Influence of visuospatial models construction and usage on college students' academic achievement in molecular and hybridization geometries in Ghana

Research article

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Abstract

This action research study examines the visual-spatial model's effects on science students' performance in molecular and hybridization geometries. Although the diagnostic test revealed both groups showed similar conceptual abilities and challenges, the studies' outcome showed that the visuospatial model's approach to teaching the molecular and hybridization geometries enhanced the student's conceptual understanding. The visuospatial model representations allow students to learn about the abstract subject matter of disciplines' scientific knowledge. Therefore, the use of visuospatial models in teaching enhances students' visual imaginations and thoughts about concepts.

Keywords: achievement, computer-assisted instruction, chemistry learning, hybridization, intelligence

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Introduction

Chemistry learning seems to be a mystery to students. Many students cannot link chemistry to their everyday lives (Childs, Hayes & O'dwyer, 2015). These students perceive learning chemistry as challenging and complicated, which should be for a specific group of students, especially those with a high intelligent quotient (IQ). As a result of this perception, students cannot recognize the value of chemistry in choosing chemistry-related future careers, not to talk about those in the science technology and mathematics-related (Osborne, Simon & Sue, 2003). Differences exist between students due to the different ways they learn. Therefore, teachers need to create a learning environment that promotes creativity and allows students to learn using an appropriate style (Gardner, 2012; Gardner & Hatch, 1989).

Some researchers have revealed students' difficulty in understanding and conceptions of bond angles, isotopes, and allotropes (Schmidt, Baumgärtner & Eybe, 2003). For instance, some researchers have revealed that students have alternative conceptions concerning molecular hybridization, molecular geometries, and associated bond angles (Harrison & Treagust, 2000). While some researchers link students' difficulty understanding chemistry concepts to low quality and fragmented content knowledge (Wu & Shah, 2004), others attributed it to intense inadequate understanding of concepts and processes of scientific inquiries by students (Smart, Witt & Scott, 2012), and use of less engaging instructional approach (Bagheri et al., 2013). There is a need to provide students with opportunities to learn by resorting to alternate instructional methods (Peterson, 2012). Moate and Cox (2015) suggested that teachers should use innovative teaching that focuses on learning, shifting towards a learner-centered approach to foster creating, thinking, and developing knowledge.

However, advocates of the learner-centered approach have suggested integrating pedagogies where students learn through construction and building models to boost understanding of concepts and make predictions. Johnstone (1993) pointed out that to motivate learners to appreciate chemistry and improve upon their knowledge of ideas, a new approach for learning and teaching chemistry needs to include the three scope of representational teaching and learning mode: macro-chemistry, where chemistry is experienced with senses as touchable and visible; sub-microchemistry, which explains macro-phenomena at the atomic and molecular level base on kinetic perspective, and finally representational chemistry which includes symbols, equations, stoichiometry, and mathematics. This suggestion made by Johnstone (1993) opened a new way of research into teaching chemistry. Other researchers who used Johnstone's view have suggested understanding models provide a critical perspective of concept, scope, and limitation for the development of chemistry learning (Justi & Gilbert, 2002). When students get the chance to try out and experiment with their theories, they are able to reinforce and solidify their knowledge of chemistry. An example of such methods is symbolic transformations applied to graphic objects (Kozma & Russel, 2005).

Meanwhile, researchers have also suggested that learners must be allowed to explore their learning environment and make decisions on their own instead of been fed with information all the time (Ameyaw & Sarpong, 2015). These models are linked to the visual interpretation of the concept learned, creating an impression on the student's mind. However, students face challenges with visuospatial thinking and an inadequate understanding of the model's role (Ameyaw & Sarpong, 2015).

Gardner (2012) explained that visual-spatial intelligence enhances their creativity in poster making, videos, problem-solving, and ideas illustrations. On the other hand, Gardner (2012) outlined how students' visual-spatial intelligence helps design, color, and detailing learning components. Habraken (2004) noted that visual-spatial intelligence involves incorporating and using pictures, images, and shapes to interpret and create an understanding of the relationship between images and reality. Creating an opportunity for students to expand their specific learning skill necessarily increase visual-spatial intelligence (Habraken, 2004). Teachers should, therefore, engage students through active classroom activities to comprehend learning materials. Such engagement does not necessarily emphasize what to teach but teaches through teaching methods to improve student's learning (Leaning, 2015). According to Dykstra Steinbrenner & Watson (2015), teacher and student engagement promote effective interactions, ultimately increasing students' chances of classroom success.

