Improving students' performance in naming and writing structural formulae of hydrocarbons using the ball-and-stick models

Kenneth Adu-Gyamfi
University of Cape Coast

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IMPROVING STUDENTS' PERFORMANCE IN NAMING AND WRITING STRUCTURAL FORMULAE OF HYDROCARBONS USING THE BALL-AND-STICK MODELS

[1]Peter Abum Sarkodie, [2]Kenneth Adu-Gyamfi
[1]University of Education, Winneba, Ghana
[2]Mampong Technical College of Education, Ghana

Abstract. Learning chemical concepts at the submicroscopic and symbolic levels has been identified as a difficult task for science students. Studies have shown that IUPAC nomenclature of organic compounds, which is at the symbolic level of learning chemical concepts, is a difficult concept when it comes to students' learning. The current study involved a pre-service teacher and 60 high school students and investigated how students could improve upon their performance in naming and writing of structural formulae of hydrocarbons with the aid of ball-and-stick models. The pre-service teacher and the students were purposively selected to participate in the study. After seven weeks of teaching and learning of IUPAC naming and writing of structural formulae of hydrocarbons where the students physically manipulated the models, it was found that the students' performance and attitude improved after the intervention. It is therefore recommended that science educators should continuously use already existing and newly developed models in teaching chemical concepts to help students to actively conceptualise such concepts at the symbolic level.

Keywords: hydrocarbons, structural formulae, students' performance

Introduction

There are three levels of teaching and learning of chemical concepts. The three levels are macroscopic, submicroscopic, and symbolic. The macroscopic level represents chemical concepts through observation; the submicroscopic level represents chemical concepts through the arrangement and motion of molecules, atoms, or subatomic particles; and the symbolic level represents chemical concepts through the use of chemical symbols, formula, structures, equations, or numbers (Johnstone, 1991). The submicroscopic and symbolic levels of representing chemical concepts have long been identified as potentially difficult areas as far as students' learning science are concerned (Ben-Zvi et al., 1987). The difficulty associated with these two levels is as a result of the abstract nature of the teaching of such chemical concepts and students most of the time are pivoted at learning chemical concepts using everyday observations (Ben-Zvi et al., 1986). Wu et al. (2001) noted that, the difficulty is as result of the fact that students view equations or formulae of chemical substances as combination of letters and numbers while Keig & Rubba (1993) viewed the difficulty as a result of students' inability to translate one representation into another. Calik & Ayas (2005) further explained that the difficulty for students in learning chemical concepts is as a result of their inability to show linkages between knowledge acquired and everyday experience. Kozma et al. (2000) identified that the students' difficulty in learning chemical concepts is partly due to the fact that students cannot directly perceive molecules and their properties.

Hydrocarbons are organic compounds composing of only carbon and hydrogen atoms, for example, CH_4, CH_3CH_3, $CH_2{=}CH_2$, $CH{\equiv}CH$, and C_6H_6. Hydrocarbons can either be alkanes, which contain carbon-carbon single bonds; alkenes, which contain at least one carbon-carbon double bond; or alkynes, which contain a carbon-carbon triple bond (Fessenden & Fessenden, 1990; Solomons & Fryhle, 2008). There are two groups of hydrocarbons; namely saturated and unsaturated hydrocarbons, however, each carbon atom has to maintain tetravalency that is having four covalent bonds attached to the carbon atom in a molecule. In the saturated hydrocarbons or alkanes, all the four bonds around any carbon atom in the molecules are single bonds and in the unsaturated hydrocarbons (alkenes and alkynes), there is always a carbon-carbon multiple bonds in the molecule. The structure and naming of hydrocarbons serve as the foundation for moving to similar tasks for organic compounds containing other functional groups (Fessenden & Fessenden, 1990). Naming and drawing of hydrocarbons, like all other chemical concepts at the symbolic level are associated with some degree of difficulty in learning with respect to their structures, equations, and chemical reactions.

