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## STUDY OF THE USE OF THE THREE LEVELS OF THINKING AND REPRESENTATION

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As is well-known, the chemical knowledge is acquired at three levels: **the macroscopic and tangible** (what can be seen, touched and/or smelt); **the sub-microscopic** (atoms, molecules, ions and structures) and **the representational** (symbols, formulae, equations, mathematical manipulation, graphs etc.).

In order to acquire *real* knowledge, all factors involved in the educational process (authors of textbooks, teachers, electronic sources of information and students) should do everything possible to avoid formation of school-made erroneous notions (misconceptions).

Reported here are the findings of a study on the presence of students' misconceptions regarding the three levels of representation in the chemistry teaching in the Republic of Macedonia. As our study showed, many school-made misconceptions are due to the fact that students do not distinguish between the three levels of thinking/representation.

**Key words:** the three levels of thinking/representation; chemistry teaching; misconceptions; interviews

### INTRODUCTION

There are many terms that refer to students' misbelieves. Some authors use the word *preconceptions* or *preconcepts* to emphasize the importance of children's ideas developed before and during their early school years; others use *misconceptions*, *misunderstandings*, *misinterpretations of facts*, *naive believes* etc. The expression *alternative conceptions* is considered by some authors as some kind of compromise that incorporates students' faulty views during science teaching [1]. Still, in the literature on chemistry education, the prevalent word describing the erroneous notions is the word *misconceptions*. The term "misconception" could be defined as "an idea which is wrong because it has been based on a failure to understand a situation" [2] although alternative definitions could also be given.

The misconceptions are powerful, extremely persistent and highly resistant to change or alteration, creating obstacles to further learning [3, 4].

The erroneous notions can be formed before the schooling or in its early stages (sometimes, these are called *preconcepts*) but could also originate from the content of textbooks, as well as from teachers (their knowledge and attitude). Thus, although the teaching process generally leads to acquiring and understanding various concepts, in some cases it may misguide students and lead to the formation of misconceptions.

Needless to say, chemistry is a subject which, necessarily, is based on *concepts*, many of which are abstract and are therefore hard to grasp and learn, especially when the students are put in a position to *believe without seeing*. This is most certainly a basis for occurrence of new or strengthening of already existing misconceptions.

Misconceptions can be derived from the textbook illustrations and used animations [5, 6], textbooks of other subjects, the inconsequent chapter organization [7], the teachers [8, 9] or the way of teaching. Misconceptions that originate from the

teaching process are known as *school-made misconceptions* [10].

According to Johnstone [11], the chemical knowledge is acquired at three levels: a) **the macroscopic and tangible** (what can be seen, touched and/or smelt); b) **the sub-microscopic** (atoms, molecules, ions and structures) and c) **the representational** (symbols, formulae, equations, mathematical manipulation, graphs, etc.) and this is now considered to be a truism. None of the above-mentioned aspects is superior to another; on the contrary, they rather complement each other.

Some of the reasons for occurrence of misconceptions in chemistry could be traced to problems of the specific terminology and used wording, especially when introducing the concepts of substances, the particles of which they consist and chemical symbols used for their representation (macroscopic, sub-microscopic and symbolic respectively).

Many school-made misconceptions are due to the fact that students do not distinguish between macroscopic and sub-microscopic explanations [12–16]. There are, at least, two possible reasons for the emerging of misconceptions when dealing with the three mentioned levels of representation. The first is the risk of "overloading the working memory space" [17] when students are introduced to all three levels *simultaneously*. Secondly, neglecting the sub-microscopic level during teaching may also lead to the appearance of certain misconceptions. Seemingly, it would be better that chemistry concepts are taught progressively: starting with macroscopic observation, through the sub-microscopic interpretations and *only then* work with the symbolic representations.

Many basic chemistry concepts are difficult to teach because "the definitions of these concepts given in textbooks either lack precision, or invoke ideas that beginners are not familiar with, and have to accept on trust" [18]. Conceptual knowledge about chemical reactions (a subject present in any chemistry textbook) implies awareness of the three levels of representation. Students have to be able to go from the macroscopic level (observations, experiments) to the sub-microscopic level in order to understand the changes that happen during chemical reactions and then learn to present the acquired knowledge in a symbolic way. Unfortunately, chemical reactions are being taught, most of the time, only through chemical equations, thus stimulating only the low-level knowledge (memorizing and/or recognizing) [19, 20].