In addition, visual-spatial models help describe the classroom atmosphere and bridge the gap between what is being taught and how students comprehend the material (Ramadas, 2009). Therefore, students must have "opportunities to develop and test their models as an alternative way of learning chemistry, which is symbolic transformations applied to graphic objects" (Halverson et al., 2009). Moreover, our interactions with science students at St. Joseph College of Education (JOSCO) and Odorgonno Senior High School (OSHS) suggest different conceptions about bond angles, molecular geometries, and molecular hybridization, which adversely affect their performance in the examination. Meanwhile, these concepts are assessed at the end of the semester examination organized by the University of Cape Coast and West African Examination Council (WAEC). Upon this revelation, this study was conducted to investigate problems associated with teaching and learning molecular geometries and the related bond angles and determined if using visual-spatial models can enhance instruction and understanding of this content area in Colleges of Education Ghana.

Theoretical framework

This study was designed to apply to the theory of multiple intelligence in an undergraduate chemistry class. According to Gardner's theory of intelligence, each human has seven ways of relative processing information independently, with each form differing from the other in specific ways as is exhibited (Gardner & Hatch, 1989). Students show their intelligence in different forms, and using multiple intelligence enables teachers to select the best way to present information to students to process it since individuals differ in intelligence. As a result, teachers should provide opportunities for individual students to interact in different ways and different proportions. The visual-spatial intelligence of students refers to their ability to understand maps, artwork, and illustrations in learning. According to the theory's proponents, when teachers choose a learning style and assess understanding, it should be done to allow a vast range of students to participate in classroom learning. Teachers should help to support students to build strengths and improve their confidence and self-efficacy. Teachers are reminded to use approaches to develop their lessons, including observing students' participation in classroom activities or interactions with peers and offering extra time to build on their multiple intelligence. In choosing a learning style, teachers must bear in mind that students learn differently, and each approach has its educational implications and learning experiences. Students with a more robust education with diverse learning experiences enable them to remember due to the adequate preparation promoting increased diversity, acceleration of change, and success (Gouws, 2007).

Bag & Usak (2006) mentioned that teachers are provided with a conceptual framework for organizing and reflecting on pedagogical practices and curriculum assessment through the theory. Given that, teachers must develop new approaches that meet the needs of various learners in their classrooms. The different learning style suits learners with another intelligence focusing on a broader range of skills and abilities. Gardner suggests instructional methods such as cooperative learning, creative play, role-play, etc., that support multiple intelligence helps students to gain and use knowledge. The theory is based on a learner-centered approach where teachers' role as facilitators is to provide a helpful foundation for students' abilities and skills. Since students vary in intelligence and strengths in spatial relations or interpersonal knowledge, teachers need to use the multiple intelligence theory to reach a particular goal (Naz, 2020).

Research questions

The study focused on gathering data to answer the following research questions:

1. What challenges do St. Joseph's College science students face during their studies in molecular geometries with associated bond angles?

2. What effect do visuospatial models have on students' performance in molecular geometries and associated bond angles?

Methodology and methods

Research Design

This study is action research that determined the effect of the visuospatial model on college students' understanding of molecular geometries with respective bond angles. In action research, the researcher tries to design or organize intervention(s) and curtail an identified situation peculiar to a particular educational environment. Therefore, action research was chosen for this study since it focused on the immediate application of theory and involved a systematic problem-solving method. Hence, action research focuses on identifying classroom issues and improving classroom practices concerning that problem by the teacher himself when performed by a teacher. Based on these features of action research, it was appropriate for this study. The study also employed experimental (quasi-experimental) investigation of the quantitative approach with controlled subjects being studied by changing, manipulating, or adding new variables to measure desirable behavioral pattern manipulation, modify way (Shadish & Cook, 2002).

Sample and Sampling Procedure

The study's population was all science students at St. Joseph's College of Education. Purposive sampling and convenient sampling were used to select one hundred and twenty student teachers (120) who participated in the study. In purposive sampling, the researcher determines the respondents' type appropriate for the research and then assigns them (Suri, 2011). However, for having quick access to the accessible population, student teachers at St. Joseph College of Education, which is within one of the researchers' working environment, was used for the study. Moreover, simple random sampling was used to group the students in the experimental group.

The two groups were selected from two different science classes, with one group randomly chosen as a control. The control group was taught with the traditional approach (teaching at the Sub-microscopic level). Intervention strategies (projecting three-dimensional shapes with video and computer simulations and building molecular forms and hybridized orbitals with locally available materials) were applied in teaching molecular geometries with associated bond angles in the experimental group. The participants were asked to make repeated counting from one to five till everybody in the class was counted. All those having standard numbers were put in one group. Members in such groups were enrolled in course sections (construction of angles, building models, and drawing shapes) designed by the researchers. One of them served as an instructor for the course and assessed the groups' performance output and individuals forming the groups.