Kozma et al. (2000) realised that the name of a compound could account for the different atoms present in that compound as well as its physical properties. In addition, the name of a structure of a compound would in some cases reflect the elemental components of that compound. Thus, the act of naming a compound is not necessarily giving the compound an IUPAC name but the name should be unambiguous with respect to the structure of the compound (Kozma et al., 2000). Ege (as cited in Kozma et al., 2000) stated emphatically that scientists cannot talk about Organic Chemistry relegating structural diagrams to the background, that is chemical scientists in the area of Organic Chemistry always draw molecular structures for the reactions they talk about. This is because molecular structures of compounds help to identify the constituent atoms, the relative spatial arrangement of the atoms, and the chemical bonding between the atoms.

The IUPAC nomenclature of organic compounds has been with us for many years (Fessenden & Fessenden, 1990; Solomons & Fryhle, 2008) and the current IUPAC rules were updated in 1993. In Ghana IUPAC nomenclature is taught in high school through to the university in subjects such as Integrated Science and Chemistry. The West African Examination Council (WAEC) Chief Examiners' Reports have over the years reported on the low performance of candidates in Integrated Science 1 at high school level. This is particularly evident in the area of chemical concepts (WAEC, 2002; 2005; 2006; 2008; 2010). The Chief Examiner (CE) in 2005 explained that there had been improvement in candidates' performance in Integrated Science 1. However, the CE identified that the number of candidates who answered the question on Chemistry aspects was very low and such candidates showed poor performance in such areas. For instance, the candidates could not even explain correctly the concept of IUPAC nomenclature when they were asked to do so. In 2006, the CE asserted that the candidates could not clearly show the difference between organic compounds in general and hydrocarbons, in particular the candidates were seen to be faltering in providing the IUPAC names of sample organic compounds. An empirical study of Adu-Gyamfi et al. (2013) further exposed the weakness of senior high school (SHS) students in using the IUPAC nomenclature system to name and write formulae of organic compounds. This identified weakness is common for both hydrocarbons and non-hydrocarbons such as alkanols, alkanoic acids, and alkyl alkanoates. The students' difficulties in using IUPAC nomenclature in drawing structural formulae of organic compounds stem from the fact they could not identify the correct number of carbons in a continuous chain as well as any substituent group and its point of attachment from the IUPAC name when drawing the structures (Adu-Gyamfi et al., 2012).

Since the performance of students in Integrated Science could be considered generally as low in many senior high schools in Ghana, author 1 decided to assess the performance of students in learning Integrated Science in one of the SHSs in Sekyere East District of Ashanti Region in the area of naming and writing of structural formulae of hydrocarbons. The performance of the students in the test was low and this called for an intervention to assist students to overcome their difficulties in naming and writing of formulae of hydrocarbons.

The purpose of the study was to investigate how students could improve upon their performance in naming and writing of structural formulae of hydrocarbons with the aid of models. The use of a model has become necessary as Wu et al. (2001) asserted that for students to understand scientific knowledge they need to learn how to create a linkage amongst abstract concepts. The model allowed the students who participated in the study conducted by Wu and his colleagues to visualise their conception of nature of matter such as organic molecules in a concrete manner. In addition, teachers in the area of Chemistry Education appreciated that the spatial visualisation ability of students is an essential tool in the teaching and learning of chemical concepts. This spatial visualisation ability of students enable them have correct perception of molecules; have a good understanding of chemical concepts and processes; and to have a good understanding of the relationship among molecular structures and their properties (Savec et al., 2006).

The current study was guided by three research questions: (1) how effective would the use of model be in improving students' performance in naming and writing of structural formulae of hydrocarbons; (2) what is the attitude of students towards naming and writing of structural formulae of hydrocarbons; (3) what is the perception of the pre-service teacher towards the use of models in teaching naming and writing of structural formulae of hydrocarbons.

The current investigation into the effectiveness of using models in teaching naming and writing of structural formulae of hydrocarbon was necessary as the researchers saw the need to collaborate with a pre-service teacher on development and use of ball-and-stick models for teaching naming and writing of structural formulae of hydrocarbons. The pre-service teacher's involvement would help develop him professionally in the areas of instruction and content such that he could transform his teaching (Borko, 2004; Smith et al., 2003) with respect to the use of models in teaching chemical concepts.

