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Original Article

# Identification of Misconceptions through Multiple Choice Tasks at Municipal Chemistry Competition Test

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**Abstract**

In this paper, the level of conceptual understanding of chemical contents among seventh grade students who participated in the municipal Chemistry competition in Novi Sad, Serbia, in 2013 have been examined. Tests for the municipal chemistry competition were used as a measuring instrument, wherein only multiple choice tasks were considered and analyzed. Determination of the level of conceptual understanding of the tested chemical contents was based on the calculation of the frequency of choosing the correct answers. Thereby, identification of areas of satisfactory conceptual understanding, areas of roughly adequate performance, areas of inadequate performance, and areas of quite inadequate performance have been conducted. On the other hand, the analysis of misconceptions was based on the analysis of distractors. The results showed that satisfactory level of conceptual understanding and roughly adequate performance characterize majority of contents, which was expected since only the best students who took part in the contest were surveyed. However, this analysis identified a large number of misunderstandings, as well. In most of the cases, these misconceptions were related to the inability to distinguish elements, compounds, homogeneous and heterogeneous mixtures. Besides, it is shown that students are not familiar with crystal structure of the diamond, and with metric prefixes. The obtained results indicate insufficient visualization of the submicroscopic level in school textbooks, the imprecise use of chemical language by teachers and imprecise use of language in chemistry textbooks.

**Keywords**: *compounds, conceptual understanding, elements, homogeneous and heterogeneous mixtures*

## Introduction

It is well-known fact that certain ideas and concepts, which are usually confronted with scientifically accepted concepts, already exist in students' minds before their first exposition to chemistry classes, i.e. before the process of formal learning (Bodner, 1986). Such concepts are commonly referred to as preconceptions. For instance, students believe that water vanishes as it evaporates (Barke, Hazari & Yitbarek, 2009), that sugar melts in the mouth, that air fills the empty space or that mass changes when the form changes and the like (Integrated Physics and Chemistry Modeling Workshop, 2001). These misunderstandings usually have a negative impact on further adoption of chemical knowledge since they lead to the creation of misconceptions, that is, erroneous concepts that hinder further acquisition of scientifically accepted concepts and thus negatively affect the learning process. The existence of common misconceptions across various levels of education and throughout the world can be explained by their simplicity and receptivity. According to Allen (2010), pupils tend to associate misconceptions in a meaningful way so that one complements the other, building a meaningful, but at the same time an incorrect conceptual framework. At the same time, during the formation of misconceptions students invest a significant amount of mental effort, so once created and adopted misconception is difficult to eliminate and replace with a proper, scientific concept.

On the contrary, chemistry concepts are quite complex, thus forcing students to simplify them, often by forming misconceptions, which then act as bridges, bypassing the gaps between existing and new concepts, which are abstract. Apart from the abstract nature of chemical concepts, several additional factors contribute to the creation of misconceptions. The first one is language or the use of words that are also present in everyday life, but in chemistry they have specific meanings (Bergquist & Heikkinen, 1990) such as for instance term pure. Thus, in everyday life pure water refers to clear or drinking water, but in a chemical sense the same term refers to a pure substance which consists of water molecules only. In terms of language, ambiguities can be created by teachers or authors of chemistry textbooks, which result from inconsistent and imprecise use of language (Chittleborough, 2004). For example, with the sentence “Methane is composed of carbon and hydrogen” teachers may unconsciously make students think that methane is a mixture consisting of carbon and hydrogen.

Another important source of difficulty has been pointed out in the literature. It is the idea that the chemical contents can be taught at three levels, only one of which can be directly available to sensory perception (Chandrasegaran, Treagust & Mocerino, 2009; Johnstone, 1991; Nelson, 2002; Tsaparlis, 1997). These levels are macroscopic, submicroscopic and symbolic. The macroscopic level refers to contents that can be perceived by the senses. Submicroscopic level is the level of particles (atoms, molecules, ions, electrons, etc.), while the symbolic level is a construct that links knowledge at the macroscopic and submicroscopic level through the application of symbols, formulas and equations (Gilbert & Treagust, 2009). Since the substance at the submicroscopic level is not perceptually accessible, this is the most abstract level, and that is why students, as well as their teachers, very often bypass this level and seek their own explanations to make content easier to adopt (Boo, 1998; Gabel, 1998). However, meaningful understanding of chemical concepts is only possible if students manage to develop chemical reasoning at the submicroscopic level (van Berkel, Pilot & Bulte, 2009).