Study Instrument

The study's nature and the target group's story involved using instruments such as questionnaires, test item administration, and student groups' evaluation forms. The test items that constituted contents concerning molecular and hybridization geometry with their associated angles were used to determine individual students understanding levels in the two cohorts before and after applying the intervention strategies.

Validity and Reliability of the Instrument

Copies of the questionnaire were tested on two different science classes in the college, which were not used for the study. This enabled the researchers to establish the validity and reliability of questions by removing ambiguities that were captured. Again, the interventional strategies were applied to some students other than those involved in the study, and this was to ensure the validity and reliability of the results. This brought out faults in the structure of the questions asked and the interventional techniques, and the necessary modifications were made.

Data Collection Procedure

After carefully selecting the respondents using the appropriate sampling techniques, the respondents were briefed on the pre-interventional questionnaires, after which copies were given out to them. The answered questionnaires were collected after thirty-five minutes of administration. The pre-interventional questionnaire results for both control and experimental groups were quantified using statistical tools such as Microsoft Office Excel to establish facts to answer research question 1. Moreover, the experimental group (group A) was engaged in video lessons and classroom lesson activities to introduce molecular geometries and bond angles, determine molecular geometries, and use locally available materials to construct given organic molecules. The control group (group B), on the other hand, was also engaged in lessons on molecular geometries and associate bond angles using a conventional teaching approach. The researchers involved the two groups in two similar tests on the content been taught. The researchers scored the outcome of the post-interventional test performed by individual students in both the control and quasi-experimental groups. The post-interventional scores obtained from the two groups were compared using descriptive statistics using percentages, standard deviations to determine visuospatial models' effectiveness in teaching molecular geometries and associate bond angles.

Data Analysis Procedure

The pre-interventional questionnaires' responses were presented in tabular forms. The post-interventional scores of students in both control and experimental groups have been analyzed through a descriptive and inferential statistical approach with mean, standard deviations, and percentages. Independent t-test, measures of central tendency, and spread were determined to ascertain the difference in mean score, and the standard deviation for both groups is also presented.

Results

What are the challenges the Science Students of St. Joseph College faced during their studies in Molecular Geometries with associated Bond Angles?

The research question was answered by soliciting information from respondents (student-teachers) on the challenges they faced during their lessons in molecular geometries and associate bond angles. The responses obtained have been presented in Table 1.

Table 1: Challenges encountered by students in FDC 114C

Challenge perspective	Frequency (N)	Percentage (%)
Difficult in getting concepts	20	17.1
Lost interest due to general poor performance	9	7.7
Teaching was mostly lecturing	9	7.7
Inappropriate reading materials	5	4.3
Lack of assignments and activities	4	3.4
Difficult in getting concept lecturing method	53	45.3
The lesson was theoretical and in a large class	10	8.5
Use of lecture methods with no book for revision	7	6.0

According to Table 1, 20 of the respondents representing 17%, had difficulties understanding the concept taught, 9 students representing 8%, indicated that they lost interest in chemistry because of students' generally poor performance in FDC114C. Also, 62 of the respondents representing 53% of the entire population studied indicated that they had difficulties getting the concepts because of the lecturing method used by the teachers who handled FDC114C. Moreover, 5 of the respondents representing 4%, indicated that they had a problem with inappropriate reading materials, whereas 4 of them, representing 3%, indicated that they were neither given assignments nor engaged in activities during their studies in molecular geometries with bonds angles. Again, 10% representing 9%, suggesting that the lesson was primarily theoretical in a large classroom where more classes were combined.

Lastly, seven (7) of the respondents representing 6%, indicated no books for them to use as revision materials. The pre-interventional test scores used to confirm students' challenges in both the control and the experimental groups have also been presented using descriptive statistics, as shown in Table 2 below.

Table 2: Descriptive statistics of the pre-interventional scores for the two cohorts

Variable	Group	Mean	Std. Deviation
Pre-test	Control	22.53	10.35
	Experimental	22.48	10.32

Table 2 represents the pre-interventional test's descriptive statistics for the two classes before the treatments were introduced. The mean scores for both groups were almost the same (22.53 for the control group and 22.48 for the experimental group) at a 95% confidence level. This shows both groups had similar conceptual understanding indicating there were no differences in their ability levels. However, these values were far below the average of the total test score of 100%. This confirms that students were facing challenges during their studies in molecular geometries and associate bond angles.