In the last few decades many misconceptions concerning various chemistry (and science in general) topics have been documented [1, 21] and many

science misconceptions and difficulties in learning and understanding chemical concepts have been reported [22–29]. The misconceptions regarding the three levels of representation are closely related not only to the false ideas about the chemical reactions [30–32], but also to the ideas involving the particulate nature of matter [15, 33–43], the law of conservation of matter [44, 45], the physical and chemical changes [18, 30, 31, 46, 47], the solutions [24, 48] etc.

Particle theory concepts are an integral part of the eighth-grade (secondary-school) curriculum in the Republic of Macedonia. At the very beginning of learning chemistry as a subject, students encounter the bulk properties (physical and chemical) of substances and then their structure. Chemical symbols, formulae and equations come later. Nonetheless, as will be shown, the results of our investigation showed that many students have not developed an accurate understanding of these concepts and the consistency in reasoning among students of different levels of study confirmed the fact that they retained their misconceptions over the years.

Sadly, this is not the case only of our students but vagueness is present even in the presentations of the periodic table of elements. If one looks closely, it can be noticed that some data refer to the *atoms* of the elements (e.g. electronic configuration) and other are related to the *elementary substances* that are composed of these particles (e.g. density) [49]. All three levels of representation are present and mixed (obviously, in an unfortunate manner) in the published form of the periodic table, so it undoubtedly brings some confusion among students.

The interference of macroscopic (colour, density, melting point or solubility) and sub-microscopic concepts (size and mass of the particles) by students may be due to the lack of ability to adequately describe the learned concepts [10] but is, even more likely, a result of a confusion of ideas. Thus, in many cases, the ideas of students that *when a gas is being compressed* (macroscopic representation), *the particles* (sub-microscopic representation) *are not only pushed closer together but also compressed themselves* are present [16]. Further examples are given by Barke et al. [10] who quote some students' statements, such as: "sulfur particles are yellow", "sugar particles are sweet", "water is a fluid and consists of liquid particles", "ice particles are solid", "carbon particles burn and turn to ash" etc.

Misconceptions originating from interference between the three levels of representation in the chemistry teaching process are present not only

among students, but also among teachers, educators and researchers and even among respected authors of scholarly papers, as well as authors of textbooks. Thus, in many textbooks statements can be found in which a *substance* reacts with one or more *particles* (atoms, molecules, ions ...), such as: "This ion reacts with the glucose, oxidizing it to form an acid and the ion itself reduces to elementary silver" [50]. Similar (basically incorrect) notions are present in statements such as: "When forming ionic compounds, iron gives off three electrons." [51], "The elementary substance phosphorus consists of four atoms of element phosphorus." [51], "Acid molecules comprised of one hydrogen atom are called monoprotic acids." [52] etc.

In view of such an unfortunate state of affairs, it is clear that an in-depth understanding of concepts is needed rather than just memorizing facts and rote learning. One of the possible solutions to ameliorate the situation is to have teachers and educators focused on the implementation of instructional programs aimed to help students in overcoming erroneous concepts they have. Another, perhaps simpler, solution is to educate the educators to notice such false statements and correct them during their class work.

In the present paper we report the findings from an experimental study of students' misconceptions regarding the three levels of representation. The investigation was intended to check the capability of students of different educational levels (samples of students from secondary- and high-schools were tested) to transfer their knowledge through the three levels of representation. Given is a list of misconceptions detected among students, as well as excerpts from interviews to give evidence for the students' reasoning. We believe that the results of this research will find their place in the chemistry teaching in the Republic of Macedonia, and, hopefully, will ameliorate it.

## EXPERIMENTAL SECTION

In this study, as is the case in many educational investigations, a combination of quantitative and qualitative data collection techniques was used and two kinds of instruments were implemented: multiple-choice concept tests and interviews (semi-structured individual interviews and focus groups), such a combination being known as triangulation [53, 54]. Interviews, both individual [55, 56] and in a group [57–60], have been successfully used as data collection instruments in educational studies when looking for in-depth explanations. Details about the instruments and the procedures are given

elsewhere [32, 43]. Additionally, a pilot study, testing the possible misconceptions regarding the law of conservation of matter has been performed [61, 62].

The percentage of correct answers to the test items as well as that of wrong ones was estimated. The high value of the latter could indicate presence of students' misconceptions on the tested concepts [19]. Namely, as a somewhat rough rule of thumb, a statement represented as a distractor can be considered to be a misconception if it is chosen by more than 20 % of the students.

