

CLASSROOM: INEXPENSIVE MODELS FOR TEACHING ATOMIC STRUCTURE AND COMPOUNDS AT JUNIOR SECONDARY SCHOOL LEVEL OF EDUCATION

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ABSTRACT

Improvisation is the best way of making up for non-available science teaching resources in basic schools in Ghana. As a result this project was designed to find out whether less expensive locally available materials could be used to make models of the atomic structure and whether such models could contribute towards students understanding of the topic. The models made were tried in three junior secondary schools and the students tested in the topics taught. The marks obtained were compared with that of students who did not benefit from using the models. The views of a sample of students who benefited from the models were also analyzed. The results showed that the models generally enhanced the understanding of the topics. In School A the average marks are 28.30% for control and 67.60% for test experiment; in school B, 42.10% for control and 77.37% for test experiment whilst in school C the control experiment recorded average of 59.73% as against 78.47% for test experiment. The differences between the means for the control and test experiments were very highly significant in the three schools. Also, distinctions were recorded in classes where the models were used but not in classes where they were not used. Comments from students generally suggest that they found the models useful for teaching and learning.

KEYWORDS: Atom, Molecule, Compound, Nucleus, Improvisation

INTRODUCTION

The whole world has become a global village as a result of advancement in science. Science now dominates almost every field of our lives such that every country is trying to go ahead of other countries in providing new ways of life. Take for instance the craze of companies to outdo one another and the centerpiece of this is science. According to Sharma (2001) science is a cumulative and endless series of empirical observations that result in the formation of concepts and theories that can be subjected to modification in the light of further empirical observations.

Judging from the spate of scientific advancements in the world today, it can be said that much depends on scientific research. However, people with scientific knowledge can best undertake scientific research. If this is true then the best medium of acquiring scientific knowledge is through the studies of science. This presupposes that every nation needs to include science in its curriculum such that children can acquire some scientific knowledge from early stages of their education.

Sharma (2001) stated that the process of learning science takes place at different levels depending on the prior experience of the learner, his/her intellectual ability and the presentation of materials. The learning process could be categorized into three levels, namely, association, conceptualization and creative self-direction. Most of the higher learning in the cognitive as well as affective domains takes place by conceptualization. Creative self-direction is the

highest level of learning science and under favourable conditions people are able to progress from association formation, through a process of conceptualization to a kind of learning that characterizes the creative artist. When a student has this level of learning then he/she can work independently on his/ her own initiative.

One of the objectives of teaching science is the inculcation of the scientific attitudes and the training in the scientific method. This is possible through instruction, demonstration and experimentation. However, most teachers in Ghana concentrate only on instruction whilst it is through demonstration and experimentation that most of the desired scientific attitudes are developed (Sharma, 2001). Most often many science teachers argue that they cannot undertake practical lessons because of lack of science equipment. Meanwhile improvisation makes the student active worker and not only a passive observer. It also develops in the student scientific thinking and reasoning through personal experimentation, demonstration, instruction and verification of the basic facts of science studied in the books and personal contact with the teacher (Bhandula, Chadha, and Sharma, 1999). This makes the children satisfied to a greater extent and whips up their interest in science. A habit of tackling any problem by scientific method is developed in the mind of the student and thus he/she becomes able enough to face every problem in a systematic and organized manner. The preceding submissions amply point to the fact that the use of improvised science apparatus has numerous advantages for the learner

compared to when no apparatus and experiment is used at all. However, it is a common knowledge that many science teachers in Ghana find it difficult improvising apparatus for some topics in the general science syllabus at the Junior Secondary School and the Senior Secondary School levels, especially chemistry topics. One of such chemistry topics is the atom in relation to formation of ions, compounds, molecules and balancing of chemical equations.

