Chapter 2
Students' Misconceptions and How to Overcome Them

Misconceptions are not only to be observed in today's children or students – even scientists and philosophers developed and lived with many misconceptions in the past (see Chap. 1). Historical concepts and their changes are very interesting because similar ideas can help our students today: just like early scientists did they develop their own concepts by similar observations e.g., in regard to combustion. Ideas that are developed without having any prior knowledge of the subject are not necessarily wrong but can be described as **alternative**, **original** or **preconcepts** [1]. Every science teacher should know these preconcepts for his or her lessons – this is why many empirical researchers are working all over the world.

Increasingly however, researchers are also finding chemical misconceptions in advanced courses. 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 as many 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 preconceptions and school-made misconceptions: recommending alternative strategies to the traditional approaches, setting up convincing laboratory experiments, using more structural models or new technology-based methods etc.

2.1 Students' Preconcepts

Self-developed concepts made by students do not often match up with today's scientific concepts. One fails to take into account that these young folks have often, through observation, come up with their own mostly intelligent ideas of the world. In this sense, they are in good company considering that ancient

H.-D. Barke et al., *Misconceptions in Chemistry*, DOI 10.1007/978-3-540-70989-3_2,

scientists and natural philosophers also used their power of observation and logic in order to shape their ideas. Often, these scientists and philosophers did not use additional experiments to back up their theories (see Chap. 1).

When students talk about combustion, saying that "something" disappears and observe that the remaining ash is lighter than the original portion of fuel, then, they have done their observation well and have come up with logical conclusions. This is why we cannot describe their conclusions as incorrect but rather as:

– original or pre-scientific ideas,
– students preconceptions or alternative ideas,
– preconcepts.

It is common to come across several preconcepts at the beginning stages of scientific learning at the elementary, middle and high school levels of chemistry, biology and physics. Before conclusions are systematically made regarding the important issues of chemistry in the following chapters, three general examples of a student's **preconcepts** will be presented:

– 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 this subject must lead the child to the idea: "The sun cycles around the earth". In some of her interviews, Sommer [2] 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" [2].

Greek natural philosophers developed their ideas 2000 years ago. Ptolemy especially imagined the earth to be at the center of everything and pondered: "The sun moves 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 Ptolemy's 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 Ptolemy, 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 young people have enough opportunities to first express and compare their ideas of the universe. Only after children feel 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 mixes 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 also 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 or students may realize their conceptual change (see Sect. 2.3).

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" [3]. 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 of biology lectures 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" [3].

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 separate areas of the cognitive structure.

Teachers cannot automatically assume that in a particular lesson any preconceptions regarding this lesson will appear. It is necessary to diagnose such concepts and, in the case of misconceptions, 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, 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 in the historical humus theory and could not understand when the German Justus von Liebig experimentally verified photosynthesis in the middle of the 19th century.

2.2 School-Made Misconceptions

When students get involved in a subject matter that is more difficult, a different type of problem arises: school-made misconceptions. Due to their complexity, it is not often possible to address certain themes in a cut-and-dry manner. Despite competent and qualified teachers, occasionally questions remain open and problems are not really solved for a full understanding: school-made misconceptions develop. A few examples should illustrate this.

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, and hydrated ions are not connected, they move freely in the salt solution.

Amazingly one can observe that even today – in the year 2004 – 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" [4]. A magazine for young students – published in the year 2004 [5] – contains the same misconceptions (see Fig. 2.1).

