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Build-it-Yourself Atomic Modeling Kit: Development of a Low Cost Atomic Modeling Kit Using Waste Material for Middle and Upper Level School Students

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ABSTRACT

To understand most of the chemistry concepts, it is essential to have an adequate knowledge on the three-dimensional arrangement of atoms in compounds. Since molecules and polyatomic ions have specific three-dimensional shapes, students often find it difficult to visualize the molecular geometry with the abstract concepts. It can be observed that without providing the vital educational tools such as atomic models and personal computer based modeling software, it is difficult to achieve the desired objectives of teaching some concepts in chemistry. Molecular modeling kits are hardly available in schools and in open market in Sri Lanka and most other developing countries. These two issues are identified as difficulties faced by Sri Lankan students studying chemistry in urban and rural areas. This study explains the development of a build-it-yourself low cost atomic modeling kit using waste material. This proposed build-it-yourself atomic modeling kit can be built by students themselves with a minimum effort. These atomic model based class room teaching practices allow students to visualize and understand spatial arrangement of atoms for given molecules. Also, the use of waste material generated in the classroom help students to understand the ways they can contribute to minimize the environmental pollution.

KEYWORDS
atomic modeling kit, waste, low cost, build-it-yourself

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Introduction

In the current Sri Lankan education system students face extremely competitive examinations at the end of grade 11 and grade 13 classes. The majority of students decide the subject stream they will be following in grades 12 and 13 based on examination results at the end of grade 11. Even though Chemistry is not offered as a separate subject in this examination, it is a major component in the Science curriculum in grades 9, 10 and 11. The eligibility of a student to apply to a Sri Lankan state university is decided based on the outcome of the examination set at the end of grade 13. Students studying under Biological Science and Physical Science streams in grades 12 and 13 must study Chemistry as a compulsory subject. Concepts and applications related to bonding,

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geometry and resonance structures of inorganic and organic molecules covers a major component of the grade 12 Chemistry curriculums.

Learning outcomes of some of these topics include analysis of primary interaction of polyatomic system to determine the bonding patterns, resonance structures and shape, synthesis of structure and geometry of a given molecule and evaluation of a given system to propose resonance structures for inorganic and organic molecules. However, due to the inability to visualize the three dimensional spatial arrangement of atoms in these molecules (Springer, 2014), students face many difficulties in achieving the expected outcomes. To overcome this issue, class room activities based on atomic models can be introduced (Smiar & Mendez, 2016). Use of atomic models to understand the valence shell electron pair repulsion (VSEPR) theory is a highly effective method (Pfennig & Frock, 1999). Also it helps students to visualize the three dimensional arrangement of atoms in these molecules based on the VSEPR theory (Pfennig & Frock, 1999). Even though activities based on atomic models are identified as an answer for this issue, the unavailability and the cost of such kits make it impossible to implement these methods in Sri Lanka.

Use of commonly available materials to build atomic models for school activities is previously reported (Cipolla & Ferrari, 2016). However, these models do not have the options to indicate the nonbonding electron pairs. The model and the activity reported in this paper are based on common waste material found in a school setup such as empty ball point pens and waste paper. Proposed methodology allows students to have their own atomic modeling kit, which can be used throughout their school life. Since this proposed kit can be built with zero cost, any school teacher in a developing country can adopt this to make atomic modeling kits available for students. The kit can be built by students themselves; also they can add more atoms later based on the activity. This activity can also be used to make awareness among students about the proper management of waste generated in schools.

Aim of the study

Design a build-it-yourself low cost atomic modeling kit using stationary waste material to make atomic modeling kits available among Sri Lankan school students.

Problem statement

Inaccessibility of atomic modeling kits to school students due to cost and unavailability of such models in the open market have hindered quick learning of chemical concepts related to spatial arrangement of molecules.

Method

Waste material such as used ballpoint pens, newspapers, color papers, yoghurt spoons, and steel wire are used as the raw materials. Protractor, ruler, scissor, binder glue and a compass were also used as accessories to build the atomic modeling kit.