According to Baja and Godman (1984) an element is a substance that cannot by any known chemical means be split into two or more simpler substances. Elements are made up of atoms. An atom is the smallest particle of an element that can take part in chemical reaction (Andrew and Rispoli 1991). The electrons are in constant motion round the nucleus. The nucleus is made up of the protons and neutrons. The number of protons in an atom is equal to the atomic number, which is equal to the number of electrons. Atomic number of an element is the number of protons in an atomic nucleus. Therefore atomic number tells the number of electrons in a neutral atom and the numbered position of the element in the periodic table. The number of neutrons in the nucleus can be worked out from the atomic number and mass number. The mass number of an atom is the number of protons plus neutrons in the nucleus. Electron energy levels are called electron shells (Andrew and Rispoli, 1991). Consecutive shells are formed round the nucleus with increasing energy outside.

The lowest energy level is that which is nearest to the nucleus (Kneen, Rogers and Simpson, 1984). These are some of the fundamentals of chemistry constituting part of the Junior Secondary School syllabus and the understanding of them can propel students to take interest in the subject at the higher levels of learning. Contrarily, since teachers can hardly improvise apparatus to teach these topics, the teaching is most often in abstract form and makes the understanding for students difficult. As a result students generally shy away from general science in the Junior and Senior Secondary Schools as well as chemistry in the Senior secondary Schools. In an attempt to reverse the trend and make students take interest in atoms and its related subtopics as well as general science and

chemistry as a whole this project was designed to find out if locally fabricated models of the atomic structure will contribute towards students understanding of the topic. Thus, the project found out whether less expensive locally available materials could be used to make models of the atomic structure. It also found out whether the models made could be used to explain the atomic structure, formation of ions, compounds, and molecules as well as balancing of equations in junior secondary schools. The project also found out how the models could contribute to the understanding of the topics when they were used in teaching the topics and students views about them.

METHODOLOGY

EXPERIMENTAL PROCEDURE

Atoms

A cardboard or plywood was cut into rectangular or circular shape. Nylon or twin thread of a particular colour was cut and pasted in a circular form in the middle of each board. A piece of hook loop (sticker) was cut into pieces and glued inside the circular thread with the adhesive part of the sticker upward. Canes of diameter 1.5 to 2 cm were cut into pieces 1cm long. The cane pieces were divided into two sets. One set was painted green and the other set painted brown. Since the atom is made up of electrons (which are negatively charged with charge of -1), protons (which are positively charged with a charge of $+1$), and neutrons (which have no charge and therefore they are electrically neutral) the green pieces were used as the protons whilst the brown pieces were used as neutrons in an atom. White paint was used to write positive (+) sign on all the green cane pieces. The second half of the hook loop (sticker) mentioned earlier was cut into pieces and glued on both the green and brown cane pieces with the adhesive part of the stickers outside. With the aid of the sticker, the green and brown cane pieces were put in position in the middle of the circular thread. This represents the nucleus of the atom made up of protons and neutrons (Plate 1a).

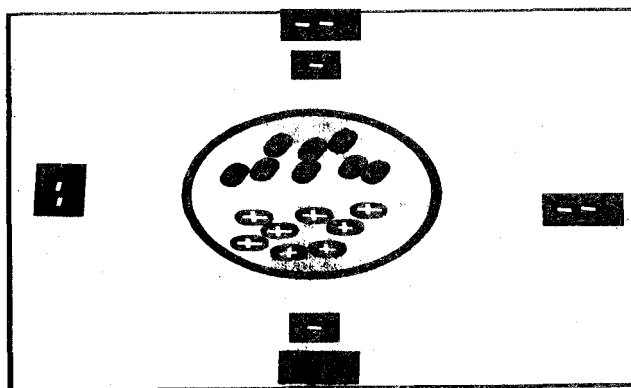


Plate 1a: Model of the atomic structure

Another thread with different colour was glued round the nucleus in succession to depict the electron shells. Another cane with smaller diameter (0.5 – 1 cm) than those used for the protons and neutrons was cut into pieces as before. They were painted red and marked negative (-) with white paint. Stickers were pasted on them as in the case of protons and neutrons. Similarly, the other half of the stickers were cut into pieces and glued on the circular nylon threads surrounding the nucleus (Plate 1a).

