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Review

Structure of Matter – Diagnosis of Misconceptions and Challenge

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Abstract: Students at schools and universities may know formulae and chemical equations, but are weak in mental models according the structure of metal- and salt crystals. Especially concerning ions as particles in solid salts or in salt solutions they show a lot of misconceptions, i.e. NaCl molecules in rock salt or Na-O-H molecules in sodium hydroxide solution. One way to challenge those misconceptions can be a periodic table containing symbols of atoms and ions on the base of Daltons atomic model, showing atoms and ions by spheres of different sizes. Combining metal atoms "left and left in PSE" to giant structures will show structures of pure metal crystals and alloys, combining nonmetal atoms "right and right in PSE" to molecules will show molecular structures of volatile substances, combining ions "left and right in PSE" will show ionic lattices of salt crystals. With those steps in early chemistry education the understanding of salts and electrolyte solutions will be scientifically correct – misconceptions should be minimized.

INTRODUCTION

Teaching chemistry for chemists at universities seems easy: you have to deal with well-known textbooks of General chemistry, with Inorganic, Organic and Physical chemistry - mostly in this order. Teaching chemistry education for chemistry teachers is a difficult subject - there are not many textbooks, there is no special order of all topics. One suitable idea to teach chemistry education or chemistry didactics at universities is the "Pie chart" of Figure 1. Within chemistry education, many researches are talking about misconceptions of pupils at schools. A chemist has not to consider them, but the chemistry teacher should know the misconceptions to avoid them, and to find lessons to prevent from those well-known misconceptions.

Therefore the topic "Learners ideas and misconceptions" is one of the biggest sectors (see Fig.1) – it may be taught as a first chapter in a lecture and is reflected in the following paper.

"At last I found a lecture worth to come up early in the morning; excellent examples and experiments of teaching chemistry; now I know what chemistry education means and why it is so important for my studies; good to have the clear concept of the 'pie chart' from the beginning of all lectures" (Barke *et. al.*, 2012). These comments of would-be-chemistry teachers show that the lectures of chemistry education in our Institute at University of Muenster are helping them very much for their first steps to think about teaching chemistry at school.

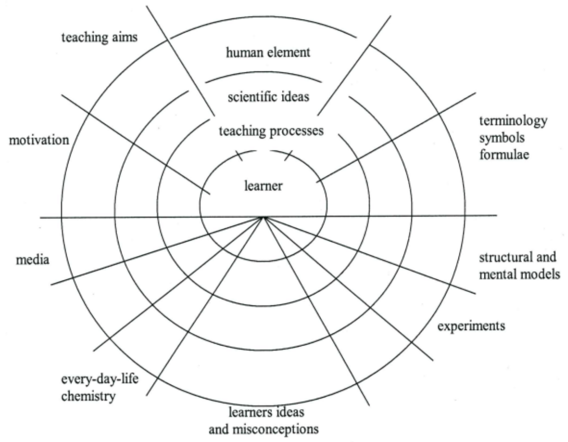

Figure 1. Main subjects of a lecture in chemistry education, "pie chart" metaphor (Barke *et. al.*, 2012).

The most important subjects of the lectures in one semester can be presented in a kind of "pie chart" (see Fig. 1): "Learners ideas and misconceptions; experiments; structural and mental models; terminology, symbols and formulae; every-day-life chemistry; media; motivation; teaching aims" (Barke *et. al.*, 2012). Because we want to give much emphasis to the "learner", she or he is therefore placed in the centre of the diagram. Secondly, "scientific ideas" should be reflected in association with appropriate "teaching processes" for the learner. Finally there should be reflections on the "human element" or the "chemistry contexts" (Mahaffy *et. al.*, 2006).

In our experience, students like the subject "learners ideas and misconceptions" very much. At the beginning of courses in chemistry education, would-be-chemistry teachers are really not clear with "preconcepts" and "misconceptions", with the existence of these concepts in the mind of young people – sometimes also in their own mind. They don't have the idea how important it is to know more about these concepts and how to integrate them into chemistry education at school. Therefore we published the book "Misconceptions in Chemistry" (Barke *et. al.*, 2009) for all who are studying chemistry for chemistry teaching or are already teaching chemistry at school. We also want it, in the sense of Professor Jung, a physics educator in Germany: "One should really write a book on diagnosing misconceptions and give it to all teachers". The psychologist Langthaler made similar comments: "If you, as a teacher, would have more diagnostic abilities and tools, many problems with your students would never even arise".

