STUDENTS' ABILITIES OF READING IMAGES IN GENERAL CHEMISTRY: THE CASE OF REALISTIC, CONVENTIONAL AND HYBRID IMAGES

Tamara N. Rončević
University of Novi Sad, Republic of Serbia
E-mail: tamara.hrin@dh.uns.ac.rs

Željka Đ. Ćuk
Osnovna škola "Sever Đukić", Republic of Serbia

Dušica D. Rodić, Mirjana D. Segedinac, Saša A. Horvat
University of Novi Sad, Republic of Serbia
E-mail: dusica.milenkovic@dh.uns.ac.rs

Abstract

This research deals with students' abilities to read chemistry textbook images about dispersed systems. Secondary school students were included as the research participants, and their abilities to propose the titles of the realistic, conventional, and hybrid textbook images about dispersed systems, were analyzed. Additionally, their written interpretations about images contents were also analyzed. The collected data provided information about students' misunderstandings about dispersed systems. These misunderstandings, some of which are the original outcome of this research, provided the significant results. In addition, it was found that students had the most difficulties with reading realistic textbook images. Namely, they relied on what they literally saw on the realistic image (i.e. photography) without providing proper connection with chemical contents about dispersed systems.
Keywords: *visual representations, reading images, images types, general chemistry*.

Introduction

The visualizations play an important role in both science and science education. According to Gilbert (2010), visualizations, or more precisely visual representations exist in two different forms: internal and external. Internal visual representations (IRs) enable students to retrieve information from long term memory to solve problems, make decisions, etc. (Rapp & Kurby, 2008). Namely, IRs are structures in the memory (Zhang, 1997) that can be defined as mental outcome of visual display of an object or event (Rapp & Kurby, 2008). On the other hand, these objects, physical symbols, and dimensions that exist in our environment are external visual representations (ERs) (Zhang, 1997). ERs could be seen with the naked eye (Uttal & O'Doherty, 2008) and they provide the opportunity to us to internally think about abstract phenomena (Eilam & Poyas, 2010). Certainly, in chemistry education, students are faced with many abstract concepts. Henceforth, there are lots of possibilities for the application of various ERs, such as pie, line, or bar graphs, maps, molecular models, drawings, and photographs.

In this research one particular type of ERs, the textbook images, were of special interest. In the science education literature, many researchers conducted autonomous analysis of the images presented in the textbooks. For example, Dimopoulos, Koulaidis, and Sklaventi (2003) noted the classification of images by type and function. Regarding their type, images were characterized as realistic, conventional and hybrid. The realistic images represent reality in accordance with the human optical perception (e.g. drawings and photographs). Conventional images represent reality in a codified way, and they are constructed observing the techno-scientific conventions (e.g. graphs, maps, two-dimensional representations of molecular models). They are important for a scientific writing. At the end, hybrid images are combinations of elements from both realistic and conventional images.

Apart from the autonomous analysis of the textbook images, there are studies that were conducted in order to investigate students' ability to "read" images. Colin, Chauvet, and Viennot (2002) investigated students' difficulties in reading images in optic, as well as teachers' awareness of those difficulties. For the purpose of the study, they used textbook images along with the corresponding text elements. In some studies, the authors looked at textbook images in order to design own images particularly for the research. Ametller and Pintó (2002) developed theoretical semiotic framework in order to investigate secondary school students' interpretations of images about energy. These authors found that specific features of science images can cause difficulties for students while reading images, for example, the polysemic use of the arrows.

The present research focused on secondary school students' abilities to read images, analyzing two aspects: (i) proposition of the image title, and (ii) interpretation of the image content. In order to verify how usage of image can help chemistry learning in classroom, it was decided to use textbook images. Therefore, the following research tasks were defined:

(1) Analyze students' abilities to propose the title for the set of realistic, conventional, and hybrid textbook images.
(2) Analyze students' abilities to interpret the content of the realistic, conventional, and hybrid textbook images.
(3) Analyze students' misunderstanding while reading images.

Research Methodology

Study Participants

103 students (37 males, 63 females, and 3 unknown) from four classes of one grammar school from Novi Sad, Republic of Serbia, participated in this research. All of the students were enrolled in the first grade of grammar school and were 15-16 years old. Students were taught by the same chemistry teacher who holds a Master's degree. According to the evaluation, at the end of the first semester of the first year, 52% of students had excellent achievement in general chemistry, 39% had very good achievement, 7% had good achievement, and 2% had satisfactory achievement.