Against this background, it can be concluded that the elimination of misconceptions is a very important task in the teaching process, which must be preceded by identification of misconceptions. Regarding determination of misconceptions, conventional techniques can be classified into two categories: subjective and objective (Dhindsa & Treagust, 2009). Due to low efficiency and required time, subjective methods are less used than objective ones, which on the contrary, allow examination of a large number of students in a short period of time. Among the techniques that are most commonly used we can mention interviews, drawings, tasks, multiple choice tasks (where common misconceptions are given as distractors), two-tier diagnostic tests, concept maps, and others. After identifying misconceptions, it is important to develop effective strategies for their elimination, as it is usually a slow and demanding process. Namely, to transform misconceptions into scientifically accepted concepts there must be student dissatisfaction with the existing concepts or inability to explain new problems or situations. In order to be adopted, new concepts have to be more reasonable, clear, acceptable and more plausible than existing concepts (Posner, Strike, Hewson & Gertzog, 1982). By introducing new ideas, existing concepts of students can be questioned, which can lead to the creation of cognitive conflict, which is inevitable in the process of misconception elimination (Trumper, 1997).

It is recommended that new concepts should be introduced over existing proper students' concepts, or by applying the so-called "bridging analogues" (Clement, 1993). Very often, for this purpose, experiments that allow students to integrate their knowledge in a meaningful way are being performed (Chittleborough, 2004). Encouraging students to discuss their ideas through active discussion and exchange of opinions and attitudes is argued as particularly important (Vosniadou, Ioannides, Dimitrakopoulou & Papademetriou, 2001). The teacher and teaching methods, including chemical models and representations, play a very important role in finding explanations for abstract concepts. Today it is known and widely accepted that teaching, based on the intercorrelation of levels of representation (chemical triplet), is a key component of a meaningful understanding of chemical concepts (Gabel, 1999).

## Methodology

### Aim of the research

The main objective of this study was to determine whether there are some common misconceptions among the students talented for chemistry, i.e. students who take part in chemistry competitions, similar to those that regularly occur among primary school students. Within the defined objective, following research tasks have been set:

T1: To identify areas of satisfactory conceptual understanding
T2: To identify areas of roughly adequate performance
T3: To identify areas of inadequate performance
T4: To identify areas of quite inadequate performance
T5: To identify areas of conceptual difficulties

### Research sample

***Participants.*** The research sample comprised 101 seventh grade students from the municipality of Novi Sad, aged 13-14. The research involved the use of a competition test. Students' identities and gender, were unknown to the authors.

***Contents***. The applied test included the following topics (for complete data see Institute for the Advancement of Education, 2012):

- ***Chemistry and its importance***. The subject of studying chemistry. Chemistry within natural sciences and its application.
- ***Basic chemistry concepts***. Substances. Physical and chemical properties of substance; Physical and chemical changes of substance; Pure substances: Elements and compounds. Mixtures. Separation of the mixture components.
- ***The structure of substances***. Atom. Chemical symbols. Structure of atom. Nucleus of atom. Atomic and mass number. Isotopes. Relative atomic mass. Electron shell. Periodic table of elements. Molecule. Chemical formula. Covalent bond. Construction of molecules of elements and molecules of compounds. Ionic bond. Relative molecular mass. Atomic, molecular and ionic crystal lattices.

### Research instrument

The authors used tests for the 2013 municipal chemistry contest for this research. The test consisted of 37 tasks that were divided into four sections. Sections 1 and 2 contained multiple choice questions. Section 3 contained fill-in-the-gaps questions, and section 4 contained calculation tasks. For the purposes of this study, only multiple choice questions were analyzed. This test contained 25 multiple choice questions with four given answers only one of which is correct.

- Section 1 contained 11 tasks. The tasks required knowledge about basic chemical concepts including knowledge about elements (tasks 8, 10), compounds (tasks 3.11) and mixtures (tasks 1, 2, 4, 5, 6, 7, 9).
- Section 2 contained 14 tasks. The tasks required knowledge about chemistry and its importance (tasks 7, 9), about basic chemical concepts (tasks 1, 2, 13), about structure of substance (tasks 3, 4, 5, 6, 10, 11, 12).