What will be the effect of visuospatial models on students' performance in molecular geometries and associated bond angles?

In determining the effect of the visuospatial model on students' performance in molecular and hybridization geometries with associate bond angles, data were collected on individual students' performance on Molecular and hybridization Geometries with associate Bond-Angles before using the two different approaches in teaching the two cohorts on the subject matter. This was done to ascertain college students' knowledge on the topics and whether they had similar ability levels before and after applying the two different approaches to the two cohorts. Students' scores in the two cohorts were subjected to descriptive statics to obtain information to address research question two. The descriptive statistics results have been presented in Tables 3 and 4.

Table 3: Descriptive statistics of the pre-interventional scores for the two cohorts

Variable	Group	Mean	Std. Deviation
Pre-test	Control Experimental	22.53 22.48	10.35 10.32

The results of the Pre-Interventional Assessment are displayed in Table 3. According to the table, both the experimental and control groups had almost the same mean score values with mean difference of 0.05.

Table 4: Independent samples t-test for control and experimental group pre-test

	Mean Difference	t	df	Sig. (2-tailed)
Cont-Exp.	0.05	-12.52	238	0.400

There was no statistically significant difference between the control and experimental group in the pre-test scores; t (238) = -12.52, p= 0.400.

Table 5: Descriptive Statistics of the Post-Interventional Scores for the Two Cohorts

Variable	Group	Mean	Std. Deviation
Post-test	Control Experimental	36.92 77.55	10.38 10.64

Table 5 showed that the experimental group's post-interventional exercise mean score was 77.55, while the control group's post-interventional exercise mean score was 36.92. A control group standard deviation of 10.38 was found, whereas the experimental group was found to have a standard deviation of 10.64 in the table.

Table 6: Independent samples t-test for post-test control and experimental group pre-test

	Mean Difference	t	df	Sig. (2-tailed)
Control-Experimental	40.63	29.9	238	0.000

The table above showed a statistically significant difference between the control and experimental groups in the post-test scores; t (238) =29.9, p=0.000 (2-tailed).

Discussion and Conclusion

Chemistry is as science is rooted in technological breakthrough and connected to the different wheel of science. Chemistry is essential and supportive in various areas of our lives, including medicine, agriculture, transportation, housing, industries, etc. Life is made more meaningful with chemical products such as drugs, cosmetics, paints, soap, fertilizers, etc., from chemistry knowledge and application (Childs et al., 2015). Many careers, such as the health sector, food processing industries, extractive industries, petroleum, and petrochemical industries, are linked to chemistry. Unfortunately, this same chemistry is perceived by students as one of the most challenging courses (Childs & Sheehan, 2009; Schmidt, Hans-Jürgen, 2000; Baah & Anthony-Krueger, 2012). The data gathered shows that 60% of the respondents complained that they had difficulties understanding chemistry concepts (Table 1). This means that students' difficulty understanding chemistry concepts is therefore of global concern and calls for chemistry teachers' immediate effort to find appropriate means to demystify chemistry concepts to have confidence in studying chemistry as a course. Unfortunately, those teachers who handled these students in FDC114C could not engage learners in a series of activities that could boost students' interest in learning molecular geometry with associate bond angles.

Table 1 indicates that 8% of the students lost interest in chemistry due to general poor performance in FDC114C. It also depicts that learners' challenges were enormous, ranging from inappropriate reading materials, lack of assignments and activities, lack of textbooks for revisions, and large class size. This would adversely affect students' performance and interest in chemistry. But it could also be that teachers who handle FDC 114C had a different perception of chemistry. For instance, as students view chemistry as a challenging course, the teachers might perceive otherwise, affecting students' conception and understanding (Uchegbu et al., 2016; Jimoh, 2003).