More than three decades ago, it was found that manipulation of physical materials could have long-term effects on students' understanding and hence, their performance in a concept (Gabel & Sherwood, 1980). The study by Savec et al. (2006) found that both in-service and pre-service teachers perceived that one of the chemical concepts where physical materials can be of good use is teaching and learning of structural formulae of organic molecules. Wu et al. (2001) then described how a specially designed approach to teaching can influence the performance of students in IUPAC nomenclature of organic compounds. This is because their model, eChem enhanced the performance of students as shown in a pretest-posttest single-group study; where the mean score of the students in the pretest was significantly lower than the mean score of the students in the posttest. The study of Kozma et al. (2000) confirmed other studies that make use of representations to help to enhance students' understanding in symbols that are used to express scientific concepts.

From the literature review above, it can be seen that the importance of models in the teaching and learning of chemical concepts cannot be over-emphasized and therefore should be a good first point of departure for their use across the curriculum (Savec et al., 2006). This is because the use of three-dimensional models makes students engage in science lessons and it has been found to support students' understanding in many scientific concepts (Barnett et al., 2000). According to Duit (as cited in Jansoon et al., 2009), there are two reasons why science educators use models; to communicate scientific models such as atomic structure and to explain scientific concepts to students. Wu et al. (2001) asserted that visualisation and representation of chemical concepts (formulae) helped students to overcome their difficulty in learning chemical concepts such as naming of compounds at the symbolic level. The students involved in their study were able to create linkages between visual and conceptual areas of representations and for this reason that the current study chose to assist a pre-service teacher to use a traditional ball-and-stick models to teach the concept of naming and writing of structural formulae of hydrocarbons to SHS Integrated Science students.

The use of traditional three-dimensional objects in place of computer-assisted (pseudo) ones in the current study was due to an insufficient number of computers in most of the schools and in particular where the study was conducted. Though some authors prefer the combination of traditional and pseudo application of three-dimensional objects in teaching and learning of chemical concepts (Barnea & Dori, 1999; Wu et al., 2001) but in most parts of Africa in general and Ghana in particular there is a shortage of computers and as a result the use of traditional three-dimensional objects in Chemistry Education cannot be over-emphasized in such communities. However, the study was managed in such a way to minimise its shortcomings in the teaching by allowing students to draw their mental images of the given molecules and be involved in open class discussion with the pre-service teacher as the lesson progressed.

Methodology of the study

The research design used in the study was a single group pretest-posttest action research design, where the researchers worked in collaboration with a pre-service teacher in teaching and developing lessons on IUPAC naming and writing of structural formulae of hydrocarbons, using ball-and-stick models. The choice of action research was necessary as it can be applicable in all settings where problem solving involves people, tasks, and procedures that are yearning for solution. It further encourages more positive attitude to work, and continuous professional development in the areas of instruction and content. In addition, action research is not the usual thinking of teachers but a more systematic and collaborative way of obtaining data based on reflection; and further not a research conducted on other people but conducted by particular people on their work in order to improve their own work (Cohen et al., 2007). The current study targeted the professional development of the pre-service teacher (Goodnough, 2010) as a major part of the study and therefore the selection and use of action research. The purpose of the professional development was to enhance the pre-service teacher's teaching practices in the science classroom. It was also necessary as the action research was intentional and systematic in solving problems of teaching. The study used both quantitative and qualitative methods to collect and analysed data respectively from test, observations, and conversations with students and the pre-service teacher to justify how effective the ball-and-stick model would be in enhancing students' performance in naming and writing of structural formulae of hydrocarbons.

Sample

There were five SHS in the Sekyere East District of Ashanti Region of Ghana but only one school was purposively involved in the study. This is because the pre-service teacher in the school was willing to work extra hours during the period of the study. There were three year groups of students: namely the first, second, and third year groups. The target students for the study were all SHS 2 students as the concept of IUPAC nomenclature of organic compounds is taught at this level in Integrated Science. Also, at the time of the study, it was found that the second year students were yet to learn IUPAC nomenclature under Integrated Science. The SHS 2 students were stratified into 12 groups with respect to their normal classrooms of learning. As all students took Integrated Science as a 'Core Subject', all the SHS 2 students were important for the purposes of the study. This therefore led to the purposive selection of five students from each class to have one class of 60 students. These students were selected as they agreed to meet the pre-service teacher outside the normal instructional hours for the conduction of the study.