The total time available for solving all 37 test tasks was 120 minutes.

**Instrument Psychometrics**

Within metric characteristics of the applied test, a Cronbach's alpha, difficulty and discrimination indices of tasks, and difficulty and discrimination indices of test were considered. All of the above calculations were performed using statistical package IBM SPSS Statistics 20.

The obtained calculated value of Cronbach's alpha for the tested sample (n=101) was 0.74, which is greater than the threshold value of 0.70 as suggested by Murphy and Davidshofer (2005) indicating good reliability.

Calculated item difficulties range from 11.54 to 95.16, providing a wide range of difficulty items. Only two tasks have index difficulty less than 30 %, which puts them in the category of difficult tasks (Luxford & Bretz, 2014); 10 tasks have a difficulty indices greater than 80 %, which classify them in the category of easy tasks, while 13 tasks are categorized as tasks of moderate difficulty. The mean value of the test index difficulty is 68.98, which means that the test has moderate difficulty. Regarding discrimination indices, they vary in the range 0.07 to 0.43. An important fact is that none of the tasks has a negative value of the aforementioned index, so all of them can be processed in further analysis, i.e. the analysis of misconceptions. The obtained average discrimination index for all tasks is 0.22, and since it is greater than the benchmark of 0.20, according to Ebel and Frisbie (1991) it can be said that the test has acceptable discrimination, that is, it adequately differentiates between the successful and less successful students. Based on the results presented, it can be concluded that the applied test has satisfactory metric characteristics, and therefore can be used in further analysis of misconceptions.

**Procedure**

Within distractor analysis, the percentage of correct answers to the test items, as well as the percentage of wrong ones was examined. According to Gilbert (1977) a response represented as a distractor can be considered a misconception if it is chosen by more than 20 % of the students. This method of misconception identification was applied in a number of studies in the field of chemical education (Gilbert, 1977; Dhindsa & Treagust, 2009; Stojanovska, Petruševski & Šoptrajanov, 2014; Ozmen, 2008). Further analysis of item responses included the consideration of the percentage of correct answers. According to literature (Gilbert, 1977), correct answers given by approximately 75 % of the students or more (for items with four distractors) can serve as an indicator of satisfactory conceptual understanding (SCU). Frequency of choosing the correct answer in a range 50-74 % represents a roughly adequate performance (RAP). Furthermore, 25-49 % frequency indicates inadequate performance (IP), while obtained frequency less than 25 % represents quite inadequate performance (QIP).

## Results and discussion

### Analysis of misconceptions

Based on the results of the applied analysis, a total of 9 misconceptions in 8 tasks were identified. Out of these, 6 refer to the students' inability to distinguish between homogeneous mixtures, heterogeneous mixtures, elements and compounds. This type of misconception is well known and extensively documented in the literature (Barker, 2000; Costu, Ünal & Ayas, 2007). Apart from this common misconception, two more types of misconceptions have been identified. Namely, it has been shown that students are not familiar with the crystal structure of the diamond and metric prefixes. Table 1 summarizes the identified misconceptions.

In the first task, students were expected to recognize fog as an example of a heterogeneous mixture. However, a surprisingly large percentage of respondents selected the answer that the fog is homogenous mixture. Based on these findings, it can be concluded that students, even the best among them, equate terms of water vapour and mist. Barke, Hazari and Yitbarek (2009) suggest that in daily life terms vapour, mist and fog are often used interchangeably, and therefore students believe that fog is composed of water molecules in the gas phase.

In task No. 2 the most frequently selected answer was that 10 karat gold is an example of a compound, with the selection rate of 24.8 %. For students, 10 karat is likely a determinant which indicates a complexity of a given substance. Knowing that gold is located in the periodic table of elements, a large percentage of students probably assumed that 10 karat gold is a compound derived from the element, pure gold.