In planning coursework in the past few decades, teachers were under the impression that young pupils are bringing hardly any knowledge of science. Therefore, teachers had only to decide how to plan a lecture in order to transmit scientific ideas to their pupils, perhaps incorporating laboratory experiments or new technology-based methods.

However, latest studies in science education show that children and adolescents have many images and ideas about nature and their own surroundings: in the area of combustion they have mental models according to a destruction concept instead of the conservation of mass, in the area of gases children are thinking that gases have no mass or density, in the area of substances they think that substances can change the color: "Copper roofs on churches are changing from red to green, silver spoons are changing to black color".

Research of students' conceptions in chemistry is based on the constructivist approach to learning, in which students are supposed to construct their own cognitive structure. According to this approach, learners before, during and after instruction generate their own meaning based on their background, attitudes, abilities, experiences etc. As long as students construct or build their own concepts, their constructions differ mostly from the scientific ones. These different concepts are variously described by different researchers as: misconceptions, alternative conceptions, naïve beliefs, erroneous ideas, private versions of science, personal models of reality, spontaneous reasoning, developing conceptions, misunderstanding, mistakes, misinterpretation of facts, personal constructs and persistent pitfalls - to name just a few (Blosser, 1987; Elizabeth, 1990; Eylon and Linn, 1988; Fensham *et. al.*, 1994; McGuigan and Schilling, 1997; Nakhleh and Mary, 1992; Wandersee *et. al.*, 1994). The term "misconceptions" is used for the simple reason that researchers refer to it more often.

In order to promote successful learning or at least to simplify it, science educators should diagnose which preconceived images and explanations students hold. In this regard, Treagust (1988) suggests using specific questionnaires to diagnose misconceptions of content and basic ideas: "By using a diagnostic test at the beginning or upon completion of a specific science topic, a science teacher can obtain clearer ideas about the nature of students' knowledge and misconceptions in the topic" (Treagust, 1988).

With this knowledge, teachers are better able to plan their own questionnaires and interviews in order to find out specific preconceptions and misconceptions of their students. Teachers become more aware of such misconceptions and are able to discuss them in their classrooms. Once the alternative conceptions of the students have been identified, the teacher has to decide how to deal with them: giving the scientific idea first and then discussing misconceptions, or go over students' misconceptions first, make them uncomfortable with their own ideas and instruct the scientific concept afterwards (Gilbert *et. al.*, 2002).

Gabel (1999) found out that many teachers are not familiar with or do not acknowledge the science education research regarding misconceptions. Therefore, they do not intend to incorporate them into their lecture plan: "Probably nine out of ten instructors are not aware of the research on student misconceptions, or do not utilize ways to counteract these misconceptions in their instruction". Gilbert *et. al.* (2004) call upon all teachers, not only to increase their awareness of the diagnostic methods available for finding misconceptions, but also to implement them in their lessons. They also suggested that teachers should be aware of these diagnostic tools during their teacher-training curriculum: "The pre-service and in-service education of prospective and experi-enced chemistry teachers can play a crucial role in bridging the gap between chemical education research and classroom practice". In this regard, they point out "increasing chemistry teachers' awareness of chemical education research, improving the use of chemical education research findings and involving chemistry teachers in chemical education research" (Gilbert *et. al.*, 2004).

STUDENTS' MISCONCEPTIONS AND HOW TO OVERCOME THEM

Misconceptions are not only to be observed of today's children or students – even scientists and philosophers developed and lived with many misconceptions in the past: see the Phlogiston Theory of the German scientist Stahl in the 17th century (Barke *et. al.* (2009). Historical concepts and their changes are very interesting: as the early scientists the young students today develop their own ideas by similar observations e.g., the destruction concept with regard to combustion. Ideas that are developed without having any prior knowledge of the subject are not necessarily wrong - they can be described as **preconcepts** instead of misconceptions.

Increasingly however, researchers are finding alternative conceptions in advanced courses also. Because they cannot be only attributed to the students but mainly caused by inappropriate teaching methods and materials, they can be called **school-made misconceptions**. They are clearly different from preconcepts that tend to be unavoidable. Inappropriate teaching methods can be stopped by keeping teachers up-to-date in their subject through advanced education.

One should attempt to find important preconcepts and school-made misconceptions and discuss them with pre-service and in-service teachers. Another important task is to make suggestions of instructional **strategies to improve**

lessons, which will lead to challenge preconcepts and school-made misconceptions: recommending alternative strategies to the traditional approaches, setting up convincing laboratory experiments, using more structural models and mental models, or new technology-based methods etc.