Context of the Study and Study Instrument

The research was conducted in the second semester of the first grade of grammar school in the 2017/2018 school year. For the purpose of the research, one teaching theme from general chemistry was chosen: “Dispersed systems”. In order to examine students’ abilities to read images in a chosen theme, it was decided to use textbook images. The recommended and one of the most used textbooks (“General Chemistry 1: Textbook for first grade of secondary school”) was chosen (Nedeljković, 2016). It was seen that selected theme includes 18 images in total, of which 8 realistic, 2 conventional, and 8 hybrid. In the process of choosing images for examination, were included: one full professor and two assistant professors in the field of Chemistry teaching, and one master student who were profiled to be chemistry teachers. Henceforth, 2 realistic, 2 conventional and 2 hybrid images were included in the knowledge test. All images included in the knowledge test were printed in black-and-white. However, the researcher presented images in original color, one by one, using computer and video projector. This ensured that students could see the content of image more clearly. The knowledge test was conducted on one school class (45 minutes) in May 2018, and students were required to propose the title for each of six images, and then to interpret the content of the image. By that, two types of data were collected: proposed titles of images, and written interpretations of contents of realistic, conventional, and hybrid images.

Data Analysis

The collected data were analyzed qualitatively. Firstly, two researchers analyzed together students’ written answers for each image. Then they developed a table for each image with several categories of proposed titles. Along with each title category, the number of students and corresponding percentages were included in the table. Since six images were included in the knowledge test, six tables were developed. After that, other three researchers carefully analyzed developed tables and each disagreement was solved through the discussion. Since several title categories of images indicated the presence of students’ misunderstandings of observed theme (“Dispersed systems”), the researchers looked into their written interpretations of images contents in order to collect more specific information about such misunderstandings.

Research Results

The first realistic image included in the knowledge test presented *The blue color of the sky as a result of Tyndall's effect.* From the total number of research participants, 19.4% were able to recognize that this realistic image has relation with Tyndall's effect. However, only 7.8% of students could interpret the content of the image in the sense of Tyndall's effect. For example, one student wrote: “Sunlight is scattering on particles in a colloid where a bright spot is on each one, and we see blue light scattered”. In the next category of proposed titles for this image belonged students who observed *Solar radiation*; *Reflection of sunlight*; or *Luminosity.* This category of proposed titles could be acceptable because Tyndall’s effect is related with sunlight. However, when students’ interpretations were analyzed, it was obvious that their proposals of image titles were reflection of what they literally saw on the realistic image. The same could be said for the relatively large group of students who proposed the titles: *Sun in the sky*; *Sun and clouds*; *Cloudiness*. The third group of students proposed the title: *Air as a dispersed system*. To this group belonged the students who proposed the title: *Coarse dispersion*. They believed that air is coarse dispersion where dispersed phase particles are bigger than 100 nm and could often be seen by naked eye. By that, we identified first misunderstanding within our study participants.

The original title of the second conventional image was *Solubility curves of various ionic (solid) substances.* The title that fully matches the one from the textbook was proposed by only one student. Six students proposed very similar titles (*Solubility curves of ionic substances* or *Solubility curves*). However, more than half of the total number of students suggested the correct titles for this conventional image, such as: *A graph of temperature dependence of solubility*; *The influence of temperature on the solubility*; *The solubility of the compounds in 100 g of water at the given temperature*. It was pleased to find that many students have developed crucial skills to deal with visual data presented in the form of graphs, as students will need such skills outside of classroom in everyday life. It is interesting to note that some students mixed this graphic display with a chemical reaction rate graph and with a graph showing the changes in energy in chemical reactions. Also, the small number of students believed that presented conventional image shows chemical equilibrium graph by not observing the fact that the included salts are strong electrolytes that are completely dissociated into ions in aqueous solution.