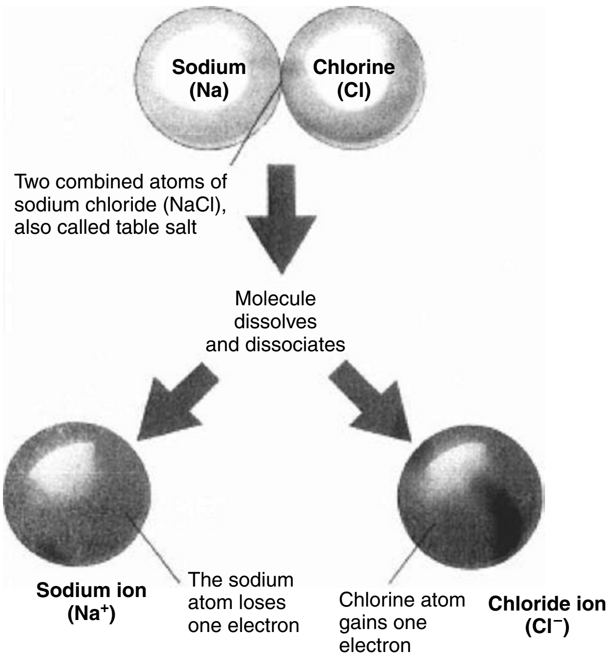

Fig. 2.1 Today's misconceptions about common salt and salt solution [5]

Also 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. Regarding the question which particles are found in mineral water which contains calcium chloride, many students answer "Cl-Ca-Cl molecules" [6]. In this case, misconceptions have been developed during lessons – these misconceptions are school-made! Such misconceptions even occur if ions in the recommended issue of electrolysis of salts have not been correctly taught [7]. In the cited publications and in the following chapters, suggestions and ways in teaching the issue of ions and ionic bonding in a more successful and effective manner will be presented.

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 in its original form through "physical" separation procedures. 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. Critical students regard this solution as being 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 the transformation of matter into "chemical" and "physical" processes [8]. 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" [1] – one often hears these or similar statements in classrooms about compounds, which supposedly "contain" certain elements. These expressions arise from a time 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!

2.3 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 anchae them in the minds of students.

Teachers should also be aware that students will be insecure 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" [1]. One should try to help students begin to reflect on the use of such every-day language. 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. Such abilities could certainly have a positive effect on society in that such scientific knowledge would not only be discussed in colloquial terms, but that the students could competently use the proper terminology and pass it on to friends and family.

Many school-made misconceptions occur because there are problems with the specific terminology and the scientific language, specially involved substances, particles and chemical symbols are not clearly differentiated. If the neutralization is purely described through the usual equation, $HCl + NaOH \rightarrow NaCl + H_2O$, then the students have no chance to develop an acceptable mental model that uses ions as smallest particles.

When questioned, on which the neutralization reaction is based, students mostly come up with mental models of H-Cl molecules and of Na-O-H molecules. If one would discuss both ion types in hydrochloric acid and sodium hydroxide solutions, and if one would sketch them in the form of model drawings [9], it would probably be possible for the students to develop the right mental model and scientific language at this level (see Chap. 7). This would also enable them to interpret the equation for the above reaction with the help of ionic symbols.

Johnstone [10] elucidated this connection (see Fig. 2.2): "We have three levels of thought: the macro and tangible, the sub-micro 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 in balance, but not the learner" [10]. Specially Gabel [11] points out that teachers like to go from the macro level directly to the representational level and that students have no chance of following this concept: "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 symbolic level" [11].

It appears to be particularly difficult even at secondary schools to make this transition from the macroscopic level directly to the representational level. This, again, leads to school-made misconceptions, students are mixing substances from the macroscopic level with particles from the sub-micro level: "hydrochloric acid is giving one proton" (instead of "one H_3O^+(aq) ion gives one proton"), "oxygen takes two electrons" (instead of "one O atom is taking two electrons"). On the one hand, the students do not see any connection between both levels, on the other hand it is left up to them to figure out which mental model they may choose concerning the sub-microscopic level: they are building up ideas on their own, mostly wrong ones.

The misconception 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

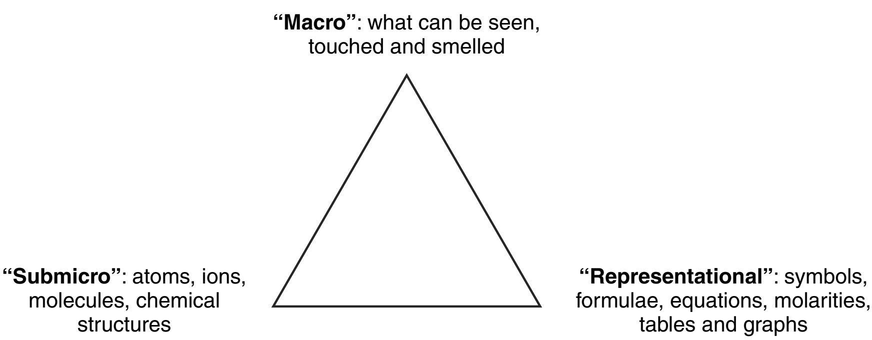

Fig. 2.2 "Chemical Triangle" according to Johnstone [9]