Students' preconcepts. Self-developed concepts made by students do not often match up with today's scientific concepts. One does not take into account that these young folks, through observation, come up with their own mostly intelligent ideas of the world. In this sense, they are in good company with ancient scientists and natural philosophers: they also used their observation and logic in order to develop their ideas. Often, these scientists and philosophers did not use additional experiments to back up their theories.When students talk about combustion, saying that "something" disappears and observe that the remaining ash is lighter than the original portion of coal or wood, then they have done their observation well and have come up with logical conclusions - this is why we cannot describe their conclusions as incorrect. Therefore the teacher has to demonstrate convincing experiments according to the fact that colorless gases are formed by the combustion of a candle, of wood or paper: carbon dioxide and water steam.

In the same sense the following examples of pupil's preconcepts will show that teachers experiments, models and explanations are highly needed to come up with the scientific concept:

- the sun revolves around the earth,
- a puddle is sucked up by the sun's rays,
- the wood of a tree comes from the soil.

Sun and earth. Most children's first experiences regarding the sun are accompanied by comments made by their families and neighbors: "Look, the sun will rise in the morning, at midday it will be at its highest point and in the evening it will set". Observations regarding sunrise, sunset, its own cycle and the common manner of speech regarding the sun must lead the child to the idea: "The sun cycles around the earth". In some of her interviews, Sommer (2002) even comes across the idea of the earth as being a disc: "Children imagine the earth to be a disc over which the sky stretches parallel. The sun, the moon and the stars are to be found in the sky; there is no universe" (Sommer, 2002).Greek natural philosophers developed their ideas 2000 years ago. Ptolemaeus especially imagined the earth to be at the center of everything and pondered: "The sun moving around the earth". It was at the end of the 16th century that Copernicus, after exact observation of the movement of the planets, came up with the heliocentric image of the earth: "The earth is one of the sun's many planets, like these planets, the earth is revolving in a particular pathway around the sun and it also revolves on its own axis". Considering the uproar of the church at that time and the ensuing inquisitions, one can imagine how stable Ptolemaeus' theory was present in the minds of people of the time. It was the real wish of the church to keep people in this ignorance: The earth was supposed to be the center of the universe.

Children and adolescents often, through their own observations, come up with similar concepts like Ptolemäus, of course – there is no way to make discoveries like Copernicus and to develop the heliocentric view of the earth. Teachers have to use the best methods and technology, e.g. a planetarium, in order to convince the kids to free themselves from their original ideas and to accept that the earth is revolving around the sun.

In order to have convincing lessons, it is important that pupils have enough opportunities to first express and compare their ideas of the universe. Only after children are feeling uncomfortable with their ideas the new and current worldview should be introduced. The children should realize that their view of the world is also quite common and even scientists in the past believed that "the sun moves around the earth". Good teaching with models like moving spheres in a planetarium should finally convince children of the revolving earth.

Puddles and sun rays. Through conversations with elementary school children regarding the disappearance of puddles on a sunny day, it is obvious that they believe that the sunrays "soak up the water", that "water disappears to nothing". When asked, many teachers admit that they find this explanation "cute" and often do not bother to correct or discuss it: they let the children be with their "sunray theory" and their view of the "elimination of water".

If, on the other hand, the teachers would carry out experiments showing the vaporization of water and the resulting condensation of the steam to liquid water, the scientific view could be started. If one also introduces the idea of particles and the mental model of increasing movement of the water particles through heat, a child would much better understand that the water particles mix with air particles and therefore remain in the air.

They, furthermore, would understand that particle movement and diffusion of energy-rich particles are responsible for the evaporation of water. This would lead the children to a logical understanding of the conservation of mass for later science lessons and understanding chemical reactions, especially regarding combustion. It is necessary however, that children can express their own view about the "disappearance of water" before they learn the scientific concept. To be convinced by the scientific concept they should look to demonstrated or self-done experiments and compare with their own view. Following these discussions after more experiences with evaporation and condensation of water children may realize their conceptual change.

Wood and earth. "When people are given a piece of wood and asked how the material got into the tree, they commonly reply that most of it came from the soil" (Bark *et. al.*, 2009). Even though, in biology, the subject of photosynthesis is taught with the use of carbon dioxide, water, light and heat for the synthesis of sugar and starch, still many students when asked where wood comes from, reply: "from the soil". Most students seem to have their knowledge in special "compartments" of their brain. They do not link them to their every-day life understanding: "Presumably most of the graduates would have been able to explain the basics of photosynthesis (had that been the question), but perhaps they had stored their learning about the scientific process (where carbon in the tree originates from gaseous carbon dioxide in the air) in a different compartment from their 'everyday knowledge' that plants get their nutrition from the soil" (Taber, 2002).