In task No. 6 respondents were required to recognize still mineral water as a homogeneous mixture. However, 26.7 % of respondents answered that mineral water is a heterogeneous mixture. These results are quite surprising, especially because water is the

Table 1. List of identified misconceptions.

| **Task** | **istractor misconception indicator** | **istractor choosing fre uency** |
|---|---|---|
| 1. | Fog is a homogeneous mixture | 38.6 |
| 2. | 10 karat gold is a compound | 24.8 |
| 6. | Mineral water is a heterogeneous mixture | 26.7 |
| 7. | Glass is a heterogeneous mixture | 24.8 |
| 9. | Bronze is a heterogeneous mixture | 41.6 |
| 9. | Bronze is element | 27.7 |
| 10. | Graphite is a compound | 35.6 |
| 19. | $10^{-6}$ refers to the prefix *nano-* | 27.7 |
| 23. | The structure of the diamond can be represented by an ionic lattice model | 24.8 |

most common substance for students and typical example of a homogeneous mixture in most 7th grade textbooks. In task No. 7 the same problem was observed, and that is the students' inability to distinguish homogeneous from heterogeneous systems. A large percentage of students believed that glass is a heterogeneous mixture, although this is yet another example of a substance from students' everyday life. Sheehan and Childs (2013) came to a similar conclusion as they found that students believe that all mixtures are heterogeneous mixtures.

In task No. 9 two more misconceptions were identified. Namely, only a small percentage of respondents knew the correct answer that bronze is a homogeneous mixture, while more frequent responses were that the bronze is heterogeneous mixture, or even an element. The results of this task can be compared with the results of task 7. It can be concluded that students are likely to believe that two or more solids cannot be mixed so that the resulting mixture in all parts has identical composition.

In task No. 10 respondents were expected to recognize graphite as an allotropic modification of carbon, and therefore conclude that graphite is an element. Only a small number of respondents were familiar with this fact, while majority of them answered that graphite is a compound.

In task No. 19 students were asked to recognize that factor 10- 6 refers to the prefix micro-. While less than half of the students knew the correct answer, a large percentage of them elected response nano-. This could be explained by the fact that the prefix nano- was the most prominent one, and students could hear it at school, in the media, or in words such as nanotechnology, nanotubes, nanofibers etc.

Last misconception was identified in task No. 23, in which students were expected to know the structure of diamond. Slightly more than half of tested students had known that the structure of the diamond can be presented by the model of atomic crystal lattice, while a significant number of students thought that diamond structure can be presented by a model of ionic crystal lattice.

These results indicated that a significant number of the most successful students do not possess adequate knowledge on the submicroscopic level.

### Analysis of correct responses

Frequencies of choosing the correct responses by tasks are given in Table 2. Results summarized in Table 2, as expected, show that in most of the tasks (12) students displayed a satisfactory level of conceptual understanding or achieved roughly adequate performance (9). In a several tasks students realized weaker performance or more specifically, inadequate performance in 2 tasks and quite inadequate performance in 2 tasks. Since this study included students who achieve best outcomes in chemistry, high performances are, in a way, expected. However, a relatively large number of identified misconceptions is quite surprising. One of possible causes of these misconceptions is probably traditional chemistry teaching, which is widespread in Serbian schools. This kind of instruction is characterized by a low degree of interaction among levels of representation, or even more often, by the lack of certain levels, primarily submicroscopic i.e. particulate level. Inability to classify substances into four offered categories probably occurs as a result of the lack of knowledge about the particulate nature of a given substance. It means that students are not able to determine which particles make the given system, and they are therefore unable to perform classification. In addition, it is possible that definitions of elements, compounds and mixtures in the recommended textbooks for the 7th grade of primary school have largely contributed to creation of misconceptions in the analyzed contents.

Table 2. Frequencies of choosing the correct responses by tasks.