Research instruments

The main research instrument for the study was achievement test interspersed with the researcher's observations and conversations with the pre-service teacher and the students. The achievement test was made up of pretest and posttest items which were constructed by the pre-service teacher. The pretest items consisted of 10 items with each scoring one mark. There were four, four, and two items respectively in the areas of alkanes, alkenes, and alkynes. The unequal distribution of the number of items with respect to alkanes, alkenes, and alkynes was due to the fact that the pre-service teacher perceived that much more time was going to be spent on teaching the alkanes and alkenes as compared to the alkynes and in fact this was what happened. In all there were five items on naming of and five items on writing of structural formulae of hydrocarbons. The items were in the areas of unbranched-, branched-, and substituted chains of alkanes, alkenes, and alkynes (Appendix). The posttest items were the same as the pretest items but different order of arrangement.

The test items were constructed by the pre-service teacher and were content validated by the two authors who were the researchers. The items were then compared to standardised test items used by the WAEC for assessing high school students' knowledge in Integrated Science. The items were then pilot-tested with students of similar characteristics from another high school in another district of Ashanti Region. After the pilot test, the items were analysed and those items that were too difficult or too weak were deleted to obtain the final 10 items. Since the items were scored either right or wrong, the KR 21 coefficient of reliability was calculated as 0.7, which shows the final test instrument was reliable.

Each lesson of the pre-service teacher on IUPAC naming and writing of structural formulae of hydrocarbons was observed by the first author. The author 1 took field notes which were immediately converted into summary observation after each day's lesson. The summary observations were analysed together with the pre-service teacher for him to appreciate the strength and weakness of his lessons and the attitudes of the students in the lesson.

The interviews, which took the form of conversations with some students and the pre-service teacher after each lesson, helped to ascertain students' conceptual development and interest in the lesson throughout the period of the study. A conversational type of interviews was adopted to prevent the pre-service teacher and the students from adapting defensive mechanisms in responding to issues we intended to probe. It helped a lot as the pre-service teacher or the students felt free and natural in interacting with the researchers.

Data collection procedure

The author 1 first discussed with the pre-service teacher our intent to conduct research with the students from the school where he was carrying out his one-year teaching practice and that he would be an important factor in teaching naming and writing of formulae of hydrocarbons. The pre-service teacher was briefed on the task involving nature of what we intended to do and what his roles would be during the period of the study. Upon the agreement and mutual understanding we had with the pre-service teacher, the author 1 met the Headteacher of the school and sought permission to conduct the study in the school. The meeting and the discussion thereafter were smooth as the pre-service teacher was one of the students of author 1. The Headteacher then introduced the author 1 and the pre-service teacher to members of Science Department who also assured of their support when necessary. The selected students were later selected and issues and stages of the study were discussed with them. The study involved three stages as it was an action research. These were pre-intervention, intervention, and post-intervention stages.

At the *pre-intervention stage*, author 1 first interacted with some students and found out that they could not respond to questions on naming and writing of structural formulae of organic compounds. After this observation, the idea of helping the students to improve on their performance in IUPAC naming and writing of structural formulae of hydrocarbons was conceived. The pre-service teacher then gave the pretest items to the selected students to complete. The students' responses in the pretest were scored. The analysis of the scores of the students in the pretest revealed that indeed the students from the school like any other Ghanaian student at the SHS level had difficulty in naming and writing of structural formulae of hydrocarbons. It was then necessary to design some structured activities to enhance the students' performance in the concept of IUPAC naming and writing of structural formulae of hydrocarbons.

At the *intervention stage* of the study, the pre-service teacher was exposed to the technique of using the ball-and-stick models to teach chemical concepts such as naming and writing of structural formulae of hydrocarbons. In the ball-and-stick model kit there were plastic or wooden balls and sticks. The ball representing the carbon atom was black with four bonds and that for the hydrogen atom was white with only one bond. Balls similar to those for hydrogen were provided for the halogens, where chlorine was represented by a green ball and bromine by a blue ball. The pre-service teacher then developed and prepared his lesson sequence for eight weeks as presented in Table 1.