This example should indicate that preconcepts can even still be used for a subject when the related lectures have dealt with the appropriate scientific idea. When one forgets or deliberately avoids making connections between this newly attained knowledge and well-established observations, the new scientific knowledge will not stay stable – the learner is going back to his or her previous preconcepts:

both, preconcept and scientific thinking are stored in “compartments”, in separated areas of the cognitive structure.

Teachers cannot automatically assume that in a particular lesson any preconcepts regarding this lesson will appear. It is necessary to diagnose such preconcepts and to plan a lesson which integrates new information with these concepts. If the lesson is about photosynthesis it would be advisable to bring in everyday aspects, that wood is made up of carbon dioxide and water steam from the air, that starch or sugar molecules are made up of carbon dioxide and water molecules. One could emphasize that plants need the earth in order to transport minerals from the roots to the branches but that, as hard as it is to believe, the solid and massive wood develop due to chemical reactions of colorless gases. Again, one could point out that even ancient scientists believed of the historical humus theory and could not understand when the German Justus von Liebig experimentally verified the photosynthesis in the middle of the 19^{th} century.

School-made misconceptions. When students get involved in a subject matter of advanced courses that is more difficult, a different type of problem arises: school-made misconceptions. Due to their complexity and difficulties in teaching these subjects, it is not often possible to address certain themes in a way to understand them completely. Despite competent and qualified teachers, occasionally questions remain open and problems are not really solved for a full understanding according the actual scientific concept: school-made misconceptions are developing. A few examples should illustrate this.

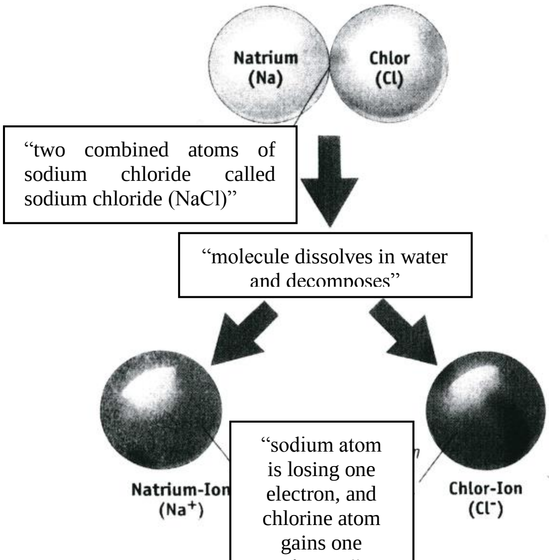

Figure 2. Today’s misconceptions about common salt and salt solution (Gerlach, 2004).

Composition of salts. A famous example of school-made misconceptions of our students arises from the Dissociation Theory of Arrhenius. In 1884, he postulated that "salt molecules are found in solid salts as the smallest particles and decompose into ions by dissolving in water”. Later with the concept of electrons, the misconception that “atoms of salt molecules form ions through electron exchange” was born. Today, experts recognize that there are no salt molecules, that ions exist all the time – even in the solid salt. By dissolving the solid salt, water molecules surround the ions, hydrated Na^+(aq) ions and Cl^-(aq) ions are moving free in the salt solution.

Amazingly one can observe that even today the historic misconceptions are quite common: “Sodium chloride consists of sodium and chlorine atoms. Each chlorine atom takes an electron from the sodium atom so the chlorine atom will have a negative electrical charge, the sodium atom a positive one” (Gerlach, 2004). Also a magazine for young students - published in the year 2004 (Welt der Wissenschaft) - contains the same misconceptions (see Fig. 2).

In the related subject of chemical bonding, one elaborates mostly on electron-pair bonding and only briefly on ionic bonding. The result is that students will not have any lasting concept of ions in an ion lattice or in salt solutions. Regarding the question which particles are found in mineral water which contains calcium chloride, many students are answering “Cl-Ca-Cl molecules” (Barke *et. al.*, 2003).

In this case, misconceptions have been developed during lessons - these misconceptions are school-made! Such misconceptions even occur if ions in the recommanded issue of electrolysis of salt solutions have been taught (Hilbing and Barke, 2004).

