridization. Salame (2022) explained that the difficulties in understanding the hybridization concept can result from poor control of fundamental knowledge for its learning: the atomic orbital concept and the linking of the orbitals symbolization (s, p …) with their directional aspect.

Based on complexity and abstract nature of teaching hybridization, interventions such PhET simulations are employed with the aim of enhancing students' understanding and application hybridization (Markic& Childs, 2016). However, extant studies in Ghanaian literature have not extensively explored and experiment how PhET simulation can be used to teach hybridization and it's on students' outcome. This study therefore explored the effect of the usage of PhET simulation to teach hybridization at the senior high school, Collins Senior High school. The study looks for answers to the following research hypotheses: "There is no statistically significant effect of PhET simulation intervention on student knowledge of hybridization; and "There is no statistically significant difference of male and female students in terms of the effect of PhET simulation intervention". The study involved students from Collins Senior High School in the Asante Akyem North in the Ashanti Region of Ghana in carrying out the study. The findings of this investigation will help people better comprehend the effect of the use of PhET simulation which could be of a use as teaching learning resource for teaching hybridization. With this knowledge, suitable policies and interventions can be developed on the teaching of hybridization to young people nationwide. This study contributes to the body of knowledge on the phenomena of teaching hybridization by presenting a contextual view of the activity, particularly among Ghanaian students.

LITERATURE REVIEW

Theoretical Framework

The study drew on Shulman's (1986) theory on PCK, which formed the basis for a knowledge of teachers on their subject matter and its impact in promoting effective teaching and learning. Shulman (1986) viewed PCK as how the content of a concept is introduced by making use of instructional techniques such as analogies, diagrams, illustrations, examples, explanations, and demonstrations, and organizing the subject matter in a way that will motivate learners to understand'' (p. 8), the concepts taught. In addition, knowledge of representation of specific information and instructional techniques, comprehension of learning challenges, and students' ideas of specific content, are crucial factors in Shulman's (1986) theory of PCK. PCK is a distinct body of knowledge for classroom instruction, according to Shulman (1986), that represents the combination of subject matter and teaching methodology into an understanding of how specific content, difficulties, or issues are planned, represented, and modified to the diverse interests and abilities of learners, and presented for instruction.

It is important to appreciate how the learning environment is organized as a teacher in order to facilitate students' grasp of concepts of specific topics and contribute to their intellectual understanding and development. The ability to demonstrate and make the teaching of a subject simple to understand and to learn is the PCK (Shulman, 1986). PCK assists teachers in developing competency in providing the content in alternative interactive knowledge, and adaptive reasoning of the content to students/learners in classroom instruction (Jacob et al., 2020). It is also the combination of understanding the content, pedagogical methodologies, and learner knowledge to create an effective classroom environment (Pihie & Sipon, 2013). Again, PCK is an important information required by teachers to plan the lesson, select appropriate teaching methods, select instructional materials to address the needs of the students during the teaching and learning process (Jacob et al., 2020).

Components of Pedagogical Content Knowledge

The study adopted the conceptual framework PCK model of Magnusson et al. (1999). PCK model by Magnusson et al. (1999) outlined the key and important components of teachers' PCK that influence how chemistry teachers teach the concept of hybridization in this study. The model developed by Magnusson et al. (1999) is considered as extremely reliable model to analyze PCK of chemistry teachers (Boesdorfer, 2012). The model of Magnusson et al. (1999) demonstrates that numerous factors can be utilized to categorize the concept of PCK in the case of this study. Thus, knowledge of the subject matter (including substantive and syntactic knowledge), knowledge of pedagogy and educational goals, knowledge of the classroom, and knowledge of content, including knowledge of particular learner and school characteristics, are the variables in the model. Halim and Meerah (2002) identified ways of representing particular ideas or concepts that will make learning easier to help interpret PCK. "Orientations towards teaching science," "knowledge of science curriculum," "knowledge of students' comprehension of science," "knowledge of instructional techniques," and "knowledge of assessment for science" are among the PCK components in Magnusson et al. (1999) model for teaching science.

Chemistry teachers receive orientations for teaching the subject and the content as part of their training in the university and other higher institutions. Understanding the purposes and objectives for teaching science at a specific grade level is part of the teachers' approach towards teaching science. According to Nargund-Joshi and Liu (2013), teachers' preferences for teaching science may be thought of as either filters or amplifiers that influence how they behave in the classroom as a whole. To start changing the way teachers behave in the classroom, it is important to examine their views on how science is taught and learned. The orientations that teachers receive as part of their training influences their knowledge of chemistry curriculum, students learning, teaching techniques and approaches for chemistry instruction and assessment techniques for assessing learners learning in the chemistry classroom.