Used newspapers were crumbled into perfect spherical shaped balls of two sizes to build the core of the atoms. Then each ball was covered with an extra layers of paper soaked with glue to obtain a perfect spherical shape. This step was repeated until the desired size was obtained. Smaller paper balls were used as the hydrogen atom and paper balls with larger radii were used as carbon and other heteroatoms such as oxygen and nitrogen.

Development of hydrogen atoms

A back side cap of a used ballpoint pen was inserted in to the selected spherical shaped paper balls. The back side cap has a space perfectly fitting with the empty ink tube of the ballpoint pen which is used as the bonding connectors. After the back cap is connected to the paper balls, more layers of paper were applied around the spherical shaped object to connect the cap firmly to the object. Developed hydrogen atom is shown in Figure 01. Finally the object was wrapped with white tissue papers to provide the correct color of the hydrogen atom.

Figure 1. Hydrogen atom developed using waste paper with one connecting pad made with one back side cap of an empty ballpoint pen.

Development of atoms with multiple valances

A ring shaped cardboard stencil was used to identify the places to insert the back cap to develop the atoms with multiple valences as shown in Figures 02. Atoms with four bonds connected in tetrahedral orientation was developed using a piece of cardboard created to represent the bond angle of 109.5°. Atoms with six bonds in octahedral arrangement was developed using the cardboards stencil shown in Figure 03.

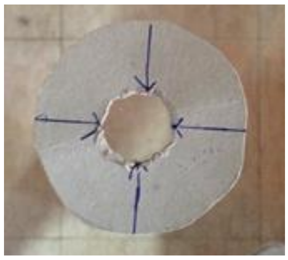
a  b  c 

Figure 2. Cardboard stencils used to mark 180°, 120° and 90° angles on atoms to develop connecting pads.

An atom that has 6 connection pads with 90° angle among each connection pad (octahedral arrangement) is shown in Figure 03. This was developed using the 90° cardboard stencil.

Figure 3. An atom with 6 connection pads with 90° angle among each connection pad.

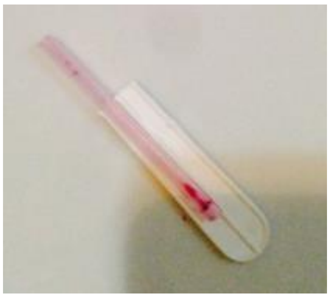
Empty ballpoint pen tubes were used to build the bonding connectors with proper length to represent sigma bonds. These bonding connectors properly connect with the back caps of the pens on the atoms. The number of connecting pads and the color of each type of atoms are given in Table 01.

Table 1. Number of the connecting caps and the color of each type of atom

Atom	Color	Number of connecting holes	Angle between connecting pads (degrees)
Be	Dark green	2	180
B	Gray	3	120
C	Black	4,5,6	109,120/180,90
N	Dark blue	4,6	109,90
O	Red	4, 5	109
P	Orange	5	120/180
S	Yellow	6	90
F	Green	4	109
Cl	Purple	4	109
Xe	Pink	6	90

A yoghurt spoon attached to a piece of the ink tube of an empty ballpoint pen as shown in the Figure 04-a, was used to represent a nonbonding electron pair. Metal wires bent from both ends connected to two pieces of empty ballpoint pen ink tube as shown in Figure 04-b was used to represent pi-bonds.

a



b

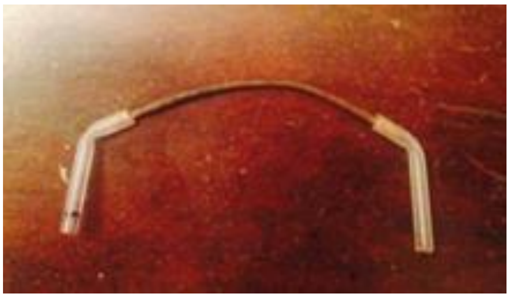


Figure 4. a- A non-bonding electron pair is represented using the handle of a yogurt spoon connected with an empty ballpoint pen ink tube, b- a pi-bond is represented using a bent metal wire connected with two pieces of empty ballpoint pen ink tubes.