This study's result is also in line with studies conducted by Baah & Anthony-Krueger (2012), which pointed out that students have difficulties learning chemical representations. A related survey of ÖZMEN & AYAS (2003) also pointed out that most chemistry students still hold alternative conceptions about chemical representations and structures after receiving substantial chemistry instruction. Moreover, studies revealed that students are unable to provide equivalent expressions from a given illustration. Therefore, it was not surprising to witnessed students' poor performance in the pre-interventional test because students might have received instructions on the concept without any conceptual understanding. For instance, Wu et al. (2001) found many students struggled to translate with formula, electron configuration, and ball-and-stick model when students' performances on translations were correlated to underlying concepts understanding. The authors attributed the students' inability to translate among formulas to a lack of knowledge of the underlying concept. This argument is also supported by Nieswandt (2007), who argued that conceptual understanding allows students to interpret the information provided by the initial representation. Students will face difficulties in constructing the target representation without it. As a result, chemistry students can quickly encounter some conceptual challenges, as witnessed in students at St. Joseph College of Education. Therefore, it requires the innovativeness and resourcefulness of a teacher handling the students to provide a platform that gives an 'escape velocity or 'conceptual basement' to conceptualize concepts. The mean score values obtained from the pre-interventional exercise, as indicated in Table 2, show that the two cohorts were similar ability levels. Therefore, the pre-interventional exercise outcome demonstrates that the two cohorts had similar characteristics in terms of ability level and conceptual challenges of the Molecular and hybridization geometries with associate bond-angles.

On the other hand, the study findings show a significant difference between the two cohorts' performances (Table 6). For instance, the mean scores in the post-interventional exercise for the experimental and control groups were 77.55 and 36.92, as indicated in Table 3. A higher performance is shown by the large discrepancies in the two-mean scores. There appears to be a twice difference in the mean score value of the experimental group (77.55) and the control group (58.55). (36.92). Additionally, as shown in Table 4, the experimental group standard deviations (10.38) were fewer than those of the control group (10.64). Students who had received intervention, however, were closer together on post-intervention scores than control group students, meaning that the standard intervention methods had a positive impact on the control group.

Again, the findings from Table 4 shows that the visuospatial models approach enhanced students' academic achievement better than the traditional (conventional) teaching approach as the means predicts in both experimental and control groups. This indicates that the visuospatial models use enhanced students' conceptual understanding far better than the conventional method. The significant difference between the mean scores of the control and the experimental group (mean difference of 41) justifies the assertion made by (Snir, Smith & Ra, 2003) when they concluded that visuospatial models help in engaging students with fundamental ideas, especially for students who have developed relevant macroscopic conceptions and interrelated conceptions and for that matter can result in more significant achievement in science than would be the case with conventional instructional approaches.

Furthermore, many reasons contributed to the differences in performance between the two cohorts. For instance, using the visuospatial models in the teaching and learning environment gives the learner more space to explore. As a result, the visuospatial models were likely to boost students' desire to learn the concepts, improving their performance than the conventional approach where the teacher passes information to the learner. This traditional approach restricts learners' curiosity and thinking to build intrapersonal connections essential for learning (Dole, Bloom & Kowalske, 2015). Again, the control group's low achievement scores follow a similar study conducted by Milner-Bolotin, Kotlicki, and Rieger (2007), who reported that the conventional teaching approach does not support students' academic satisfaction.

Moreover, visuospatial models' use enhances learners' ability to interact with their environment and collaborate among peers. This is likely to improve their communication skills, critical thinking ability, and criticize their works and accept criticism. This is also in line with the outcome of research conducted by (Wu & Shah, 2004), which reported that curricula that include sets of model representations provide students with opportunities to learn about the conceptual subject matter of a particular discipline's nature of scientific knowledge. Sincerely, visuospatial models in teaching enhanced students' ability to visualize their imaginations and their thoughts about molecular and hybridization geometries with associate bond-angle. Therefore, this could positively contribute to the higher performance among the experimental group. In addition to these reasons, it should also not be forgetting that interacting with peers improves communication skills and, as a result, boost their confidence level. This could also positively influence students' performance in molecular and hybridization geometries with associate bond-angles.

The study results revealed that the students exposed to the visuospatial models performed better than their counterparts who were taught using the traditional teaching method. This is supported by a study by (Lazarowitz & Naim, 2013) that found students who used "hands-on" learning to build three-dimensional models achieved significantly higher learning outcomes in higher cognitive questions. This indicates the benefits of how actively students are engaged in the "hands-on" learning process. As a result, students' high performance in the experimental group may be because the models used to teach molecular and hybridization geometries describe natural processes better and offer a more precise understanding to the experimental group students (Dori & Kaberman, 2012). The experimental group's high-performance scores show that physical manipulation and handling of objects during the visuospatial model construction were beneficial. This implies that physical manipulation and handling of things is an effective way for students to learn science and, for that matter, chemistry.

Recommendations

Based on this study's results, it is recommended that visuospatial models capable of engaging students as active learners should teach chemistry and its related topics. Chemistry teachers should be encouraged to collaborate with students to use locally available material to develop relevant models to boost students' interest in chemistry. The chemistry syllabus should expand the use of locally available models in teaching molecular structures to other chemistry areas so that students can relate chemistry to their daily lives.

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