Now, since the number of protons in the nucleus equals number of electrons surrounding the nucleus of an atom, the number of green pieces of canes in the nucleus is always equal to the number of red pieces on the shell. Thus, a loss of an electron means that there is one extra proton (positive charge and in this case green piece of cane) in the atom than electrons (negative charges and in this case red pieces of cane). Hence the atom will have a charge of positive one (+1). On the other hand, a gain of one electron means that there is one extra electron (negative charge) than protons (+). Hence, the atom shall have a charge of negative one (-1).

The mass number is equal to the sum of protons and neutrons in the nucleus of the atom (i.e. green + brown pieces of cane). Therefore by counting both the green (protons) and brown (neutrons) pieces of cane in the nucleus of the model will give the student the mass number of the atom.

2.1.2 Molecules and compounds

Cardboard materials were cut into the symbols of various chemical elements, equal sign (=), minus sign (-) and positive signs (+). Similarly, cardboards were cut into the shape of figures such as 1, 2,3,4,5 etc. The non-adhesive half of a strip of hook loop (stickers) was glued to the letters, symbols, mathematical signs and figures with the adhesive part exposed. A plywood or cardboard was cut into the shape of a rectangular board 60 cm by 150 cm. The other half of the hook loop (sticker) was stretched and pasted on the rectangular board in straight lines with the adhesive part up. The board was used in the place of a chalkboard. With the aid of the stickers, the chemical symbols, figures and signs were used in writing ions, molecules and compounds (Plate 1b).

The use of the model atomic structure built, the chemical symbols, figures, equal sign, plus and minus signs helped in writing ions and chemical equations. For example, using sodium atom, there are eleven (11) protons (in this case 11 green cane pieces) and eleven (11) electrons (in this case 11 red cane pieces). However, the outermost electron shell contains 1 electron (in this case 1 red cane piece) that is far short of the 8 needed to have a complete outermost electron shell. In this case sodium atom easily loses the single electron (the single red cane piece) in the outer most shell. Since number of protons (in this case green cane pieces) is equal to number of electrons (in this case red cane pieces), this loss means it is left with 10 electrons or negative charges (in this case 10 red cane pieces with negative sign) in the atom whilst there are still 11 protons or positive charges (in this case 11 green cane pieces with positive sign). Thus, there is one extra proton (+ charge) represented by one green cane piece with positive sign with no corresponding electron (- charge) or red cane piece with negative sign. So by picking the symbol of sodium (Na) and sticking it on the board and a single positive sign representing the single extra positive charge pasted at the top right hand corner of the symbol (Na +), this forms a cation. Similarly, chlorine has 17 protons (positive charges), in this case 17 green cane pieces with positive sign and 17 electrons (negative charges), in this case 17 red cane pieces with negative sign. The outermost electron shell contains 7 electrons, in this case 7 red cane pieces with negative sign. Thus, it needs only one electron, in this case one red cane piece with negative sign to have 8 electrons (in this case 8 red cane pieces with negative sign) required in the outermost shell. On gaining this single electron or negative charge, in this case one red cane piece added to become 8, there are now 18 electrons or negative charges, in this case 18 red cane pieces compared to 17 protons or positive charges, in this case 17 green cane pieces with positive sign in the nucleus. Thus, there is one excess negative charge, in this case one red cane piece with negative sign. So, if the symbol of chlorine (Cl) is pasted on the board and the single negative charge (-) is placed in the top right hand corner of it, then chlorine anion (Cl⁻) is formed. Since positively charged and

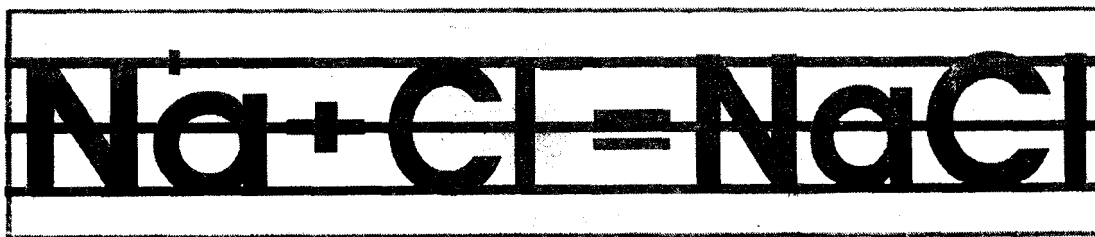
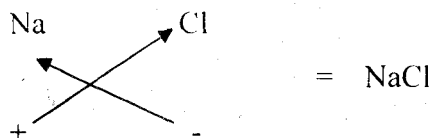


Plate 1b Board for Chemical equations

negatively charged atoms can combine to form a compound, the two ions can come together to form a compound called Sodium chloride (NaCl). Basically, the two atoms presented in plate 1b behaved as in table 1 and exchange charges to form the compound (NaCl).