These atoms, sigma and pi-bond connectors and nonbonding electron pairs were used to build various molecules. Molecular structures of ethylene and ammonia built using this low cost atomic modeling kit are shown in Figure 05.

Activity

Two grade 12 student groups were selected for the study. One group of students (n = 44) was provided with these low-cost atomic modeling sets and the topics such as molecular structure, shape of the molecule and hybridization were discussed with demonstration. Students were allowed to use the model to build various atomic models as a group activity. The same topics were discussed with the second group (n = 42) without providing low-cost atomic modeling sets. A questionnaire developed on the discussed sections was given to students of both groups to evaluate the knowledge on the topics discussed in the class. The questionnaire is based on a complex organic molecule and the students were instructed to answer questions based on the hybridization and geometry of two polyatomic ions and four molecules. The score of the questionnaire was recorded for all the students in both groups and Student-t test was used to analyze data statistically. Feedback from students and teachers were collected and used to evaluate the proposed low cost atomic modeling kit based teaching method.

a b

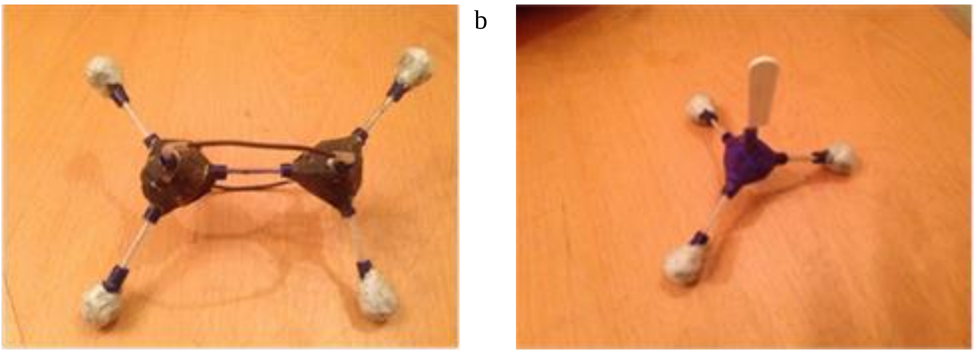


Figure 5. a- An ethylene molecule built using two carbon atoms, 4 hydrogen atoms and two pi-bond connectors to represent one pi-bond, b- an ammonia molecule build with one nitrogen atom, three hydrogen and one non-bonding electron pair .

Results

The average score of the group that used the developed atomic models was 36.3 with a standard deviation of 8.1, and the average score of the control group with no modeling kits was 27.4 with a standard deviation of 13.3. Questionnaire scores were statistically tested using Student-t test at 95% limit. There is a significant difference between the test scores of two groups. Feedback from the students was also used to evaluate the effectiveness of the proposed atomic modeling kit in classroom teaching. Students supplied with a modeling kit provided a positive feedback towards the use of activity based teaching for the selected sections. Since these modeling kits were developed using waste material commonly found in schools, students start to show interest uncover other ways to reuse waste materials . Also students showed interest to understand the possible other methods that can be used to recycle common waste materials found in homes. Teachers reported that the use of build-it-yourself atomic modeling kit can help students to visualize and decide the special arrangement of atoms for given molecules using VSEPR theory.

Conclusions

The method proposed to build a low cost atomic modeling kit based on waste materials can be developed easily. This model can be used as a teaching tool at any level by adding extra components such as non-bonding electron pairs and extra atoms. Based on the statistical test results it can be concluded that this proposed low cost atomic modeling kit can be used to improve the student knowledge significantly compared to using the traditional teaching methods.

Disclosure statement

No potential conflict of interest was reported by the authors.

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