Chemical reactions. It is traditional in chemistry lessons to separate chemical reactions from physical processes. The formation of metal sulfides from its elements by releasing energy is described in every case as a chemical reaction. In contrast, the dissolving of substances in water is often regarded as a “physical process” because matter “does not actually change”, the dissolved substance can be regained through “physical” separation. If one takes sodium hydroxide and dissolves it in a little water, a colorless solution appears and releases heat; the solution conducts electricity and produces a high pH value. This solution is of course a new material and the production of heat shows an exothermic reaction. From this example one can see that it does not make any sense to separate “chemical” and “physical” processes (Barke and Schmidt, 2004). If we routinely continue to do this in the sense of “we’ve always done it this way”, automatic school-made misconceptions would arise based on teaching traditions in school.

Composition of water. “Water is composed of hydrogen and oxygen” (Barke *et. al.,* 2009) - one often hears these or similar statements in classrooms about compounds, which supposedly “contain” certain elements. These expressions arise from the 19^{th} century when it was common to analyze and find out which elements make up certain compounds. Insiders know the background of these statements – for novices however, they will lead to school-made misconceptions: students would associate the substances copper and sulfur in the black copper sulfide, particularly as experiments show that one can remove these elements out of copper sulfide. It would be better, in introductory classes, to point out that the metal sulfides could be produced from metals and sulfur or to show that one can obtain the elements from the compound. Later on, if one is aware of “atoms” and “ions” as the smallest particles of matter, one can expand on these statements, that the compound “contains” special atoms or ions, that one water molecule contains two H atoms and one O atom connected and arranged in a particular spatial structure. But the pure sentence “water contains hydrogen and oxygen” will develop school-made misconceptions!

Students’ concepts and scientific language. One should be aware that newly acquired concepts are not sustainable forever and can be easily affected when lessons are over. Concepts regarding life in general, which have been sustained over several years, are more deeply rooted than new concepts, which have more recently been picked up in lessons. It is therefore necessary to repeat and intensify these newly "acquired" concepts in order to reach their deep-rooted integration in the minds of students.

Teachers should also be aware that students will have certain insecurity when discussing these new scientific concepts with friends or relatives – they will resort to slang or every-day language. Although they know about conservation of mass they will have to deal with terms like "the fuel is gone" or "spots are removed" (Barke *et. al.*, 2009). One should try to help students begin to reflect on the use of such every-day language and to describe the reaction of fuel with oxygen to form carbon dioxide and water, or to point out that the fat of spots is dissoved in gasoline or ethanol. Then, they could discuss these thoughts with friends or relatives – in this sense, they would become competent and improve the much wished ability to be critical.

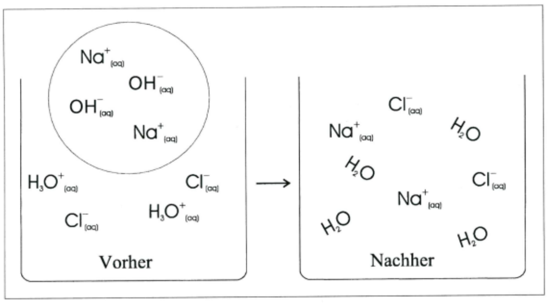

Figure 3. Mental model of the hydrochloric acid and sodium hydroxide reaction (Barke *et. al.*, 2009).

Many school-made misconceptions occur because the specific terminology and the scientific language are not clearly differentiated. Especially for involved substances, particles and chemical symbols, it is not easy to apply the specific terminology. If the neutralization reaction is purely described only through the usual equation $HCl + NaOH \rightarrow NaCl + H_2O$, then students have to memorize it with nearly no understanding. To give them the chance to develop an acceptable mental model one has to use the ions as smallest particles and to offer a mental model of the neutralization (see Fig. 3). After pointing out that Na^+(aq) ions and Cl^-(aq) ions are "spectator ions" and have nothing to do with the reaction, students will better accept the real neutralization reaction with the equation: $H_3O^+(aq) + OH^-(aq) \rightarrow 2\ H_2O(aq)$.

Without these considerations on the "submicro level" (see Fig. 4) students mostly come up with mental models of H-Cl molecules and of Na-O-H molecules, or come up with the "formation of salt" or with the formation of "Na-Cl molecules". If they discuss ions in hydrochloric acid and sodium hydroxide solution, and if one would sketch them in the form of model drawings (see Fig. 3), it would probably be possible for the students to develop the right mental model and scientific language at this level.