Table 1. Weekly activities for teaching the naming and writing of hydrocarbons

Week	***Activity***
1-3	Using ball-and-stick models to assist students to form covalent bonds in alkanes, alkenes, and alkynes. Drawing structures of alkanes, alkenes, and alkynes. Open class discussion of sample students' work.
4-5	IUPAC naming of structures of alkanes, alkenes, and alkynes. Repeated exercises on the IUPAC naming of structures of alkanes, alkenes, and alkynes. Open class discussion of sample students' work.
6-7	IUPAC writing/drawing of structures of alkanes, alkenes, and alkynes. Repeated exercises on IUPAC writing/drawing of structures of alkanes, alkenes, and alkynes. Open class discussion of sample students' work.
8	Evaluation of the intervention activities.

Each week the pre-service teacher had a two-hour session with the students on teaching and learning the concept of IUPAC naming and writing of structural formulae of hydrocarbons. Each lesson was observed by author 1 and after each lesson; there were conversations with the pre-service teacher and some of the students. This revealed the progress and conceptual changes of the students in the lessons and the pre-service teacher's experiences as he interacted with the students using the ball-and-stick models in teaching chemical concepts.

At the *post-intervention stage*, the posttest items were used to assess whether there had been any conceptual change after the planned and systematic activities at the intervention stage of the design. The students' responses in the posttest were scored and mean scores calculated. The mean scores of the pretest and posttest were compared to ascertain the effectiveness of the use of ball-and-stick models in teaching and learning of IUPAC naming and writing of hydrocarbons. The mean scores of the students in the pretest and posttest were further analysed and discussed with pre-service teacher and his responses were noted. Lastly, there were conversations with some of the students to ascertain whether they had also had any change in attitude towards learning IUPAC naming and writing of structural formulae of hydrocarbons (and chemical concepts in general).

Data analysis

The Research Question 1 was analysed in two ways being the quantitative analysis of the students' scores from the pretest and posttest. Means, standard deviations, and the paired-samples t-test were used to answer the research question. In the first part the means and standard deviations were used to analyse the performance of majority of the students in the pretest and posttest. The paired-samples t-test was used in the second part to test whether there was any statistically significant difference between the students' performance in the pretest and the posttest. This is because it was the most appropriate statistical tool for comparing two mean scores of the same group of students on two different occasions (Pallant, 2005). To answer the Research Questions 2 and 3, the views of the students and the pre-service teacher were transcribed according to the meanings we made from them and were used to answer qualitatively the two research questions.

Results

The Research Question 1 sought to find out how effective the use of the model would be in improving the performance of the students (involved in the study) in naming and writing of structural formulae of hydrocarbons. The mean scores of the students in the pretest and posttest are presented in Table 2.

Table 2. Students' mean scores in pretest and posttest

Test	N	M	SD	Max score
Pretest	60	2.4	1.0	5
Posttest	60	7.8	1.4	10

From Table 2, the results show that a two-third majority of the students in the pretest achieved a low mean score ($M = 2.4$, $SD = 1.0$) ranging between 1.4 and 3.4 and a maximum score of 5 out of 10. It can further be seen from Table 2 that a two-third majority of the students achieved a high mean score ($M = 7.8$, $SD = 1.4$) ranging between 6.4 and 9.2 and a maximum score of 10 out of 10 in the posttest. The findings from Table 2 show that most of the students show weak performance in the pretest whereas most of the students show an improved performance in the posttest.

The means in Table 2 show that there was difference between the mean score of the students in the pretest ($M = 2.4$, $SD =1.0$) and the mean score of the students in the posttest ($M = 7.8$, $SD = 1.4$). To ascertain whether there was any statistical significance difference between the students' mean scores in the pretest and posttest, the paired samples t-test analysis was conducted. The results from the paired-samples t-test analysis are presented in Table 3.

Table 3. Results from the paired-samples t-test analysis

Test	N	M	SD	t	df	p
Pretest	60	2.4	1.0	29.5	59	0.000*
Posttest	60	7.8	1.4			

* $p < 0.0005$

The results in Table 3 show that there was statistically significant difference between the mean score of the students in the pretest and the mean score of the students in the posttest. This is because the mean score of the students in the pretest ($M =2.4$, $SD = 1.0$, $t(59) = 29.5$, $p < 0.0005$) was statistically different from the mean score of the students in the posttest ($M = 7.8$, $SD = 1.4$). The eta square statistic was calculated as 0.94 which was an indication of large size effect. This large effect size shows that there is substantial difference in the students' performance before and after the intervention. The findings from Table 3 show that there is a significant improvement in the students' performance in the posttest as compared to the students' performance in the pretest.