questions regarding the particles related to the reaction. These could be answered using ions and ionic symbols at the **sub-micro level**. It would be even better if one used model drawings related to the hydrated ions in hydrochloric acid and in sodium hydroxide solution [9]. Only when the reaction of $H^+(aq)$ ions with $OH^-(aq)$ ions to form H_2O molecules has been made clear on the sub-micro 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.

2.4 Effective Strategies for Teaching and Learning

"All teaching should begin with children's experiences – each new experience made by children in a classroom is organized with the aid of existing concepts" [12]. "Without explicitly abolishing misconceptions it is not possible to come up with scientific sustainable concepts" [13]. "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" [14].

These statements make it quite obvious that teachers should not assume their students enter their classroom with no knowledge or ideas whatsoever. A lesson, which does not take into account that students have existing concepts, usually enables them to barely following the lecture until the next quiz or exam. After that, newly acquired information 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" [14]. 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 will they accept the teacher's information and thereby build up new cognitive structures.

For the teaching process, it is therefore important to take students' developmental stages into account according to:

- student's existing discrepancies within their own explanations,
- inconsistencies between preconcepts and scientific concepts,
- discrepancies between preliminary and correct explanations of experimental phenomena,
- possibilities of removing misconceptions,
- possibilities of constructing acceptable and skilled explanations [15].

One should especially take into consideration that, regarding constructivist theories, it is only possible to change from preconcepts to scientific concepts if

- individuals are given the chance to construct their own learning structures,
- each student can get the chance to actively learn by himself or herself,
- "conceptual growth" can occur congruent to Piaget's assimilation, or even
- "conceptual change" can occur congruent to Piaget's accommodation [15].

If a student does not believe that "sunrays absorb a puddle" (see Sect. 2.1), 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" (see Sect. 2.1), 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 to the particle model of matter and self-moving particles (see Chap. 4).

Also the advancement from a destructive concept to a preservation concept – e.g., concerning the combustion or metal-oxygen reactions – would lead to such a change in the cognitive structure, to a conceptual change.

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 [3]: "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" [3].

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 [16]. For the past 20–30 years educators continue to observe nearly the same misconceptions of students, therefore they assume that related lectures at school are not changing much. 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 should first discuss the misconceptions and come up with the scientific explanation afterwards, 2. one instructs the scientific concept first and afterwards students compare it with their own or other misconceptions from literature.

Oetken and Petermann [17] use the first hypothesis for their empirical research concerning the famous preconcept of combustion: "Something is going into the air, (. . .) some things disappear". In their lectures they showed the burning of charcoal and discussed alternative concepts like: "charcoal disappear some ashes remain". 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 tightly closed and the whole thing is weighed using analytical balance. Pressing the stopper on the flask and heating the area of the charcoal, the pieces ignite and burn until no charcoal remains. The whole contents are 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 the scientific concept afterwards can enable students to compare and investigate by themselves what is wrong with statements like "some things disappear" 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; by comparing misconceptions with the scientific concept students will internalize the concept of combustion. More results in line with this hypothesis will come up in the future.

Barke, Doerfler and Knoop [18] 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 "$HCl + NaOH \rightarrow NaCl + H_2O$" 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 related that, with regard to neutralization, other students think 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 neutralization, Na^+(aq) ions and Cl^-(aq) ions do not react but only remain by the neutralization. These ions are therefore often called "spectator ions".

So students were first introduced to 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. Preliminary data show that this hypothesis is successful in preventing misconceptions concerning the neutralization reaction. There will be more empirical research as to whether this method is the most sustainable strategy for teaching and learning.

With regard to teaching about ions and ionic bonding **Barke, Strehle and Roelleke** [19] evaluated lectures in the sense of hypothesis two: by the introduction of "atoms and ions as basic particles of matter" based on of Dalton's atomic model (see Fig. 5.10 in Chap. 5) scientific ideas according to chemical structures of metal and salt crystals are reflected upon.