The interview transcripts were used to locate gaps in knowledge and segments that can be regarded as misconceptions. Interview discussions were also used either to confirm the misconceptions found by the analysis of the tests or to indicate the existence of new ones. All interviews were conducted in Macedonian (the excerpts quoted in this paper were translated into English). The excerpts from the interview transcripts that are presented in the paper could enable the readers to examine the trustworthiness of the research procedure.

## RESULTS AND DISCUSSION

The summary of the findings from the testing and interviewing students is given in this section, with a stress on the misconceptions found among students in the test and through interview discussions. Namely, during the testing, some distractors were favoured for certain items and thus 21 misconceptions were identified in the answers given by students. Several more misconceptions emerged on analyzing the interview transcripts. The misconceptions found in the written responses are listed in Table 1. The percentages of students holding particular misconceptions were also calculated and are summarized in the same table.

Other misconceptions were detected in the test answers of certain sub-samples. Thus, among eighth-grade students, a notion that "*particles receive heat and enlarge*" (M22) was rather common (33 % of students have chosen this option in the test). Three more misconceptions were revealed in the second-year high-school sub-sample analysis. The statements commonly present among such students were that: a) "*carbon, hydrogen and oxygen atoms (of which ethanol is composed) will disappear when ethanol is ignited*" (32 %; M23), b) "*particles of a substance are shrinking during heating of that substance*" (28 %; M24) and c) "*NaCl entities in aqueous solution can be present both as molecules and ions*" (30 %; M25).

**Table 1.** Misconceptions (M) found among students during testing

Misconception	Percent
M1 Butadiene reacts with two bromines	27
M2 Butadiene reacts with one molecule of bromine	61
M3 Copper(II) sulfate from aqueous solution crystallizes as a solid substance composed of copper(II) sulfate molecules [fail to distinguish ionic from covalent substances, so they refer to all building particles as molecules]	35
M4 Particles change from solid to liquid ones	50
M5 When ethanol is ignited, carbon, hydrogen and oxygen atoms (of which ethanol is composed), will ignite too and will burn just like the ethanol	26
M6 The particles of a substance enlarge during heating that substance	50
M7 NaCl entities in aqueous solution react with the water and sodium and chlorine are formed	34
M8 Instead of $3N_2$ , in a chemical equation, one can write $6N$	23
M9 Gas (water vapor) weighs less than liquid [matter is not conserved in evaporation]	41
M10 A sealed container with a bit of acetone in it weighs less after the liquid (acetone) has evaporated	30
M11 Weight (mass) is lost in dissolving	61
M12 Solute (eg. salt) disappears when dissolved	47
M13 Precipitation reaction results in increasing the mass	34
M14 Mass increases in precipitation because solid weighs more than the liquid	21
M15 A rusting nail won't change weight	38
M16 The iron had only reacted with the oxygen in the air which does not weigh anything	27
M17 The rust eats up the metal	25
M18 Exhaust gasses from burning petrol weight less than the petrol ...	36
M19 ... because gas is lighter	31
M20 Mass is lost in combustion	36
M21 Combustion is a change of state of matter	32

In Table 2, excerpts from the conversations between the researcher (R) and student/s (S) are given to illustrate and support the finding regarding students' misconceptions. After every excerpt a brief description is given that includes the type of school (SS or HS for secondary- and high-school respectively), the level of education within the school in question (given by Roman numerals) and the sub-group to which the student belongs (high achievers are students having grade 4 or 5 and low achievers are classified those that have grade 2 or 3 according to their previous school achievements)<sup>1</sup>.

The most common misconceptions of students identified during the interviews were those

that reflected ideas about the size and shape of molecules when the substance undergoes a phase change. Some students believed that the particle size must be changed and they explained that the expansion of matter is due to the expansion of *particles* rather than to increased particle spacing (for example, molecules allegedly can stretch and expand when a substance is heated); others thought that the particles of a given substance in different states (solid, liquid and gaseous) have different properties (for example, the molecules of liquid/gaseous water are softer and weigh less than the molecules of ice/liquid water).

<sup>1</sup> In the Macedonian system of grading, five integers (from 1 through 5) are used: 5 (excellent) is the highest and 1 (fail) is the lowest grade.