Knowledge of chemistry curriculum includes the teacher's knowledge of the aims and objectives for teaching chemistry and knowledge of curricular materials suitable for teaching chemistry. Every chemistry teacher should have a knowledge and understanding about the chemistry curriculum. This includes knowledge of the goals and objectives for teaching the subject chemistry and the topic hybridization, knowledge about the programs, national policy document on science education and the relevant teaching and learning materials for teaching the topic hybridization. This means, the general goals of the chemistry curriculum, various activities and materials used to achieve these goals constitute curriculum knowledge of chemistry teachers. In addition, the knowledge a teacher possesses in a certain subject/topic, according to Parrotte (2016), is his/her content knowledge. For instance, a chemistry teacher understanding of the concept of hybridization as presented in the curriculum is the subject-matter knowledge in hybridization. Hence, a teacher understanding the various programs and curricula options including instructional resources for effective teaching and learning constitute content knowledge. Therefore, one of the components of PCK that is easily assessed, according to Parrotte (2016), is the content knowledge.

Knowledge of students learning in chemistry includes teachers knowing the requirements for teaching chemistry as well as knowing the areas of students' learning difficulties. Knowledge of students understanding according to Ijeh (2012) is how the learners comprehend what is imparted during instructions. This suggests how learners see and comprehend the topic introduced to them by the teacher in the classroom. This component of PCK creates awareness for teachers on how their students learn and understand the content taught. Also, the requirement for learning specific science concepts and areas of science that students find difficult to learn are the two categories of knowledge for students learning. For knowledge of requirement for learning according to Magnusson et al. (1999) is the knowledge and beliefs about prerequisite knowledge for learning specific knowledge as well as their understanding of scientific concepts. Thus, the age, grade level and the different learning styles of students should be understood by teachers to promote meaningful leaning. In addition, the aspect of science that students find difficult to learn is the teacher's awareness about the topics that learners find challenging to learn and the root causes of such challenges. Thus, according to Magnusson et al. (1999), students find it challenging to understand abstract concepts (like hybridization) that cannot be related to their prior knowledge. To be effective, teachers must be aware of students' various learning capacities and styles and respond appropriately. Teachers understanding of the difficulty's students experience and how they struggle to learn a concept (like hybridization) is very important during instructions. Because learning is based on what happens in the classroom, not only what students do, but also the learning environment, knowledge of students' perceptions is seen as one of the crucial aspects of teacher knowledge. This was confirmed by Halim et al. (2011) who revealed that PCK of teachers has a favorable impact on students' conceptual understanding of cell respiration

Knowledge of instructional strategies for teaching chemistry includes teachers' knowledge of subject specific instructional methods and topics, specific instructional techniques. In addition, chemistry teachers' knowledge about teaching methods includes their understanding and ideas about teaching strategies/methods or specific activities to enhance conceptual understanding among students during instruction. Knowledge of evaluation in chemistry involves the teachers' understanding of the categories of learning they employ to assess and the knowledge of the techniques of assessment in chemistry. Hence, teachers need to have an understanding about the different assessment techniques they employ during instruction to promote meaningful learning.

Concept of PhET Simulations in Chemistry

Computer simulations such as PhET are widely available in science courses and are becoming an integral part of science teaching and learning and can be used to enhance traditional instruction and promote learning. PhET, which is an interactive simulation developed by the University of Colorado Borlder, can be effective in the teaching of chemistry and physics at the high school and college level (Perkins et al., 2012). PhET interactive simulation provides an alternative approach to the traditional laboratory and can enhance students learning through visualization, demonstrations and illustrations (Makransky et al., 2017).

The PhET Interactive simulations which include several chemistry simulations are offered freely to instructors and teachers though their website at the University of Colorado Boulder (https://PhET.colorado.edu/). Each simulation is accompanied with several supplementary materials that immerse students in a guided inquiry-based learning activity (Chamberlain et al., 2014). It should be noted that PhET interactive simulations can be used as a tool for inquiry-based learning (Smetana & Bell, 2011). Furthermore, PhET interactive simulations provide students with content support, process assistance, affective learning goals reinforcement (Moore et al., 2014).