Table 1: Formation of sodium and chlorine ions

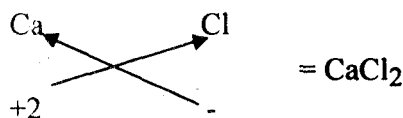
	Sodium atom		Chlorine atom	
	Before Combination	Protons 11	Electrons 2,8,1(i.e. 11)	Protons 17
After Combination	11 Sodium ion , Na ⁺	2,8(i.e. 10) +	17 Chlorine ion Cl ⁻	2,8,8(i.e. 18) -



The model can also be used to demonstrate how other elements come together to form compounds. An example is how calcium (Ca) and Chlorine (Cl) come together to form a compound, Ca Cl₂ as in table 2. Here again an exchange of the ions (valencies) of the two atoms results in the formation of CaCl₂.

Table 2: Formation of Calcium and Chlorine ions

	Calcium atom		Chlorine atom	
	Before Combination	Protons 20	Electrons 2,8,8,2(i.e. 20)	Protons 17
After Combination	20 Calcium ion ++ Ca ²⁺	2,8,8 (i.e. 18)	17 Chlorine ion - Cl ⁻	2,8,8(i.e. 18)



This means that Ca gives its valency 2 (charge of +2) to Cl and Cl gives its valency 1 (charge of -1) to Ca resulting in CaCl_2 . The figures are written as subscripts. When it is +1 or -1, the figure 1 is not written but from +2 or -2 above, it must be written. The subscript 2 against Cl is the valency of Ca.

The equations can also be balanced by pasting the relevant figures on the left hand side in front of the relevant compounds and symbols after the formation of the compounds. According to Holderness and Lambert (1976), equations must be balanced by adding appropriate numbers (coefficients) to the left hand side of the reacting species or compounds concerned, not by attempting alteration of their formulae. In many cases it is trial and error until the balancing is achieved. For example $\text{H}_2\text{S} + \text{SO}_2 = \text{H}_2\text{O} + \text{S}$ can be balanced as follows $2\text{H}_2\text{S} + \text{SO}_2 = 2\text{H}_2\text{O} + 3\text{S}$. These can all be undertaken in class with students in the form of a game or play using the models. Using the models molecules can also be formed such as $\text{Cl} - \text{Cl}$ or Cl_2 or $\text{Cl} + \text{Cl} = \text{Cl}_2$. This means that two chlorine atoms came together to form a molecule of chlorine (Cl_2). Also, two nitrogen atoms (N) can come together to form a nitrogen molecule, $\text{N}-\text{N}$ or N_2 . Hydrogen, Oxygen, Nitrogen and the Halogens exist as molecules containing two atoms when they are not combined with other elements. They are called diatomic molecules. Therefore they are represented in equations as O_2 , N_2 , B_2 , Cl_2 , and I_2 (Hill and Holman, 1989). A molecule is the smallest particle of a substance that can exist on its own (Bajah and Godman, 1984). Later, the teacher can then introduce the students to the presentation of the atomic structure, ions, molecules, compounds and balancing of equations on the chalkboard and in their books.

Trials

The models produced were given out to science teachers in three junior Secondary schools whose students were of similar standard to use in teaching topics concerned. The teaching was done in form two or J.S.S two. The teachers were given common questions on each topic to examine the students on how the models enhanced their understanding of the topics. In each case, two classes were randomly selected. One class was taught without using the model (control) whilst the other class was taught using the prepared model (test experiment). For each class 35 minutes was used during each lesson. After the lessons, the same questions were administered to the two classes (control and test experiment) and the scripts marked by the teachers using the same marking scheme and the marks recorded.