| Task | Correct response | re uency of choosing | The le el of conceptual understanding |
|---|---|---|---|
| 1. | Fog is a heterogeneous mixture | 50.5 | RAP |
| 2. | 10 karat gold is a homogeneous mixture | 8.9 | QIP |
| 3. | Potassium permanganate is a compound | 93.1 | SCU |
| 4. | White wine is a homogeneous mixture | 81.2 | SCU |
| 5. | Crystallized honey is a heterogeneous mixture | 85.1 | SCU |
| 6. | Still mineral water is a homogeneous mixture | 65.3 | RAP |
| 7. | The glass is a homogenous mixture | 58.4 | RAP |
| 8. | Neon is an element | 95.0 | SCU |
| 9. | Bronze is a homogeneous mixture | 20.8 | QIP |
| 10. | Graphite is an element | 34.7 | IP |
| 11. | Baking soda is a compound | 72.3 | RAP |
| 12. | Baking bread is a chemical change | 52.5 | RAP |
| 13. | Condensation of water vapour is a physical change | 89.1 | SCU |
| 14. | The chemical symbol of zinc is n | 93.1 | SCU |
| 15. | Bond in HCl is polar covalent | 74.3 | RAP |
| 16. | Isotopes of an element differ in A | 79.2 | SCU |
| 17. | Elementary particles of the nucleus are protons and neutrons | 82.2 | SCU |
| 18. | Pictogram represents corrosive chemical substance | 87.1 | SCU |
| 19. | The prefix that corresponds to the factor $10^{-6}$ is a *micro-* | 48.5 | IP |
| 20. | Scales are used for measuring substance mass | 83.2 | SCU |
| 21. | K , $Cl^{-}$, $S^{2-}$ contain the same number of electrons | 75.2 | SCU |
| 22. | Formula of a stable sulphur ion is $S^{2-}$ | 79.2 | SCU |
| 23. | The structure of the diamond can be represented by a model of the atomic crystal lattice | 52.5 | RAP |
| 24. | A mixture of copper and lead powder can be separated by magnet | 66.3 | RAP |
| 25. | Calcium is an element, chemical properties of which are the most similar to chemical properties of magnesium | 74.3 | RAP |

Strictly speaking, in certain textbooks one may find the following definitions:

1) Substances which are composed of two or more chemical elements are referred to as compounds
2) Mixture is a collection of two or more substances
3) Compounds are complex substances

On the basis of such incomplete (2, 3), or even incorrect (1) definitions, students can reasonably conclude that, for instance, a mixture of sulphur and iron is a compound, since it is composed of two chemical elements, or that ammonia is a mixture, as it is composed of two types of particles. Furthermore, the analysis of the textbooks showed that there is a very small percentage of graphic representations of submicroscopic level in available textbooks, which contribute much to a weaker understanding of the content at the submicroscopic level. Therefore, on the basis of the aforementioned, it is very important that chemistry teachers should be trained to analyze textbooks and to inform students about the perceived inadequacies.

## Conclusion

In this study a conceptual understanding of chemical contents of seventh grade students through tests for municipal competition has been examined. The study revealed that most of the students had satisfactory understanding of the tested concepts or at least roughly adequate performance. Still, results indicate the existence of various misconceptions ranging from 24.8–41.6 %. Most of the identified misconceptions are reflected in students' inability to distinguish between homogeneous and heterogeneous mixtures, elements and compounds. Reasons for this could be found in insufficient use of submicroscopic explanations in teaching, then insufficient visualization of submicroscopic level in chemistry textbooks, imprecise and inconsistent use of chemical terminology by teachers, and imprecise formulations in textbooks.

These and similar analyses are very important, because it is well-known that misconceptions act as barriers to learning. Therefore, their identification is very important. This first step should be followed by a step of equal importance, and that is searching for effective models of teaching that will reduce misunderstandings. It is particularly important that such studies are performed at an earlier age of students, or at the very beginning of their chemical education. This would enable educators to eliminate the perceived misconceptions on time, since the elimination of misconceptions plays a key role in the improvement of learning process.

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## References

Allen, M. (2010). *Misconceptions in primary science*. London: Open university press.

Barke, H. D., Hazari, A., & Yitbarek, S. (2009). *Misconceptions in Chemistry: Addressing Perceptions in Chemical Education*. Berlin: Springer-Verlag.

Barker, V. (2000). Beyond Appearances: Students' misconceptions about basic chemical ideas. London: Royal Society of Chemistry.

Bergquist, W., & Heikkinen, H. (1990). Student ideas regarding chemical equilibrium. *Journal of Chemical Education, 67*(12), 1000–1003.

*Bodner, G. M. (1986). Constructivism: a theory of knowledge. Journal of Chemical Education, 63*(10), 873–878.

Boo, H. K. (1998). Students' understandings of chemical bonds and the energetics of chemical reactions. *Journal of Research in Science Teaching, 35*(5), 3–12.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2009). Emphasizing multiple levels of representation to enhance students' understandings of the changes occurring during chemical reactions. *Journal of Chemical Education, 86*(12), 1433–1436.