Using this method of instruction, all questions regarding chemical bonding are reduced to undirected electrical forces surrounding every atom or ion – no electrons or electron clouds are involved at this time. However, the **structure of elements and compounds** can be discussed because spatial models or model drawings are possible based on Dalton's atomic model (see Fig. 2.3). In the first two years of chemical education only the structure of matter should be considered (see Chaps. 4 and 5) – the detailed questions regarding chemical bonding should be answered later after the instruction of the nucleus-shell model of the atom or the ion. By combining ions to ionic lattices in salt structures students learn the scientific idea about the composition of salts: cations and anions, their electrical attraction or repulsion, their arrangement in ionic lattices. Through this strategy of combining ions and using ion symbols it is possible to prevent most of the related global misconceptions (see Fig. 2.1) (Chap. 5)!

Last but not least **Barke and Sileshi** [20] formulated a "Tetrahedral-ZPD" chemistry education metaphor as another framework to prevent students' misconceptions (see Fig. 2.4). "If chemical education is to be a discipline, it has to have a shape, structure, clear and shared theories on which testable hypotheses can be raised. At present we are still in some respects dabbling in chemistry education alchemy, trying to turn lead into gold with no clear idea about how this is to be achieved. Some factions proclaim a touchstone in some pet method such as Problem-Based Learning or Computer-Assisted Learning or Multimedia Learning or Demonstration, while others are dabbling in

Chemical Reaction

Macro level:	formation of new substances	↔	transfer of energy
Sub-micro level:	change of chemical structures	↔	change of chemical bonding
Mental models:	pattern of atoms, ions, molecules	↔	electrons, wave-particle, dualism
Media:	sphere packings, molecular structures		--------

Fig. 2.3 Chemical structure and bonding with regard to the chemical reaction [1]

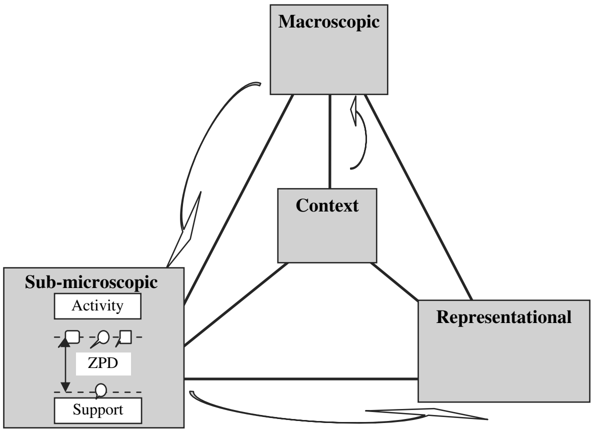

Fig. 2.4 Tetrahedral-ZPD chemistry education metaphor [20]

Conceptual Assessment, Microscale Labs, and fancy textbooks accompanied by teachers' guides. None of these things are bad, but what theory is driving them? Is there any evidence that they are achieving what they aim for? Are we any nearer to making gold?" [21].

To respond to such calls Sileshi and Barke – after reviewing the major chemistry education concepts – proposed the Tetrahedral-ZPD metaphor. This metaphor re-hybridizes the very powerful 3D-tetrahedral chemistry education concept proposed by Mahaffy [22]: macroscopic, molecular, representational, and human element. With the idea of the "Zone of Proximal Development (ZPD)" of social constructivist Vygotsky [23], ZPD should describe "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" [23].

The basic elements of this metaphor are what Shulman [24] has labeled "Pedagogical Content Knowledge (PCK)" integrated with contextual and research knowledge: "Pedagogy-Content-Context-Research Knowledge (PCCRK). Content knowledge refers to one's understanding of the subject matter, at macro-micro-representational levels; and pedagogical knowledge refers to one's understanding of teaching-learning processes; contextual knowledge refers to establishing the subject matter within significant social-technological-political issues; and research knowledge refers to knowledge of 'what is learned by student?', that is, findings and recommendations of the alternative conceptions research of particular topics in chemistry" [24].

