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The Chemistry Textbooks used by Ninth-Grade Venezuelan Students as Possible Sources of Misconceptions About The Structure of Matter

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ABSTRACT

Science textbooks are a major component of any curriculum and have an important influence on learning processes. Unfortunately, it has been found that many of these resources do not present some of the aspects that should characterize a good science textbook. The purpose of this study was to analyze the scientific quality of the contents and diagrams about the structure of matter that appear in chemistry textbooks used by ninth-grade venezuelan students. It was examined the exactitude and accuracy of : a) the most important concepts and ideas about atoms and molecules; b) the illustration of Rutherford-Bohr's nuclear model and c) the illustrations related to the arrangement of particles in the states of matter. Several inaccurate and imprecise concepts, ideas and illustrations were found. Therefore, these chemistry textbooks could lead students to construct erroneous ideas about the structure of matter.

INTRODUCTION

Science textbooks play an important role in science teaching. These instructional materials influence both how and what the students learn (Chiappetta, Fillman and Sethna, 1991a; Hamm and Adams, 1988).

In Venezuela, textbooks are, in many cases, the fundamental guides of the classroom's activities. They condition the objectives, contents and activities developed in the school , and they frequently are the only source of information that students and even teachers have (Lacueva and Manterola, 1991).

Gabel (1983) states that in the case of chemistry teaching this excessive dependence on textbooks is even greater "... as less qualified teachers replace highly competent retiring chemistry teachers ...".

Chemistry textbooks often do a superficial treatment of the subject matter. They "... mention ideas but do not develop them adequately around the models that scientists used to form these concepts." (Chiappetta, Fillman and Sethna, 1991b). This treatment of the topics is so superficial that students do not learn chemistry, they just memorize vocabulary (Gabel, 1983).

As Herron (1983) points out, science textbooks frequently "...perpetuate poor pedagogical practice."

THE PROBLEM

The particulate theory of matter is among the topics which play a fundamental role in chemistry. Nevertheless, the atomic and molecular level implicates a lot of difficulties to most of the beginning chemistry students.

Some of the difficulties are those related to the communication of concepts and ideas. Chemists shift easily from macroscopic and concrete phenomenons, to the invisible and abstract world of atoms and molecules. And all this is done using a language plenty of chemical formulas and equations. Teachers and textbooks usually go from one level to the other in a very short time. But most of the students are not able to follow these big jumps. So the conceptual and communicational demands placed on learners are difficult to reach (Ben-Zvi, Eylon and Silberstein, 1988; Johnstone, 1982).

Besides this communicational problem, it is well known that students of all ages struggle to understand and use the particulate theory of matter. Many of the difficulties that beginning chemistry students have in the study of fundamental chemical concepts lay on their misconceptions about atoms and molecules (Ben-Zvi, Silberstein and Manlok, 1990; Nakhleh, 1992). There is an accumulating body of research data which shows this situation.

Some of the misconceptions found by researches are:

- Atoms and molecules are not matter because they cannot be touched and weighed (Andersson 1990).

- Atoms and molecules change in size and weight when changing phase (Ben-Zvi, Eylon and Silberstein, 1986; Griffiths and Preston, 1992).

- Molecules do not have empty spaces between them (Mitchell and Kellington, 1982; Novick and Nussbaum, 1978).

- There is not an intrinsic motion of particles (Mitchell and Kellington, 1982; Novick and Nussbaum, 1978).

It is important to say that some of these misconceptions persist even among university students.

Now, until what extension textbooks can reinforce these ideas ?

De Vos and Verdonk (1987) say that some textbooks confuse the categories "substance" and "molecule", describing a molecule "... as the final result of a lengthy clavage procedure ". So, these textbooks explain that if we split a drop of water again and again, a water molecule will be the final result. Following this way of thinking, the students can conclude that a water molecule has all the characteristics of water (freezing point, boiling point, density, etc.).

Scientific diagrams are other important tools to make the abstract ideas in science more concrete. Furthermore, "... diagrams mediate in the development of student's understanding of ideas and concepts in science ." (Wheeler, Hill and Oludotum, 1991).

It has been found that diagrams related to the arrangement of particles may mislead chemistry students. For example, illustrations designed to explain phase changes and dissolving processes may lead to misunderstandings about the actual number, size and relative shape of the particles, and the relative spacing between particles in solid, liquid and gaseous phases (Wheeler and Hill, 1990; Wheeler, Hill and Oludotum, 1991).

These same authors state that students fail to make the distinction between models as mental inventions, and the diagrams used to represent them. Furthermore, students are not always aware of the conventions used in scientific diagrams and their limitations.

PURPOSE

The purpose of this study was to analyze the scientific quality of the content and diagrams about the structure of matter that appear in chemistry textbooks used by ninth-grade venezuelan students. It was examined the exactitude and accuracy of: a) the most important concepts and ideas about atoms and molecules, b) the illustrations of Rutherford-Bohr's nuclear model and c) the illustrations related to the arrangement of particles in the states of matter.

PROCEDURE

A survey was applied at 12 bookstores in the city of Caracas, in order to determine which ninth-grade chemistry textbooks were the most often adopted by the schools. As a result, 6 textbooks were selected for the study.

The most important ideas and illustrations about the structure of matter were analyzed, to establish their exactitude (information free of mistakes) and accuracy (information without ambiguity).

RESULTS AND DISCUSSION

Scientific Quality of Concepts and Ideas About Atoms and Molecules:

These are some of the ideas included in the analyzed textbooks that bear some mistakes or ambiguities about the structure of matter:

1. Evidences for the existence of atoms:

Four textbooks present diffussion of gases and the persistence of a pink colour when potassium permanganate is repeatedly diluted, as "clear evidences" for the existence of atoms.