The Research Question 2 sought to find out the attitude of students towards learning of IUPAC naming and writing of structural formulae of hydrocarbons. This is because some authors are of the view that the fact that there is significant difference in the students' performance before and after the intervention, which is skewed towards the performance after the intervention does not necessary indicate that the intervention caused the improvement in students' performance in naming and writing of structural formulae of hydrocarbons. To convince ourselves and our readers, we had conversational interviews with the students before, during, and after the intervention. It was a general feeling among the students before the intervention that the concept of IUPAC nomenclature is difficult as at times the formula or the name of a given organic compound can become complex. One of the students said "it is difficult to handle when there is more than one branch on the compound".

At some points during instruction, some of the students began to appreciate that they could handle the naming and writing of formulae of hydrocarbons as it was just a matter of the arrangement of the carbon atoms. This was supported by statements such as "I only need to open up the carbons and bonds to show where each carbon is in the chain" and "it is like I need to go back from the name". For example, "in but-1-ene; *ene* is a double bond, *but* is four carbons, and -*1*- is that the double bond comes after first carbon". There were also some of the students who asked for further examples to help them understand the lesson better.

After the intervention and the last exercise which was the posttest, several of the students asked if we could extend the teaching and learning of IUPAC nomenclature to other classes of organic compounds. This is because they were happy with the teaching process and wanted the pre-service teacher to enter into other classes of IUPAC nomenclature of organic compounds. An extract between one of the students and author 1 was:

Student: can we have more of this next term?
Author 1: why?
Student: it is interesting
Author 1: why do you say the lesson is interesting?
Student: I easily understand what is going on.

The Research Question 3 sought to find out the perception of the pre-service teacher, which is the experience the teacher has had teaching a chemical concept using the ball-and-stick models. Before the pre-service teacher was trained on how to physically manipulate the ball-and stick models, he was a bit skeptical about the use and the possible impact on student learning of the chemical concept. This can be seen from the following extract:

Teacher: I'm happy to work with you on this project; but will it work as expected?

Author 1: Why do you asked?

Teacher: The fact of the matter is that I haven't personally used these models before and I usually don't see science teachers using them.

Author 1: There is always the first time and be assured that you will be trained on how to use the models.

Teacher: That's okay by me, sir.

As the days went by, the pre-service teacher seemed confident and delighted in the study we were conducting. This is because he was punctual and always ready to meet the students. From this extract of the conversation between the pre-service teacher and author 1, it could be seen that the pre-service teacher was confident in himself as the intervention activities went by.

Author 1: Why do seem confident whenever it is time for us to meet the students?

Teacher: This exercise has given me the opportunity to learn my content and methods of teaching very well.

Author 1: How do mean?

Teacher: I have to read around the IUPAC nomenclature concept every day. At times areas outside the hydrocarbons we are using.

Author 1: Do you only learn the content?

Teacher: Oh no; I practice the use of the models.

Author 1: Why do you have to practice ahead of each lesson?

Teacher: It helps me to identify the challenges…; when to call on students; and when to assist them.

After the analysis and discussion of the results from the posttest with the pre-service teacher, we found that he was happy and willing to use models in his subsequent teaching. This is because he appreciated that the performance of the students on IUPAC naming and writing of structural formulae of hydrocarbons has improved. One of the extracts of the conversation between the pre-service teacher and author 1 after the posttest was:

Author 1: Is it worthy to teach SHS students with this approach?

Teacher: Yes; and I intend to use models in my teaching.

Author 1: Are you referring to the ball-and-stick models?

Teacher: Yes/no.

Author 1: Why yes/no?

Teacher: Yes; when it is applicable to use the ball-and-stick models and no; when not applicable.

Author 1: What will do then when the ball-and-stick models are not applicable?

Teacher: I will read on other models and try them out also.

Author 1: What is your final impression about the use of models in Chemistry lessons?

Teacher: I think is good to use models in teaching Chemistry… and if we were taught by such approach at the high school level, most of my mates may have liked Chemistry.