Before the models were used the students were assessed with a set of questions on the topics. This was to find out whatever knowledge they already had about the topics. To be certain that the teachers actually marked the scripts correctly, one fifth (1/5) of the number of scripts in each class was randomly selected by the researcher and crosschecked with the marking scheme. From each class, marks for thirty (30) students were selected randomly for analysis. This was done by giving a number to each student such as 1,2,3,4,5... to cover the number of students in each class. Each number was written on a piece of paper and folded. All the folded pieces of paper bearing the numbers were placed in a plastic bowl, mixed up and thirty selected without replacement with intermittent mixing. The pieces of paper were then opened up and the corresponding mark recorded. Qualitative analysis of the views of 126 students who participated in the lesson in which the models were used was done after random sampling.

Analysis of results

The frequency of marks and their percentage frequencies within certain range in relation to the Ministry of Education grading system for Junior Secondary schools were calculated. Thus:

Grade A⁺ → 90 – 100% = Distinction.

Grade A → 80 – 89% = Excellent.

Grade B⁺ → 70 – 79% = Very Good.

Grade B → 60 – 69% = Good.

Grade C⁺ → 55 – 59% = Credit.

Grade C → 50 – 54% = Satisfactory.

Grade D → 40 – 49% = Weak.

Grade E → 35 – 39% = Very Weak.

Grade F → 0 – 34% = Fail

Percentage frequencies obtained were used to draw graphs. The mean percentage marks obtained by students were also calculated. The mean values for control and test experiments were then compared by using independent t-test

RESULTS AND DISCUSSION

Teaching Results

From the preliminary results (Table 3), it is clear that few students obtained marks above 40%. This implies that many of the students did not have any prior knowledge or had little prior knowledge of the topics before they were taught.

Table 3: Mark per number of students before the topics were taught.