Johnstone (2000) elucidated this connection (see Fig. 4): "We have three levels of thought: the macro and tangible, the submicro atomic and molecular, and the representational use of symbols and mathematics. It is psychological folly to introduce learners to ideas at all three levels simultaneously. Herein, lay the origins of many misconceptions. The trained chemist can keep these three's in balance, but not the learner" (Johnstone, 2000). Gabel (1999) points out, that teachers like

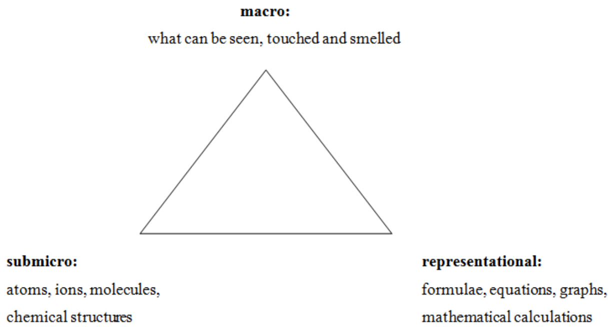

Figure 4. Three levels of representing matter in a "Chemical Triangle" (Johnstone, 2000; Gabel, 1999).

to go from the macro level directly to the representational level and that students have no chance to follow in this way: "The primary barrier to understanding chemistry is not the existence of the three levels of representing matter. It is that chemistry introduction occurs predominantly on the most abstract level, the representational level" (Gabel, 1999).

The misconceptions concerning the neutralization example above could be avoided if, after carrying out the experiment, one would describe the observations at the **macro level**. By interpreting these observations, one could ask questions regarding the particles related to the reaction. These could be answered using ions and ionic symbols at the **submicro level**. It would be even better if one uses model drawings related to the hydrated ions in hydrochloric acid and in sodium hydroxide solution (Fig. 3). Only when the reaction of H^+ (aq) ions with OH^- (aq) ions to form H_2O molecules has been made clear on the submicro level, the **representational level** and the chemical symbols will be successfully attained. On this level other reaction equations may be written or related calculations could be done.

EFFECTIVE STRATEGIES FOR TEACHING AND LEARNING

"All teaching should begin with childrens' experiences - each new experience made by child-ren in a classroom is organized with the aid of existing concepts" (Ausubel, 1974). "Without explicitly abo-lishing misconceptions, it is not possible to come up with scientific sustainable concepts" (Piaget and Inhelder, 1971). "Lessons should not merely proceed from ignorance to knowledge but should rather have one set of knowledge replace another. Chemical education should be a bridge between students' preconcepts and today's scientific concepts" (Pfundt, 1975).

These statements make it quite obvious that teachers should not assume their students enter their classroom with no knowledge or ideas. A lesson, which does not take into account that students have existing concepts, usually leads them to barely following the lecture until the next quiz or exam. After that, newly acquired informations will gradually be forgotten: students tend to return to their old and trusted concepts.

Nowadays, teachers and pedagogy experts agree that one should be aware of student's ideas before the "bridge can be successfully made between the preconcepts and the scientific ones" (Pfundt, 1975). Therefore, an important goal is to allow students to express their own preconcepts during a lesson or, in the attempt to introduce new subject matter in a lesson, to let them be aware of inconsistencies regarding their ideas and the up-to-date scientific explanation. In this way, they can be motivated to overcome these discrepancies. Only when students feel uncomfortable with their ideas, and realize that they are not making any progress with their own knowledge they will accept the teacher's information and thereby build up new cognitive structures (Duit, 1996).

If a student does not believe that "sunrays absorb a puddle", he or she can then, using the particle model of matter with the idea of moving particles, successfully develop a scientific concept about the evaporation of water. There is an extension of the already established particle concept taught in lessons before – a **conceptual growth** appears.

Should yet another student believe that "sunrays soak up the puddle", perhaps through having learned it at the elementary school, then he or she is unlikely to want to let go of this concept. Even if lessons about the particle model of matter are plausible and logical, he or she is unlikely to integrate it or to swap it against the "sun's absorption ability". If the teacher helps to understand the scientific concept through the introduction of self-moving particles, then this student has to take a huge step in releasing his old ideas: a **conceptual change** has to develop in his cognitive structure. To push this development to a new mental model it would be advantageous to do his or her own active experiments and model drawings according the particle model of matter and self-moving particles.