**Table 2.** Excerpts from the interview transcripts for corresponding misconceptions

Misconception	Excerpt
M1	I have calculated correctly: there are two atoms of bromine and that is why butadiene reacts with two atoms of bromine. (SS-VIII-high achievers)
M2	I considered that Br <sub>2</sub> is one molecule of bromine, so my answer is that butadiene reacts with one molecule of bromine. (HS-II-low achievers)
M3	<p><b>R:</b> Do you think that molecules of copper(II) sulfate exist?</p> <p><b>S10:</b> Yes.</p> <p><b>R:</b> Could you explain in more detail what do you mean?</p> <p><b>S10:</b> I don't know ... I'm not sure.</p> <p><b>S9:</b> I think that molecules of copper(II) sulfate do not exist because copper(II) sulfate is a compound.</p> <p><b>R:</b> What about water? Is water a compound?</p> <p><b>S9:</b> Well ... yes.</p> <p><b>R:</b> Does it consist of molecules?</p> <p><b>S9:</b> Yes, it does.</p> <p><b>R:</b> When is it right to say "molecules"?</p> <p><b>S12:</b> When we talk about ions, it must be an ionic bonded compound. (HS-II-high achievers)</p>
M4	My answer is that particles change from solid to liquid ones. For example, if we put ice cubes in a drink, after same time they will melt and turn to liquid state. According to this, I thought that this answer is the most appropriate. (SS-VIII-high achievers)
M5	<p><b>R:</b> Why do you think that atoms will burn?</p> <p><b>S:</b> Well, because ethanol has oxygen in its structure and it is able to burn. (SS-VIII-high achievers)</p>
M6	<p>When heating an object, particles become wider. (HS-IV-high achievers)</p> <p>When heat gets inside the particles, they are heated and, due to that, increase their size. (SS-VIII-low achievers)</p>
M7	<p><b>S:</b> Well, the whole ... NaCl ... can exist as a molecule, but if we are talking about its entities – they can not.</p> <p><b>R:</b> What are its entities?</p> <p><b>S:</b> Sodium and chlorine. (HS-III-high achievers)</p>
M8	<p><b>R:</b> Your test answer is "6N"? What does the number 2 means [pointing to 3N<sub>2</sub>]?</p> <p><b>S:</b> Nitrogen is non-metal and that's why we must write 2. If we multiply that with three molecules we get six atoms, which is the same representation as 6N. (HS-I-high achievers)</p>
M9	/
M10	<p><b>R:</b> Why did you answer that the mass of the container will be smaller than the initial one?</p> <p><b>S:</b> Well ... the substance binds to the oxygen. (HS-I-high achievers)</p>
M11 and M12	<p><b>R:</b> Why do you think that the mass will be 20 g if 1 g table salt is dissolved in 20 g water?</p> <p><b>S:</b> Well, because the salt has been dissolved in the water and it cannot be seen. (HS-I-high achievers)</p> <p><b>S:</b> The salt mass is not considered because salt disappears after the mixing (HS-I-high achievers)</p>
M13 and M14	<p><b>R:</b> What will happen to the mass of the system after the precipitate is formed?</p> <p><b>S:</b> I think it will be larger because the precipitate is not soluble and it stays at the bottom of the container. (HS-I-low achievers)</p>
M15	<p><b>R:</b> You answered that the mass of the nail is the same after the rusting. Could you explain in more details?</p> <p><b>S:</b> It means that there are exceptions of the law of conservation of matter. (HS-I-high achievers)</p>
M16	<p><b>R:</b> In this question considering the nail rusting you have answered that the mass would be the same. Please explain.</p> <p><b>S:</b> Yes, the rust appears above the metal.</p> <p><b>R:</b> What do you mean? Does it "float" in the air? Is it necessary the nail to react with something to become rusty?</p> <p><b>S:</b> Well, with oxygen.</p> <p><b>R:</b> Will the mass be the same after the reaction with oxygen?</p> <p><b>S:</b> Yes. (HS-I-high achievers)</p>