SCHOOL	SAMPLE SIZE (N)	MARKS BELOW 40%	MARKS ABOVE 40%
A	60	81.67	18.33
B	60	73.33	26.67
C	60	75.00	25.00

SCHOOL A

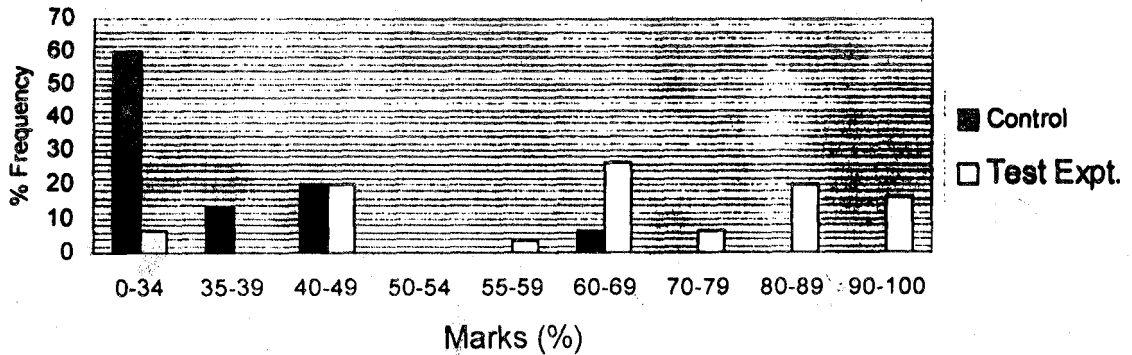


Fig. 1a: Percentage Frequency of Marks

SCHOOL B

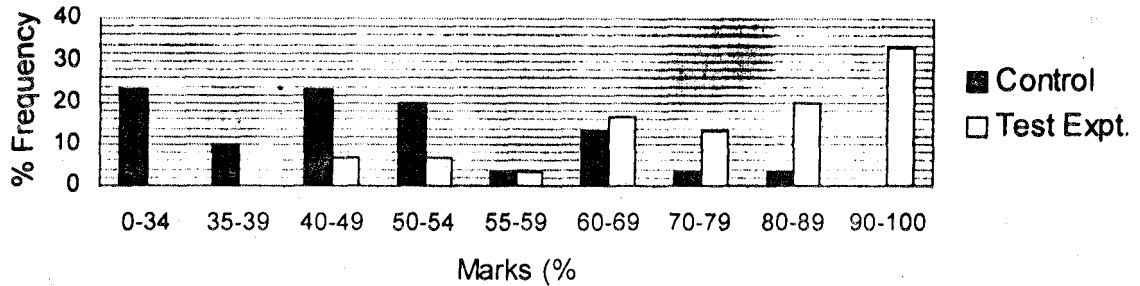


Fig. 1b: Percentage Frequency of Marks

SCHOOL C

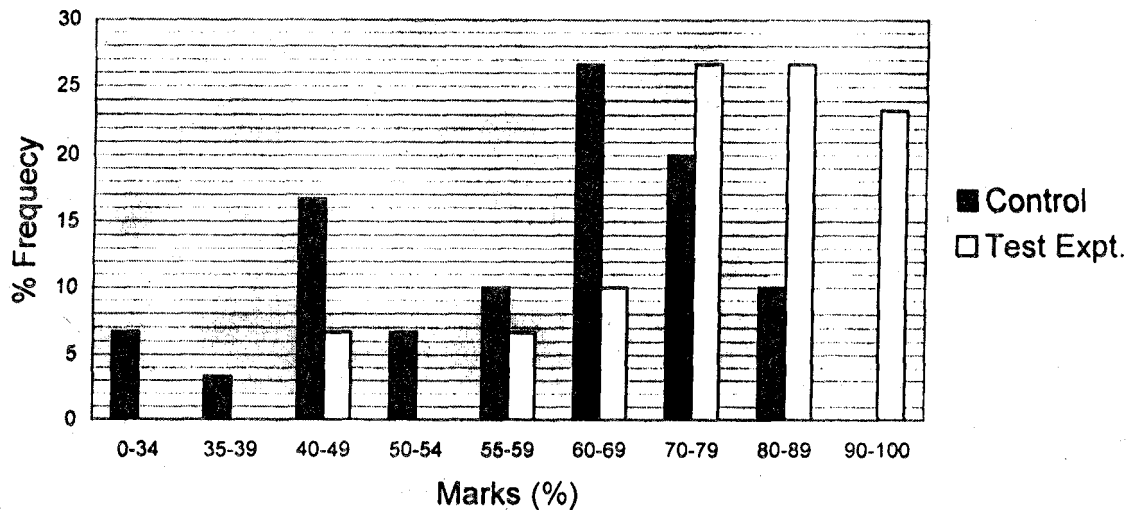


Fig. 1c: Percentage Frequency of Marks

Nacino-Brown, Oke and Brown (1992) observed that if a teacher wants to teach effectively, he/she is bound to make use of a variety of instructional materials. They further stated that models are visual three-dimensional materials that make meaning of the words of teachers in the course of teaching. For school A, there was neither distinction nor excellent recorded when the models were not used. However, 16.67% distinction and 20% excellent were recorded when the models were used (Fig 1a). This suggests that the models enhanced the understanding of the topics when they were used. Since objects and specimens are real things they provide direct first-hand experiences that are necessary for concentration. Students can see, touch, smell or even taste them, hence giving them a richer and more meaningful understanding of the things being learned.

Table 4: Mean percentage marks after the use of the models

SCHOOL	CONTROL	TEST EXPT	t-TEST
A	28.30	67.60	7.46 ***
B	42.10	77.37	8 ***
C	59.73	78.47	4.82 ***

Tabulated t-values:

2.05 (P = 0.05) *

2.76 (P = 0.01) **

3.69 (P = 0.001) ***

However, if the real thing is not available, too large to take to the class, or too small for the naked eye to see, or too dangerous for the students to manipulate, the use of models is very advantageous (Nacino-Brown, Oke and Brown, 1992). The control experiment recorded 60% failure whilst the test experiment recorded 6.67% failure. The difference between the means (Table 4) is very highly significant ($t = 7.46$, $P < 0.001$). Petty (1993) stated that the verbal channel of communication is the one most used in teaching, but for many purposes visual information is more effective. He observed that the main advantages of visual aids include more attention from students, they add variety and interest, they aid concentration and memory and their preparation shows to students that the teacher takes their learning seriously. Models and real objects bring the world into the classroom and hence promote understanding of the subject matter. In school B, 23.33% of students failed when the models were not used whilst test experiment recorded no failure. Also, control experiment recorded 0% distinction and 3.33% excellent whilst test experiment recorded 33.33% distinction and 20% excellent. The difference between the means was very highly significant ($t = 8$, $P < 0.001$) (Fig 1b and Table 4).