Taber came up with the picture of a "**Learning Doctor"** as a means of discovering individual misconceptions and a suitably-related science class regarding conceptual growth or conceptual change (Taber, 2002): "A useful metaphor here might be to see part of the role of a teacher as being a learning doctor: a) diagnose the particular cause of the failure-to-learn; and b) use this information to prescribe appropriate action, designed to bring about the desired learning…… Two aspects of the teacher-as-learning-doctor comparison may be useful. First, just like a medical doctor, the learning doctor should use diagnostic tests as tools to guide action. Secondly, just like medical doctors, teachers are 'professionals' in the genuine sense of the term. Like medical doctors, learning doctors are in practice (the 'clinic' is the classroom or teaching laboratory). Just as medical doctors find that many patients are not textbook cases, and do not respond to treatment in the way the books suggest, so many learners have idiosyncrasies that require individual treatment" (Taber, 2002).

In a project in progress, Barke and Oetken agree to diagnose preconcepts and school-made misconceptions, but in addition they will integrate them into lectures to develop sustainable understanding of chemistry (Barke and Oetken, 2008). Hence being convinced that preconcepts and school-made misconceptions have to be discussed in chemistry lectures, there are two hypotheses to influence instruction:

1. One discusses first the misconceptions and come up with the scientific explanation afterwards, 2. One instructs first the scientific concept and afterwards students compare it with their own or other misconceptions from literature.

Oetken and Petermann (2008) are taking the first hypothesis for their empirical research concerning the famous preconcept of combustion: "Something is going into the air,…..some things are going away". In their lectures they showed the burning of charcoal and discussed alternative conceptions like: "charcoal is destroyed, nothing remains". Afterwards they used the idea of a cognitive conflict: little pieces of charcoal are deposited in a big round flask, the air is substituted by oxygen, the flask is closed by an air balloon and the whole thing is weighed using analytical balance. The flask is heated at the area of the charcoal; the pieces ignite and burn until no charcoal remains. The whole flask is weighed again: the scales afterwards present the same mass as before.

Working with this cognitive conflict the students find out that there must be a reaction of carbon with oxygen to form another invisible gas. After testing this gas by the well-known lime water test, one can derive: the gas is carbon dioxide. Presenting misconceptions first and instructing afterwards the scientific concept can enable students to compare and investigate by themselves what is wrong with statements like "some things are going away" or "combustion destroys matter, mass is going to be less than before". Integrating preconcepts in lectures by this way will improve sustainable understanding of chemistry.

Barke, Doerfler and Knoop (2007) planned lectures according to the second hypothesis in middle school classes: 14 - 16 years old students were supposed to understand acids, bases and neutralization. Instead of taking the usual equation "HCl + NaOH → NaCl + H_2O" for the reaction, H^+(aq) ions for acidic solutions and OH^-(aq) ions for basic solutions were introduced, the ionic equation of the *formation of water molecules* was explained: "H^+(aq) ions + OH^-(aq) ions → H_2O molecules". Later it was told that with regard to the neutralization other students are thinking of a "*formation of salt*" because "NaCl is a product of this neutralization". Students discussed this idea with the result that no solid salt is formed by the neutralization, Na^+(aq) ions and Cl^-(aq) ions are not reacting but only remaining by the neutralization.

Figure 5. Concept Cartoon according concepts of the neutralization reaction (Temechegn and Sileshi, 2004).

So students were first instructed by the scientific idea of the new topic, and afterwards confronted with well-known misconceptions. By comparing the scientific idea and the presented misconceptions the students could intensify the recently gained scientific concept. Data are showing that this hypothesis is successful in preventing misconceptions.

Temechegn and Sileshi (2004) are proposing another way of discussing misconceptions through concept cartoons. For a special subject or experiment they take three or four persons and let them make proposals for the right explanation. In case of the neutralization reaction they ask: “What is the right model of substances after the reaction?” They offer four different statements according to the most known misconceptions (see Fig. 5), the right answer is of course: “Na^+(aq) ions, Cl^-(aq) ions and H_2O molecules”. Students may be tought by the scientific concept first and can study afterwards this concept cartoon. They will find the right answer and should discuss the three wrong ones. They will apply their new scientific concept and will find out what is wrong with the other three statements.

But the concept cartoon may also be discussed first for diagnosis of misconceptions held by the students: they compare all statements of the concept cartoon and decide which one is matching with their own mental model. By this way the teacher knows how his students are thinking and how he should prepare his lessons. With the question of the cartoon “what do you think” the teacher can get even more different thoughts about the subject or experiment he is presenting. The concept cartoon may accompany all the lessons concerning the subject. Taking the new aquired scientific concept and explaining the other alternative answers of the concept cartoon with their new knowledge students will not return to the alternative answers - and will avoid these misconceptions.