Misconception	Excerpt
M17	/
M18, M19 and M20	<p><b>R:</b> You answered that the mass of the exhausted gasses from burning gasoline will weigh less than the mass of the petrol. Please explain your answer.</p> <p><b>S:</b> It is so because the gasoline has been spent.</p> <p><b>R:</b> OK, the petrol is consumed, but I am interested in the mass of the exhausted gasses.</p> <p><b>S:</b> Their mass will be smaller because when they are exhausted in the air they become lighter than the gasoline. (HS-I-high achievers)</p>
M21	<p><b>R:</b> Why do you think that, after finishing all the changes, the mass of the test-tube will be smaller than the initial one?</p> <p><b>S:</b> Well, because the mass of the phosphorus has been decreased.</p> <p><b>R:</b> Please, explain what you mean.</p> <p><b>S:</b> It came to ... some part of the phosphorus passed into the gaseous state because the smoke can be observed.</p> <p><b>R:</b> And that is why you think that the overall mass will be smaller at the end?</p> <p><b>S:</b> That's right. (HS-I-high achievers)</p> <p><b>S:</b> Burning (combustion) is a physical change, physical form is changing; and chemical change ... something in the chemical composition. For example, the explosion is a physical change.</p> <p><b>R:</b> What kind of change is burning of alcohol?</p> <p><b>S:</b> Physical one.</p> <p><b>R:</b> What is changing here?</p> <p><b>S:</b> The alcohol evaporates. While burning, carbon dioxide is being released.</p> <p><b>R:</b> Is it possible for alcohol to evaporate if I just pour it on the table, but not burn it?</p> <p><b>S:</b> No, it won't evaporate. (HS-IV-low achievers)</p>
M22	An ice cube ... when exposed to sunlight and heat, starts to melt and its particles broaden. (SS-VIII-low achievers)

Here are some comments given by the students regarding these issues:

**"S:** *Since molecular space is changing; their size must change, too.*" (HS-III-high achievers).

**"R:** *You said that freezing will make the water molecule larger. Could you explain what did you mean?*

**S:** *Well ... the volume of ice ... water in the solid state is larger.*

**R:** *Do you think that if the volume is larger, the molecule must be larger, too?*

**S:** *That's right.*" (HS-II-low achievers)".

Several more categories of erroneous notions were registered when interviewing students although, fortunately, those were not widespread. Some of them are given below:

*"Molecules that evaporate are lighter and go upward and the ones that stay in the vessel are heavier."* (HS-III-low achievers);

*"[When water evaporates] a vapor is formed and water molecules are decomposed into hydrogen and oxygen molecules."* (HS-III-low achievers; HS-I-high achievers).

It was remarkable that many students disregard the particle conservation when describing changes. Thus, they said: *"Part of the water disappears be-*

*cause the water itself passes into the vapour."* (HS-I-high achievers). Similar findings like those mentioned above are reported in the literature [63–66].

At the end of the interviewing process, students were asked whether the particles (atoms, molecules or ions) possess similar properties as the parent material. Some improvements in thinking regarding their earlier standpoints were noticeable, but still, many of them thought that the particles possess the same properties as the materials composed of them. They pictured the particles as mini-versions of the substances they comprise. Some excerpts are given as a confirmation of the previously mentioned statements:

*"It is my opinion ... that this statement is true. It is said in chemistry textbooks ... that the atom is the smallest particle that possesses the same physical and chemical properties as the substance it originates from."* (HS-III-high achievers)

*"Well ... because we are dealing with one substance, I think that the atoms will have the same physical and chemical properties ... because substances are made up of particles."* (SS-VIII-high achievers);

*"Atoms and all the other particles of which the substances are composed do not have the same*

*properties as compounds have, because ... properties of that particular element or compound are added to the atoms.*" (SS-VIII-high achievers).

The excerpts regarding M1 and M2 in Table 2 clearly point out to the vagueness of the ideas of students and their inability to properly use the macroscopic and sub-microscopic concepts and the corresponding terminology. No differentiation is made between atoms and molecules, and between molecules (particles) and substances. Surely, a *substance can not* react with *only one or a few particles*.

Sometimes erroneous notions are not immediately perceptible and can be discovered only when looking at the in-depth responses. The next dialog is representative of that and it refers to the discussion of crystalline hydrates:

**R:** *What is your opinion? You have answered that copper(II) sulphate crystallizes as pentahydrate from water solutions. Why do you think this is the correct answer?*

**S:** *Last year we learned that ... er ... copper sulphate has five water molecules.*

**R:** *Where? Five water molecules in ...?*

**S:** *In its structure.*" (SS-VIII-high achievers).

In some textbooks [51] present are definitions of crystalline hydrates that use both macroscopic and sub-microscopic viewpoints. These can have harmful consequences to students and make difficult the discrimination between substances and their building blocks (particles), especially if such definitions are encountered in the early stages of the chemistry teaching.

In two of our previous papers [32, 43] we pointed out that it is likely that some erroneous concepts may originate because of imprecise definitions present in some *physics* textbooks [67]. It is more than obvious that some adjustments need to be done in clarifying similar concepts present in the teaching of chemistry and physics.