In the case of school C, 0% distinction and 10% excellent were obtained when the models were not used whilst 23.33% distinction and 26.67% excellent were recorded when the models were used. Whilst 6.67% failed in the class in which the models were not used, no student failed in the class

in which the models were used. The difference between the means was very highly significant ($t = 4.82$, $P < 0.001$) (Fig 1c and Table 4). It can again be argued here that the models enhanced the understanding of the topics when they were used compared to when they were not used.

The means (Table 4) also show that students in school C are generally very good followed by school B and then school A. Nacino-Brown et al (1992) stated that the greatest single factor in the teaching process is the teacher. No technique, no method no device, no gadget can guarantee success – only the teacher can do this. Croll and Nigel (1997) also observed that good management of appropriate resources could undoubtedly enhance learning. Building a higher-level task into the curriculum in all subjects demands much of an individual teacher. It is important therefore to create a network of support and bank of resources of materials and ideas. These observations suggest that differences in performance in the various schools may be due to how effective the teachers were in handling the topics in their respective schools. However, the intellectual abilities of the pupils may also be a factor.

Interview Results

In the words of Nacino-Brown, Oke and Brown (1992), the selection, utilization and evaluation of instructional materials require professional skills that can only be acquired through training and practice. Hence, in order to find out if the teachers had effectively put the models into use during the lesson, students were asked to give their opinion about how the models were used in class. The main concern of the students was that though the teachers used the models very effectively in demonstration lessons, they did not have enough practice with the models because there was only a single copy of each. This confirmed the assertion made by Nacino-Brown, Oke and Brown (1992) that students should be given the opportunity to handle and examine the materials being studied. As such teachers should plan for students' participation. When asked what students found good about the models, they intimated that 'the models made the lesson a fun', 'they enhanced the understanding of the topics', 'they made the lesson very interesting', and 'they allowed the teachers to undertake easy demonstration'. Castle (1993) stated that visual aids appeal to the eye and aural aids appeal to the ear. However, both appeal to the understanding and are essential in teaching. Garg and Garg (2001) also observed that scientific projects and models are an important and integral part of science education. Projects and models induce the young minds to develop scientific temper and harness their skills. Whilst working on these models, the student grasps the basic principles of science behind the working of each of them. In this study the students claimed that the models instilled in them skills of observation, practice, thinking, and drawing of inference. They however observed that they would have preferred that the electrons in the model move round the nucleus in a circular fashion automatically. They also said that the cards used in preparing the models were not durable enough. They went on to suggest that more durable materials

should be used and they should be involved in preparing the models. Sharma (2001) observed that low cost teaching materials are useful because the raw materials are easily available and their preparation does not involve any specialized skills and can be made by pupils, teachers and members of the community. Majority of the students (86.51% i.e. 109 out of 126 respondents) said they recommend the models for use as science teaching resources because such models can help them to develop interest in science and contribute to their understanding of topics. It will also take the abstract part of teaching science without any teaching aids. This confirms the point made by Bhandula, Chadha and Sharma (1999) among others that improvisation develops skill and basic principles, enhances longer retention and scientific thinking.

RECOMMENDATIONS

The results showed that the models largely contributed towards better understanding of the topics taught. Hence, it will be helpful if the technique involved in the preparation and use of the models can be extended to basic level teachers all over Ghana. Since, the students suggested some modifications, then there is the need to make such changes and try the models for number of times before fully disseminating the ideas behind them. Since females are generally scared by science it will be necessary to compare the performance of males and females next time that the models are tried. Also, there is the need to involve the students in the preparation of the models. This will serve as a challenge to them to practice using the models at home before coming to school.

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