As Wright (1981) says, the only thing that these experiments show about atoms is that "... if they exist, they must be extremely small."

2. Properties of molecules:

Five textbooks describe a molecule as the final result of successive divisions of a piece of substance. So, these books define a molecule as " the smallest part of a substance which carries all the properties of that substance ".

Following such definition, students can think that a molecule has macroscopic properties.

3. Elementary particles:

Atoms are described as the smallest material particles, in two of the analyzed textbooks.

4. Shape of the molecules:

Two books describe molecules as spherical particles, without making clear that this is just a simplified model

5. Mass of the atoms:

In three of the textbooks, the concept of " mass number " and " atomic mass " are confused, defining the atomic mass as the number of protons plus the number of neutrons.

6. Ions:

Two textbooks define an ion as an electrically charged atom, discarding the polyatomic ions.

Scientific Quality of Diagrams:

1. Illustrations of Rutherford-Bohr's atomic model:

In four of the six textbooks, there is a kind of illustration which confuses electronic orbits with electronic levels. Students could think that an orbit can have more than two electrons.

In two textbooks, another kind of illustration shows an external circumference which should be an electronic orbit, but the electrons surprisingly are represented in the internal area. So, what does the external circumference represent ?

2. Illustrations of solid, liquid and gaseous states:

The next details were found in some of the six textbooks:

- Particles do not present an ordered arrangement in the solid state (two textbooks).
- The spacing between particles in the liquid state is almost the same than that in the gaseous state (Three textbooks).
- Particle size does not remain constant when substances undergo changes from one state to another (two textbooks).

CONCLUSIONS

1. These chemistry textbooks may lead learners to construct or reinforce erroneous ideas about atoms and molecules. For example, students may think that molecules have macroscopic properties or they may believe that atoms are elementary particles.

2. Illustrations of the Rutherford-Bohr's atomic model may generate misunderstandings about its main characteristics.

3. Illustrations of solid, liquid and gaseous states may contribute to the reinforcement of erroneous ideas about the arrangement, relative spacing and relative size of particles.

For all these reasons, these chemistry textbooks may act as sources of misconceptions about the structure of matter.

REFERENCES

Andersson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). In Linjse, P.L., Licht, P., de Vos, W. and Waarlo, A. J. (Ed.), *Relating macroscopic phenomena to microscopic particles: a central problem in secondary science education* (pp. 12-35). Utrecht: The CD- 8 Series on Research in Education. University of Utrecht.

Ben-Zvi, R., Eylon, B. and Silberstein, J. (1986). Is an atom of copper malleable ?.*Journal of Chemical Education*. **63** (1), 64-66.

Ben-Zvi, R., Eylon, B. and Silberstein, J. (1988). Theories, principles and laws.*Education in Chemistry*. May, 89-92.

Ben-Zvi, R., Silberstein, J. and Mamlok , R. (1990). Macro-micro relationships: a key to the world of chemistry. In Linjse, P.L., Licht, P., de Vos, W. and Waarlo, A.J. (Ed.), *Relating macroscopic phenomena to microscopic particles: a central problem in secondary science education*. (pp. 183-197). Utrecht: The CD-8 Series on Research in Education. University of Utrecht.

Chiappetta, E., Fillman, D. and Sethna, G. (1991a). A method to quantify major themes of scientific literacy in science textbooks. *Journal of Research in Science Teaching*. **28** (8), 713-725.

Chiappetta, E., Fillman, D.and Sethna, G. (1991b). A quantitative analysis of high school chemistry textbooks for scientific literacy themes and expository learning aids. *Journal of Research in Science Teaching*. **28** (10), 939-951.

de Vos, W.and Verdonk, A. H. (1987). A new road to reactions. Part 4.The substance and its molecules. *Journal of Chemical Education*. **64** (8), 692-694.

Gabel, D. (1983). What high school chemistry texts do well and what they do poorly. *Journal of Chemical Education*. **60** (10), 893-895.

Griffiths , A. and Preston, K. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Scince Teaching*. **29** (6), 611-628.

Hamm, M. and Adams, D. (1988). How science, technology and society issues are presented in science textbooks. *Educational Research Quarterly*. **12** (2), 30-35.

Herron, J.D. (1983). What research says and how it can be used. *Journal of Chemical Education*. **60** (10), 888-890.

Johnstone, A. H. (1982). Macro and microchemistry. *The School Science Review*. **64** (227). 377-379.

Lacueva, A. and Manterola, C. (1991). *Textos y escuela* . Caracas: Fondo Editorial de Humanidades y Educación. UCV.

Mitchell, A. C. and Kellington, S. H. (1982). Learning difficulties associated with the particulate theory of matter in the Scottish Integrated Science course. *European Journal of Science Education*. **4** (4), 429-440.

Nakhleh, M. B. (1992). Why some students don't learn chemistry. *Journal of Chemical Education*. **69** (3), 191-196.

Novick, S and Nussbaum, J. (1978). Junior high school pupils' understanding of the particulate nature of matter: an interview study. *Science Education*. **62** (3), 273-281.

Wheeler, A. E. and Hill, D. (1990). Diagram-ease. Why students misinterprete diagrams. *The Science Teacher*. **57** (5), 58-63.

Wheeler, A. E. , Hill, D. and Oludotum, J. (1991). Chemistry diagrams: a cross cultural study within a constructivist framework. *Science Education International*. **2** (4), 7-11.

Wright, P. G. (1981). Evidence and non-evidence for the existence of atoms and molecules. *Education in Chemistry*. **18** (3), 74-75.