The title of one hybrid image taken from chemistry textbooks for the first grade of high school is the *Illustrative representation of dissolution of sodium chloride in water*. None of the students proposed a title that would completely fit with the one from the chemistry textbook, while one student proposed a very similar title: *Representation of dissolution of sodium chloride in water*. The most of the students suggested the title *Dissolution of sodium chloride in water* (or just *Dissolution of sodium chloride*, or *Dissolution of salt in water*). Some of the students used the term "dissociation" instead of "dissolution", which is also acceptable. One group of students focused their attention on a separated realistic element (magnifying glass) and on a conventional element (a model of the sodium-chloride structure). These students listed titles such as: *NaCl under the magnifying glass*; *Table salt under the magnifying glass*; *Representation of sodium chloride as a soluble substance under the magnifying glass*. It can be assumed that these students thought that the particles of sodium chloride can really be viewed under the magnifying glass. This was confirmed by students' interpretations of this image: "The magnifying glass may show a detailed dissolution of sodium chloride". Or, "A bowl is placed under the magnifying glass to facilitate the study of the obtained solution". However, one student wrote: "The substance from the image is dissolved into positive sodium ions and negative chlorine ions that are observed under magnifying glass which I believe is not possible!" Another misunderstanding appeared within the group of students who proposed the titles like *Enlarged molecules of sodium chloride*; *Molecules under the magnifying glass.* These students showed a misconception believing that sodium chloride exists in the form of molecules in a solution. Also, some students believed that there are molecules or atoms of sodium and chlorine in the solution. It is interesting to mention that three students proposed the title *Infusion*, knowing the use of 0.9% solution of sodium chloride in water in medicine.

Conclusions and Implications

In this research, the secondary school students' abilities to propose the titles of images and to interpret their content, were examined. All examined images were taken from the chemistry textbook and belonged to the one of three basic types of images: realistic, conventional and hybrid. The results showed that secondary school students have developed the ability to read images at a satisfactory level. It was found that the students had the most difficulties to read realistic images as they can often be confusing (metaphorical), decorative and without a clear attachment to the observed chemical contents. As far as conventional and hybrid images were concerned, there appeared significant results. The students were well acquainted with the interpretation of graphs and other conventional visual representations. Nevertheless, there were students who showed misunderstandings, some of which had already been recorded in the literature, and some were the original outcome of this research.

As a further direction of the research, combined application of images and multiple-tier tests could be used. In this way, the misconceptions could be more precisely identified. Additionally, the students' abilities to read realistic, conventional and hybrid images could be examined in other teaching themes from inorganic, organic chemistry, or biochemistry.

Acknowledgements

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under Grant No. 179010.

References

Ametller, J., & Pintó, R. (2002). Students' reading of innovative images of energy at secondary school level. *International Journal of Science Education*, *24*(3), 285-312.

Colin, P., Chauvet, F., & Viennot, L. (2002). Reading images in optics: Students' difficulties and teachers' views. *International Journal of Science Education*, *24*(3), 313-332.

Dimopoulos, K., Koulaidis, V, & Sklaveniti, S. (2003). Towards an analysis of visual images in school science textbooks and press articles about science and technology. *Research in Science Education*, *33*(2), 189-216.

Eilam B., & Poyas, Y. (2010). External visual representations in science learning: The case of relations among system components. *International Journal of Science Education*, *32*(17), 2335-2366.

Gilbert, J. K. (2010). The role of visual representations in the learning and teaching of science: An introduction. *Asia-Pacific Forum on Science Learning and Teaching*, *11*(1), 1-19. Retrieved from https://www.eduhk.hk/apfslt/download/v11_issue1_files/foreword.pdf

Nedeljković, T. (2016). *Opšta hemija 1: Udžbenik za prvi razred srednje škole* (*General Chemistry 1: Textbook for first grade of secondary school*). Beograd: Logos.

Rapp, D. N. & Kurby, C. A. (2008). The "ins" and "outs" of learning: Internal representations and external visualizations. In J. K. Gilbert, M. Reiner, & M. Nakhleh (Eds.), *Visualizations: Theory and practice in science education* (pp. 29-52). Dordrecht, The Netherlands: Springer.

Uttal, D. H., & O'Doherty, K. (2008). Comprehending and learning from "visualization": A developmental perspective. In J. K. Gilbert, M. Reiner, & M. Nakhleh (Eds.), *Visualization in science education* (pp. 53–72). Dordrecht, The Netherlands: Springer.

Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Sciences*, *21*(2), 179-217.