Last not least the authors also claim to take concept cartoons for assessment (Temechegn and Sileshi, 2004): finishing the topic of neutralisation the teacher offers the unknown concept cartoon (Fig. 5), asks for the right answer and for explaining the other ones.

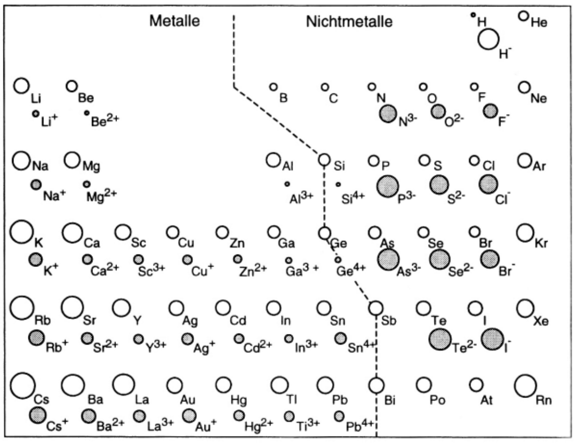

Figure 6. Atoms and ions as basic particles of matter (part of the PSE) (Barke *et. al.*, 2012).

Table 1. Chemical structures by combining atoms and ions (Barke *et. al.*, 2012).

1. Metal atoms “left and left in PSE”: (metal structure)	x Ag → Ag_x
2. Nonmetal atoms “right and right in PSE”: (molecules)	1 C + 4 H → CH_4
3. Ions “left and right in PSE”: (ionic structure)	Na^+ + Cl^- → Na^+Cl^-(s)

With regard to teach ions and ionic bonding **Strehle and Roelleke** (2007) and **Wirbs** (2002) evaluated lectures through the introduction of “atoms and ions as basic particles of matter” on base of Dalton’s atomic model (Fig. 6). For introducing chemical structures of important substances needed in chemistry lectures giant structures of metal crystals and salt crystals are reflected, also the structure of some molecules. If the Periodic Table of “atoms and ions” (Fig 6) is devided in metal atoms and ions “left in PSE”, and in nonmetal atoms and ions “right in PSE” (H atom and hydride ion belongs to this right side!) some rules are helpful in combining the basic particles of matter and visualizing the most important chemical structures (see Table 1). Following this way students are able to develop mental models according important chemical structures - through this strategy of combining ions and using ion symbols most of the related world-wide found misconceptions can be prevented!

The Structure-oriented approach (Barke *et. al.*, 2012) offers not only a way to understand chemistry through chemical structures, but also a way to improve spatial ability of students and specially the ability of girls. **Temechegn** (2001) could show that in Germany and Ethiopia boys are better than girls in interpreting chemical structures, that chemistry lectures with spatial models of metal and ionic structures and molecules are helpful to develop spatial ability.

In his empirical research **Sopandi** (2004) has shown that there are good correlations between spatial ability of students and their understanding of chemistry. The conclusion seems to be: take structural models of matter and you will not even improve spatial ability as an important ability for many subjects in school and for many professions after school you will also develop a good understanding of chemistry and avoid school-made misconceptions!

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Summary/Sažetak

Učenici, đaci i studenti u školama i na univerzitetima mogu znati formule i hemijske jednadžbe, ali mogu imati problema kod mentalnih modela koji se tiču kristalne strukture metala i soli. Osobito kada se radi o ionima kao česticama u čvrstom stanju ili u otopini soli, pokazuju mnoge pogrešne predodžbe (miskoncepcije), kao što su, na primjer molekule NaCl u čvrstoj kuhinjskoj soli, ili Na-O-H molekule u otopini natrijevog hidroksida. Jedan od načina da se prevaziđu ove miskoncepcije može biti Periodni sistem elemenata koji sadrži simbole atoma i iona na bazi Daltonovg atomskog modela, koji prikazuje atome i ione kao loptice različitih veličina. Kombiniranje atoma metala "lijevo i lijevo" u PSE u velike strukture pokazat će kristalne strukture čistih metala i legura, kombiniranje atoma nemetala "desno i desno u PSE" u molekule pokazat će molekularne strukture isparljivih tvari, kombiniranje iona "lijevo i desno u PSE" pokazat će ionske kristalne strukture soli. Ovim koracima u ranom poučavanju hemije, razumijevanje otopina soli i elektrolita bit će znanstveno ispravno - miskoncepcije bi se trebale umanjiti.