Discussion

The findings from the study have shown that the students' performance in naming and writing of structural formulae of hydrocarbons improved after the intervention. This is because the performance of the students after the intervention is significantly higher than the performance of the students before intervention. This means that the intervention namely the use of ball-and-stick models enhanced the students' performance in IUPAC naming and writing of structural formulae of hydrocarbons (Kozma et al., 2000; Wu et al., 2001). Notwithstanding the fact that students' difficulties exist in IUPAC naming and writing of structural formulae of organic compounds (Adu-Gyamfi et al., 2012; 2013), the difficulty could be overcome with the assistance of models as models enhance students' conceptual understanding in scientific concepts (Barnett et al., 2000; Wu et al., 2001).

Not only did the intervention enhance students' performance in naming and writing of structural formulae of hydrocarbons but the findings further show that the students' attitudes changed as well. This is because the students appreciated that with the use of the models they could solve problems of IUPAC nomenclature of hydrocarbon. They requested that the method of teaching of the concept should be extended to all other areas which form part of IUPAC nomenclature as it is studied under Integrated Science in the Ghanaian high schools. This means the ball-and-stick model has had an impact on the students' learning of chemical concepts. The students change in attitude towards learning of IUPAC nomenclature of hydrocarbons could be attributed to the fact that the use of models help lessen students' difficulties in learning chemical concepts (Wu et al., 2001) by making students actively involved in the lessons (Jansoon et al., 2009).

The pre-service teacher who was not sure of the effect of the ball-and-stick models on the students' conception and performance in IUPAC naming and writing of structural formulae of hydrocarbons was convinced that models can assist students to conceptualise chemical concepts at the end of the intervention. He then benefited from his involvement in the study. This is because he developed himself professionally in IUPAC nomenclature and the use of ball-and-stick models. Professional development programmes such as the one offered by the current study helped the pre-service changed his perception as result of experience (Smith et al., 2003).

Conclusions

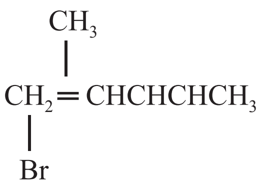
The study has shown that the use of models can enhance students' performance in naming and writing of structural formulae of hydrocarbons which form part of the IUPAC nomenclature concept. The models are effective in teaching and learning of IUPAC nomenclature of hydrocarbons because not only did the performance of the students involved in the study improve but the attitudes of the students changed positively towards learning of IUPAC nomenclature of organic compounds. Science Educators are therefore encouraged to adapt to the use of existing and any newly developed models in teaching chemical concepts as models have the tendency of making students active in such lessons, thereby enhancing their conceptual understanding in chemical concepts.

The current study confirms other studies such as Wu et al. (2001) where models enhance students' performance in chemical concepts. The current study however adds to the literature with inclusion of pre-service teacher in developing and teaching lessons on IUPAC nomenclature using models. It could be said that the pre-service teacher developed professionally in instruction and content (Borko, 2004; Smith et al., 2003). It is envisaged that the pre-service teacher would use models in teaching chemical concepts in his subsequent teaching and even as an in-service teacher, which would enhance his teaching practices. Researchers in the area of Science Education are therefore encouraged to involved pre-service teachers in research studies in design and development of instruction as well as in the design and development of curriculum materials for in-service teachers.

APPENDIX

Sample Achievement Test Items

1. $CH_3CH_2CH_2CH_3$
2. $CH_3CH_2CH=CHCH_3$
3. $CH \equiv CCH_3CH_3$
4. CH_3CHCH_3 (with CH_3 attached to the central C)

5. 
6. Propyne
7. 2-bromo-2-chloropentane
8. 6-chlorohex-2-ene
9. 5-ethyl-2-methylheptane
10. 2,3-dimethylbut-2-ene

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✉ **P. A. Sarkodie, Head of Department**
Department of Science Education
(College of Agriculture Education)
University of Education, Winneba
Mampong-Ashanti, Ghana

✉ **Kenneth Adu-Gyamfi, Head of Department**
Department of Science Education
Mampong Technical College of Education
Mampong-Ashanti, Ghana
E-mail: dondonsinco@yahoo.com