In one research study, authors' data suggest that the interactive simulations are an effective implicit scaffolding technique through experimentation that does not overwhelm the students and provides an avenue for guided-inquiry learning (Moore et al., 2013). PhET simulations with opportunity to engage in an active learning exploration which might cause a change in their epistemology of the concepts (Bing & Redish, 2012).

PhET, or Physics Educational Technology, is a site that contains interactive simulations for science (physics, biology, chemistry, earth sciences) and math at elementary, middle school, high school, and university levels. Depending on which simulation, it can be run online from the website, or it would have to be downloaded. They could be useful as a lab or a homework assignment. Within this interactive site, there are visual displays and interaction between the student and the concepts being taught which helps to develop understanding (Price et al., 2018).

A virtual learning environment has been a more widely adapted form of learning as it enhances a student's experience both inside and outside the classroom. With the increase of technology use inside the classroom as a beneficial tool, teachers and educators have looked to incorporate it in as many ways as they can. By introducing simulations as a form of learning inside the classroom, there are a set of goals focused on the students that are supported by these simulations (Moore et al., 2013). These goals include the ability to engage in scientific exploration, which includes posing questions, designing experiments, and analyzing data. Other goals mentioned are to make connections to everyday life, view science as being enjoyable and accessible, and taking ownership of the learning experience (Moore et al., 2013).

This teaching approach utilizes technology to set up a web-based platform that aids in the learning process of multiple courses (Rutten et al., 2011). These virtual environments are interlinked with our modern-day educational institutions as the use of technology has increased drastically. With this form of learning, a certain aspect of reality is simulated in a virtual environment that allows participants to explore what things would be like in the real world. High school educators have tried to adapt this new, fun way to engage students in their learning and reinforce topics learned in lecture for a deeper understanding (Couch, 2014).

Since many of the students are now tech savvy through various outlets of technology such as cellphones, computers, video games, they can be better engaged through simulations on the computer since it provides a different outlet than the traditional forms of learning such as a textbook (Couch, 2014). While the effects of simulations in education have widely been researched and evaluated, it is important to understand why teachers adopt these learning techniques in their classrooms and how are they applied while teaching (Price et al., 2018). Research data showed that more than half of the respondents cited the top four goals to be visualize science phenomena or science representations, develop conceptual understanding, engage in exploration and discovery or inquiry, and develop enjoyment or interest in science (Price et al., 2018). Three common features shared were visualizations, ability to manipulate or interact, and individualized experiences. Another common benefit discussed to using simulations is the ability to participate in activities that are not possible with the materials in a typical classroom environment.

PhET simulations have been successful in reaching large numbers of users in the K12 and college level with over 45 million runs per year and usage in all across the United States and usage in all 50 states. Although, the importance's of these technologies are evident, it can be challenging to incorporate them to improve a student's performance. As the search for higher education remains a large concern in this country, many institutions have adopted the new virtual learning environments (Rutten et al., 2011).

In order to gather more information about the implementation of PhET simulation, a survey was conducted of more than 1,500 college and high school physics educators across America (Perkins et al., 2014). Collectively, the acquired results indicate that PhET simulations are flexible tools used by educators to achieve various educational goals and respondents are using them with diverse populations that are diverse in ability, background, and major (Perkins et al., 2014).

Computer simulations have been largely applied in science education to elevate the curriculum. The application of PhET simulations in a lab has many benefits to the overall experience. One of these benefits is new possibilities for different experiments. Since not everything is possible in a classroom with the equipment given, simulations allow for students to experiment with and engage in activities that would otherwise not be possible or practical in a real setting (Wieman et al, 2010). By providing more and various kinds of simulations, students can tackle more concepts that possibly could not have been thoroughly observed in a laboratory. Another benefit that comes with the use of simulations is quick repeatability. Students have the capability of repeating the experiment or activities multiple times in order to better understand the experiment or to try and test out the experiment under different conditions. A simulation would be able to show things more clearly and in a real-world scenario which can help students grasp concepts and understand how things should be before being exposed to a messier world (Perkins et al., 2014). With simulations, scientific models are designed to be visible in order for students to grasp not only what is happening, but why is it happening. Also, students often enjoy the use of PhET simulations and find it more engaging and beneficial.