Chittleborough, G. D. (2004). *The role of teaching models and chemical representations in developing students' mental models of chemical phenomena* (Doctoral disertation). Retrieved from Curtin University. (PID: 15381).

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching, 30*(10), 1241–1257.

Costu, B., Ünal, S., & Ayas, A. (2007). A hands-on activity to promote conceptual change about mixtures and chemical compounds. *Journal of Baltic Science Education, 6*(1), 35–46.

Dhindsa, H., & Treagust, D. F. (2009). Conceptual understanding of Bruneian tertiary students: Chemical bonding and structure. *Brunai International Journal of Science and Mathematical Education, 1*(1), 33–51.

Ebel, R. L., & Frisbie, D. A. (1991). *Essentials of educational measurement* (5th edition), 220–240. New Delhi: Prentice Hall of India.

Gabel D. (1998). The Complexity of Chemistry and Implications for Teaching. *In*: B. J. Fraser, K. G. Tobin (Eds.), *International Handbook of Science Education*, 233–248. Dordrecht: Kluwer Academic Publishers.

Gabel, D. L., (1999). Improving teaching and learning through chemistry education research: A look to the future. *Journal of Chemical Education, 76*(4), 548–554.

Gilbert, J. K. (1977). The study of student misunderstandings in the physical sciences. *Research in Science Education, 7*(1), 165–171.

Gilbert, J. K., & Treagust, D. F. (2009). Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education. *In*: J. K. Gilbert, D. F. Treagust (Eds.), *Multiple representations in chemical education*, 1–8. Berlin: Springer.

Institute for the Advancement of Education (2012). Retrieved from: http://www.zuov.gov.rs/novisajt2012/dokumenta/CRPU/Osnovne_skole_PDF/Drugi_ciklus_osnovnog_obrazovanja_i_vaspitanja/4_Nastavni_program_za_sedmi_razred_osnovnog_obrazovanja_i_vaspitanja.pdf (29.1.2015.).

Integrated Physics and Chemistry Modeling Workshop, (2001). Retrieved from: https://bscw.alp.dillingen.de/pub/bscw.cgi/d6067875/chemistrymisconceptions_arizona.pdf (4.3.2015.)

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of computer assisted learning, 7*(2), 75–83.

Luxford, C. J., & Bretz, S. L. (2014). Development of the Bonding Representations Inventory to Identify Student Misconceptions about Covalent and Ionic Bonding Representations. *Journal of Chemical Education, 91*(3), 312–320.

Murphy K. R., & Davidshofer C. O. (2005). *Psychological testing: Principles and applications*. New Jersey: Prentice Hall.

Nelson, P.G. (2002). Teaching chemistry progressively: From substances, to atoms and molecules, to electrons and nuclei. *Chemistry Education Research and Practice in Europe, 3(*2), 215–228 and references therein.

Ozmen, H. (2008). Determination of students' alternative conceptions about chemical equilibrium: a review of research and the case of Turkey. *Chemistry Education Research and Practice, 9*(3), 225–233.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. *Science Education, 66*(2), 211–227.

Sheehan, M., & Childs, P. (2013). A survey of the chemistry misconceptions held by Irish preservice science teachers and the development of strategies and materials to promote understanding. Ebook proceedings of the ESERA 2013 conference, 664–672.

Stojanovska, M., Petruševski, V. M., & Šoptrajanov, B. (2014). Study of the use of the three levels of thinking and representation. *Contributions, 35*(1), 37–46.

Trumper, R. (1997). Applying conceptual conflict strategies in learning of the energy concept. *Research in Science and Technological Education, 15*(1), 5–18.

Tsaparlis, G. (1997). Atomic and molecular structure in chemical education: A critical analysis from

various perspectives of science education. *Journal of Chemical Education, 74*(8), 922–925.
Van Berkel, B., Pilot, A., & Bulte, A. M. W. (2009). Micro-macro thinking in chemical education: Why and how to escape. *In*: J. K. Gilbert, & D. F. Treagust (Eds.), *Multiple representations in chemical education*, 31–54. Berlin: Springer.
Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction, 11*(4), 381–419.

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