Sileshi and Barke further conduct an empirical research to evaluate the effects of the Tetrahedral-ZPD Metaphor on students' conceptual change (see Fig. 2.4). Knowing that high school students in Ethiopia mostly memorize chemical equations without sufficient understanding, that they are not used to thinking in models, or developing mental models according to the structure of matter, new teaching material and worksheets for the application of the particle model of matter and Dalton's atomic model are prepared.

In pilot studies lasting for six weeks the research was carried out with an experimental-control group design: pre-tests and post-tests were used to collect data before and after the intervention. First results from the post-tests indicated that the students in the experimental group, taught with the new teaching material according to the structure of matter, show significantly higher achievement compared with the students in the control group: students' misconceptions in the experimental group after they were taught using the new teaching material based on Tetrahedral-ZPD, are less than in the control group. The main studies will follow.

References

1. Barke, H.-D.: Schuelervorstellungen. In: Barke, H.-D., Harsch, G.: Chemiedidaktik Heute. Lernprozesse in Theorie und Praxis. Heidelberg 2001 (Springer)
2. Sommer, C.: Wie Grundschueler sich die Erde im Weltraum vorstellen – eine Untersuchung von Schuelervorstellungen. ZfDN 8 (2002), 69
3. Taber, K.: Chemical Misconceptions – Prevention, Diagnosis and Cure. Volume I. London 2002 (Royal Society of Chemistry)
4. Gerlach, H.: Salz auf unserem Steak. Sueddeutsche Zeitung, Magazin. Stuttgart 2004, 34
5. Welt der Wissenschaft (deutsche Übersetzung). Bath, England, 2004 (Parragon), 34
6. Barke, H.-D., Selenski, T., Sopandi, W.: Mineralwasser und Modellvorstellungen. PdN-ChiS 52 (2003), H.2, 15
7. Hilbing, C., Barke, H.-D.: Ionen und Ionenbindung: Fehlvorstellungen hausgemacht! Ergebnisse empirischer Erhebungen und unterrichtliche Konsequenzen. CHEMKON 11 (2004), 115
8. Barke, H.-D., Schmidt, F.K.: Chemische Reaktionen und physikalische Vorgaenge: mit untauglichen Schubladen zur Nulleffizienz. MNU 57 (2004), 115
9. Barke, H.-D.: Das Chemische Dreieck. Unterricht Chemie 13 (2002), 45
10. Johnstone, A.H.: Teaching of chemistry – logical or psychological? CERAPIE 1 (2000), 9
11. Gabel, D.: Improving teaching and learning through chemistry education research: A look to the future. Journal of Chemical Education 76 (1999), 548
12. Ausubel, D.P.: Psychologie des Unterrichts. Weinheim 1974 (Beltz)
13. Piaget, J., Inhelder, B.: Die Entwicklung des raeumlichen Denkens beim Kinde. Stuttgart 1971 (Klett)
14. Pfundt, H.: Urspruengliche Erklaerungen der Schueler für chemische Vorgaenge. MNU 28 (1975), 157
15. Duit, R.: Lernen als Konzeptwechsel im naturwissenschaftlichen Unterricht. Kiel 1996 (IPN)
16. Petermann, K., Friedrich, J., Octken, M.: Das an Schuelervorstellungen orientierte Unterrichtsverfahren. CHEMKON 15 (2008), 110
17. Petermann, K., Oetken, M.: Das an Schuelervorstellungen orientierte Unterrichtsverfahren – exemplarische Vorstellung des Unterrichtsverfahrens an Hand einer Unterrichtseinheit zum Kohlenstoffkreislauf. Vortragsabstract, Wissenschaftsforum Chemie 2007, Universitaet Ulm. Frankfurt 2007 (GDCh)
18. Barke, H.-D., Doerfler, T.: Das an Schuelervorstellungen orientierte Unterrichtsverfahren: das Beispiel Neutralisation. CHEMKON 15 (2008)