METHODOLOGY

The study relied on quasi-experimental design basing on quantitative research approach which makes meaningful generalization and test efficacy of an intervention (Creswell, 2013).
All SHS 1 students in Collins Senior High School in the Asante Akyem North in the Ashanti Region of Ghana made up the study's population. There were about 90 SHS 1 Science students in the Collins Senior High in 2023/2024 academic year (Asante Akyem Directorate of Education, 2023).

All the 45 SHS 1 science students in one class at the Collins Senior High School made up the study's sample. The convenient sampling technique was used to involve all the 45 SHS 1 science students in one class in the study. The study used a one-group pre-and post-test quasi-experimental design.

An experiment is "that portion of research in which variables are manipulated and their effects upon other variables observed" (Campbell & Stanley, 1963). The pre-test and post-test mean scores are assessed to evaluate the presence of any significant difference. The observed significant difference can be attributed to the implementation of the intervention.

The major tool used to gather data for this study was a test. In this study, a series of researcher-made tests (for students) were used. Tests (pre-test and post-test) were given to the group before and after the intervention (PhET simulation). Both pre-test and post-test consisted different essay typed test which were marked and scored over 100%. This catered for the performance variable in order to find out whether or not the intervention (teaching with PhET simulation) had any effect on students' understanding and performance of basic Chemistry in terms of the teaching of hybridization.

DATA ANALYSIS, RESULTS AND DISCUSSION

This study sought to examine the effectiveness of PhET simulation in enhancing the knowledge of hybridisation among science students at the Collins Senior High school in Asante Akyem North in the Ashanti Region of Ghana. The analysis of the data used inferential statistics in order to respond to the research hypotheses developed to direct the study. The study questions 1 and 2 were specifically examined using the data from the test results through the computation of paired sample t-test as well as independent sample t-test. Version 25 of the Statistical Package for Social Sciences was used in the computation of the results for the analyses.

The background information of the respondents was assessed and provided first, then the research questions that served as the study's guiding principles. The characteristics of the respondents of the survey, who were science students at the Collins Senior High School in Asante Akyem North in the Ashanti Region of Ghana are shown in Table 1.

Table 1: Characteristics of the Students

Variable	Subscale	No.	%
Gender	Male	32	71.1
	Female	13	28.9
Age	14 years	2	4.4
	15 years	24	53.3
	16 years	16	35.6
	17 years	3	6.7

Source: Field Data, 2023

Table 1 shows that 71.1% of the 45 SHS 1 students who were involved in the study were males and 28.9% were females. Thus, there were several male students. Once more, the majority of the student respondents were 15 years of age. This is because 2(4.4%) were 14 years of age, 24(53.3%) were 15 years of age, 16(35.6%) were 16 years of age and 3(6.7%) were 17 years of age.

The findings and analyses of the information gathered to address the two research hypotheses made to direct the study are presented in this section. It contained information gathered from the students' test results.

Effect of PhET simulation intervention on student knowledge of hybridization

H_0: There is no statistically significant effect of PhET simulation intervention on student knowledge of hybridization.

Only state the null hypothesis

This research hypothesis sought to find out whether or not there was a statistically significant effect of PhET simulation intervention on student knowledge of hybridization. The paired sample test was used for the analysis of the hypothesis in order to ascertain whether there was a significant difference between the post-test and the pre-test scores of the students regarding the effect of PhET simulation intervention on student knowledge of hybridization. Results from the analysis are presented in Table 2.

Table 2: Paired Sample T-test on the **Effect of PhET simulation intervention on student knowledge of hybridization**

	Group	N	Mean	Std. Dev.	Df	t-value	p-value
Students' Knowledge of Hybridization	Pre-test	45	5.42	1.73	44	-25.722	0.000
	Post-test	45	13.29	2.58			

Source: Field Data, 2023 **** significant at p=0.05 (2-tailed)**

Table 2 shows the results of the paired sample t-test on pre-test and post-test scores of the students' knowledge of hybridization regarding the use of PhET simulation intervention. From Table 2, it was realized that the pre-test score had a mean score of (*M=5.42; SD=1.73*) while the post-test score had a mean score of *(M=13.29; SD=2.58*). This shows that the post-test scores of students' knowledge on hybridization after the use of the PhET simulation intervention was higher than that of the pre-test scores. This means that, the intervention (PhET simulation intervention) had a positive effect and improved students' knowledge and understanding on hybridization. Again, the standard deviation (*SD=2.58*) of the post test score indicates that the individual test scores of the students' knowledge on hybridization varied more than that of the pre-test scores (*SD=1.73*). However, when the mean scores of the two groups were tested using the paired samples t-test at 5% significant level, two-tailed, the results revealed that there was a statistical significant difference between the pre-test scores of students and the post test scores of students' understanding on hybridization ($t(44)= -25.722,\ p = 0.000$). Therefore, the use of the PhET simulation intervention is significant and has a positive effect on students' knowledge and understanding on hybridization.