Another, very "popular" misconception among students was the one that *all* substances are built of molecules. Mostly, examples using sodium chloride were given. Many of the students had difficulties in recognizing ionic substances and had problems in defining their entities. Actually, many students thought that *molecules* are present in solid sodium chloride and that ions are formed only when it is dissolved. They related the sodium chloride formula to the term "molecule" simply because the symbols Na and Cl were written together. Similar findings were reported in the literature [6, 26, 63].

The following excerpts are representative of the erroneous belief of students that entities in ionic substances resemble covalent ones.

*"When it is not dissolved, molecules are present. In an aqueous solution ions are formed."* (HS-III-low achievers).

**R:** *Are the NaCl entities in the solid substance molecules, ions or both?*

**S:** *Molecules.*

**R:** *Why do you think so?*

**S:** *There are no ionic properties when a substance is not in aqueous solution. When it is not dissolved it does not act as an ion.*" (HS-III-middle achievers).

This clearly shows that there is a school-made misconception among students concerning the building particles in ionic substances, expressing it on the sodium chloride example. One possible reason for such a wrong concept can be found in some textbooks [52] where the structural formulae of ionic compounds are represented in the same way as those of the covalent ones, giving examples using calotte models for every entity of every substance, including the ionic ones. In this way, a distorted picture in the minds of the students is created that can last for a very long time.

Many misconceptions about the law of conservation of matter were noticed among high-school students. Thus, students believed that when something is burned it is used up and nothing remains (M20) or when nails get rusty they lose weight (M16). A student even claimed that "*gasoline transforms into light, heat and energy*" (HS-I-high achievers).

During the discussion it was observed that some students did not make any difference between mass and density, so they gave statements such as: "*A precipitate occurs when there is a mass difference, for example you can see precipitate in a cup of coffee*" (HS-I-low achievers).

The findings briefly outlined above indicate that many misconceptions were present among students, some originating (erroneously) from the observations of the macroscopic properties of substances and transferring these properties in the sub-microscopic world.

In our study, we found out that a large portion of students held the belief that the molecules themselves have the properties of the bulk matter. Furthermore, the data analysis from the tests and interviews clearly showed that students had certain difficulties in: a) recognizing symbolic representations (e.g. confusing symbols for atoms and formulae for molecules); b) making distinction between ionic and covalent substances and their particles and c) the ability to distinguish substances from molecules (i.e. differentiate concepts at macroscopic and sub-microscopic level).

In conclusion, it is our firm belief that it **must** be categorically stated (by teachers, educators and researchers) that neither **the substances are molecules** nor **molecules are substances**. This statement should be strengthened by usage of visualization techniques (models, animations or computer software) as a required tool in teaching abstract concepts [68, 69] and their appropriate implementation in chemistry teaching.

Within the educational system in the Republic of Macedonia many obstacles exist (including financial, experimental, personal preferences and, especially, the teaching time available to the teachers) which could slow down the implementation of many intervention programs aimed to eliminate misconceptions and replace them with scientifically correct and acceptable knowledge.

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## ИСТРАЖУВАЊЕ ЗА КОРИСТЕЊЕТО НА ТРИТЕ НИВОА НА РАЗМИСЛУВАЊЕ И ПРЕТСТАВУВАЊЕ

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Во трудот се претставени резултатите од истражување посветено на евентуалното присуство на погрешни претстави (мисконцепции) коишто се во врска со трите нивоа на претставување, односно разбирање (макроскопското, суб-микроскопското и симболичното).

Инаку, мисконцепциите можат да бидат формирани претходно, пред формално да започне процесот на поучување (*прејиконцепции*), но може да потекнуваат и од самиот наставен процес (*училишни мисконцепции*). Многу училишни мисконцепции се должат на фактот што учениците не прават разлика меѓу трите нивоа на размислување. Мисконцепциите што се резултат на мешање на овие три нивоа во хемијата се многу распространети и тешко се искоренуваат.

Во нашето истражување е направена анализа на точните и погрешните одговори на учениците на тестовите. Дадена е листа на мисконцепции што се забележани во одговорите на прашањата од тестовниот материјал кај испитуваните ученици, како и извадоци од спроведените интервјуа како доказ за размислувањата на учениците.

**Клучни зборови:** три нивоа на размислување/претставување; мисконцепции; настава по хемија; интервјуа