19. Barke, H.-D., Strehle, N., Roelleke, R.: Das Ion im Chemieunterricht – noch Vorstellungen von gestern? MNU 60 (2007), 366
20. Sileshi, Barke, H.-D.: Chemistry Misconceptions: Evaluating Remedies Based on Tetrahedral-ZPD Metaphor. Muenster 2007 (Paper presented at the 3rd Symposium of Chemistry Education, University of Muenster)
21. Johnstone, A.H.: Chemistry teaching – Science or alchemy? Journal of Chemical Education 74 (1997), 268
22. Mahaffy, P.: The future shape of chemistry Education. Chemistry Education: Research and Practice 5 (2004), 229
23. Vygotsky, L.S.: Mind and Society: The Development of Higher Mental Processes. Cambridge 1978 (Harvard University Press)
24. Shulman, L.S.: Those who understand: Knowledge growth in teaching. Educational Researcher, 15 (1986), 4

Further Reading

bimbola, I.O.: The problem of terminology in the study of students' conceptions in science. Science Education 72 (1988), 175

Abraham, M.R., Wilkinson, V.M.: A cross-age study of the understanding of five chemistry concepts. Journal of Research in Science Teaching 31 (1994), 147

Boujaude, E.B.: The relationship between students' learning strategies and the change in their misunderstandings during a high school chemistry course. Journal of Research in Science Teaching 29 (1992), 687

Bowen, C.W.: Think-aloud methods in chemistry education. Journal of Chemistry Education 71 (1991), 184

Carr, M.: Model confusion in chemistry. Research in Science Education 14 (1984), 97

Driver, R.: Pupils' alternative frameworks in science. European Journal of Science Education 3 (1981), 93

Fensham, P.J., Garrard, J., West, L.W.: The use of concept cognitive mapping in teaching and learning strategies. Research in Science Education 11 (1981), 121

Garnett, P., Garnett, P., Hackling, M.: Students' alternative conceptions in chemistry: A review of research and implication for teaching and learning. Research in Science Education 25 (1995), 69

Gilbert, J.K., Watts, D.M.: Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. Research in Science Education 10 (1980), 61

Gilbert, J.K., Osborne, R.J., Fensham, P.J.: Children's science and its consequence for teaching. Studies in Science Education 66 (1982), 623

Hihnston, K., Scott, P.: Diagnostic teaching in the classroom: Teaching – learning strategies to promote concept development in understanding about conservation of mass and on dissolving. Research in Science and Technology Education 9 (1991), 193

Kuiper, J.: Student ideas of science concepts: Alternative frameworks? International Journal of Science Education 16 (1994), 279

Lee, O., Eichinger, D., Anderson, C., Berkheimer, G., Blakeslef, T.: Changing middle school students' conceptions of matter and molecules. Journal of Research in Science Teaching 30 (1993), 249

Nakleh, M.B.: Why some students don't learn chemistry. Journal of Chemical Education 69 (1992), 191

Osborne, R., Gilbert, J.: A method for investigating concept understanding in science. European Journal of Science Education 2 (1980), 311

Posner, G.J., Gertzog, W.A.: The clinical interview and the measurement of conceptual change. Science Education 66 (1982), 195

Ross, B., Munby, H.: Concept mapping and misconceptions: A study of high-school students' understanding of acids and bases. International Journal of Science Education 13 (1991), 11
Sutton, C.R.: The learners prior knowledge: A critical review of techniques for probing its organization. European Journal of Science Education 2 (1980), 107
Taber, K.S.: Chemical Misconceptions – Prevention, Diagnosis and Cure. Volumes 1 and 2. London 2002 (Royal Society of Chemistry)
Treagust, D.F.: Development and use of diagnostic tests to evaluate students' misconceptions in science. Journal of Science Education 10 (1988), 159
Wandersee, J.H., Mintzes, J.J., Novak, J.D: Research on alternative conceptions in science. In: Gabel, D.: Handbook of Research in Science Teaching and Learning. New York 1994 (Macmillan)
Watson, R.J., Prieto, T., Dillon, J.S.: Consistency of students' explanations about combustion. Science Education 81 (1997), 425

Fig. 3.1 Concept cartoon concerning the conservation of mass [1]

http://www.springer.com/978-3-540-70988-6

Misconceptions in Chemistry
Addressing Perceptions in Chemical Education
Barke, H.-D.; Hazari, A.; Yitbarek, S.
2009, XI, 294 p., Hardcover
ISBN: 978-3-540-70988-6