This finding confirms that of Perkins et al., (2014) who conducted a study of more than 1,500 college and high school physics educators across America. Collectively, the acquired results indicate that PhET simulations are flexible tools used by educators to achieve various educational goals and respondents are using them with diverse populations that are diverse in ability, background, and major (Perkins et al., 2014). Similarly, Rutten et al., (2011) assert that, PhET simulations have been successful in reaching large numbers of users in the K12 and college level with over 45 million runs per year and usage in all across the United States and usage in all 50 states. Although, the importance of these technologies are evident, it can be challenging to incorporate them to improve a student's performance.

Effect of PhET simulation intervention on Male and Female Students' knowledge of hybridization

H_0: There is no statistically significant difference of male and female students' knowledge of hybridization regarding the effect of PhET simulation intervention.

This research hypothesis sought to find out whether or not there was a statistically significant effect of PhET simulation intervention on male and female students' knowledge of hybridization. The independent sample test was used for the analysis of the hypothesis in order to ascertain whether there was a significant difference between the post-test and the pre-test scores of male and female students regarding the effect of PhET simulation intervention on student knowledge of hybridization. Results from the analysis are presented in Table 3.

Table 3: Independent Sample T-test on the Effect of PhET simulation intervention on Male and Female students' knowledge of hybridization

Gender	Group	N	Mean	Std. Dev.	Df	t-value	p-value
Students' Knowledge of Hybridization	Male	32	43.9	5.49	39	1.742	0.041
	Female	13	40.1	7.02			

Source: Field Data, 2023 **** significant at p=0.05 (2-tailed)**

Table 3 shows the results of the independent sample t-test on pre-test and post-test scores of male and female students' knowledge of hybridization regarding the use of PhET simulation intervention. From Table 3, it was realized that the males had a mean score of (*M=43.9; SD=5.49*) while the females had a mean score of *(M=40.1; SD=7.02*). This shows that the scores of male students on the knowledge on hybridization after the use of the PhET simulation intervention were higher than that of the female students. This means that, the intervention (PhET simulation intervention) had a positive effect and improved male students' knowledge and understanding on hybridization. Again, the standard deviation (*SD=7.02*) of the female students indicates that the individual test scores of the female students' knowledge on hybridization varied more than that of the male students (*SD=5.49*). However, when the mean scores of the two groups were tested using the paired samples t-test at 5% significant level, two-tailed, the results revealed that there was a statistical significant difference between the male students and the female students in terms of their understanding on hybridization after the use of the PhET simulation intervention ($t(39)= 1.742, p = 0.000$). Therefore, the use of the PhET simulation intervention is significant and has a positive effect on male students' knowledge and understanding on hybridization as compared with their female counterparts.

CONCLUSIONS

These conclusions were arrived at as a result of the research's findings. The study found that the use of the PhET simulation intervention is significant and has a positive effect on students' knowledge and understanding on hybridization. The difference that was found to be statistically significant can be partly attributed to the intervention of the PhET simulation. It is acknowledged that the intervention may not be the sole contributor to the marked enhancement in scores. Other variables, including maturation (natural growth) and spontaneous remission (unaided recovery), may have also had an impact. However, the nature of the difference cannot be attributed to chance cannot be attributed to the factors above. Thus, a significant part could potentially be as a result of the intervention employed. Future investigations and scholars must evaluate the degree to which these factors influence post-test results. Once more, the use of the PhET simulation intervention was significant and had a positive effect on male students' knowledge and understanding on hybridization as compared with their female counterparts. This may be attributed to the fact that males are more technological inclined than their female counterparts. But there is the need for a further investigation on the factor(s) accounting for these differences in terms of gender.

RECOMMENDATIONS

The following recommendations were made for policy makers:

1. It is recommended that the Ministry of Education and the Ghana Education Service ensure that school heads and teachers adopt the use of PhET simulation as a teaching learning resource for teaching hybridization.
2. It is suggested that, male students assist their female counterparts with the challenges they may be facing on hybridization in terms of the use of PhET simulation so that they can cope in class and their performance enhanced.

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