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7. HOW TO ORGANISE THE CHEMISTRY CLASSROOM IN A STUDENT-ACTIVE MODE

Everyday, chemistry teachers all over the world are challenged by the question: Should I explain the chemistry content in a frontal mode using the blackboard, or am I able to apply methods to activate the students learning on their own terms? This chapter is based on the premise that learning processes should be based as much as possible on student-centred activities (hands-on and minds-on). A justification for more thorough student-active learning in the chemistry classroom is derived from the theory of social constructivism. Evidence for the positive effects of more student-active classrooms and cooperative learning will be discussed. This discussion will be illustrated by examples from chemistry education regarding how to activate students' thinking, to engage them into a cooperative mode of learning, or to use e.g. drama and role-play in the chemistry classroom.

THEORETICAL BASIS

> *Most people tire of a lecture in ten minutes; clever people can do it in five. Sensible people never go to lectures at all.*
> (Stephen Leacock in 'Discovery of England,' 1922, as cited in Byers & Eilks, 2009, p. 5)

From teacher-centred teaching to student-centred learning

The pedagogy of teaching secondary chemistry in many classrooms all over the world is still dominated by a teacher-centred approach. The teacher is explaining the content, is presenting experiments, and interaction with students is limited to brief periods of questions and answers. Thus, teaching is often not more than lecturing with short phases of individual tasks or guided bilateral interactions between the student and the teacher. The learning theory behind this approach is little more than a simple process of information transfer or as Byers and Eilks (2009) called it the 'Passive Diffusion Model of Knowledge Transfer.'

It is this teacher-centred practice that involves the teacher pouring information over the students and all the students are required to do is to absorb it (Figure 1). As a result, when teachers evaluate examination tests they discover all too often that what they thought they had taught, and what their students had actually

I. Eilks and A. Hofstein (eds.), Teaching Chemistry – A Studybook, 183–212.

learned, are very different. Their reaction is to try to explain better. They try looking for that little bit of magic that will enable their knowledge to be transferred over to their students. The teachers hope that the better they present the content the better their students will learn (Byers & Eilks, 2009).

But, it is not only the fact that teachers are not always able to explain everything to others in a sufficiently comprehensible fashion. It is also that the students often fail to listen or follow direction with sufficient care and attention. Sometimes they even lack the necessary cognitive abilities or prior knowledge to allow for instant understanding of the newly acquired information (see Chapter 4). The underlying problem is deeper. The problem is that learning is much more complex than merely listening, memorising and repeating (Bodner, 1986). From research, we know for a long time now (e.g. Peterson & Peterson, 1959) that most information obtained simply by listening is forgotten very quickly, with only a small percentage ever reaching the long term memory.

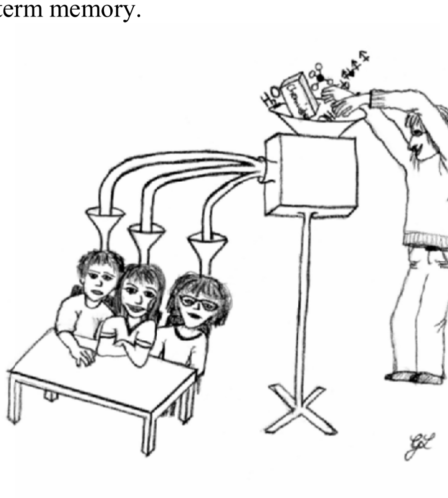


Figure 1. The 'Nuremberg Funnel' – An illustration of the belief that learning of chemistry is a simple transmission of content

Educational theory suggests that, although we might wish otherwise, knowledge cannot be transferred intact from the mind of one person into the mind of another (Bodner, 1986). Information may be presented, but meaning and understanding can only be constructed by the mind of each individual learner (Wittrock, 1989). Meaningful learning is the active integration of new information with knowledge already possessed by the learner. The subsequent interpretation of this new information will then depend heavily on what the learner already knows and what cognitive processes will occur in the mind of the learner (see Chapter 4).

This means that the quality of teaching should not be assessed in terms of the effort being put in by the teacher. The quantity and particularly the quality of learning is surely much more dependent on the effort being put in by the learner. It is quite a bit ironic. All too often when the teacher increases input to try to address learning difficulties being experienced by students, the students start to reduce their own efforts. Teaching should apply a converse approach. Teaching chemistry will become more efficient at the point where we apply methods where students become more active, hands-on and minds-on.

From behaviourism to social constructivism

The style of teacher-centred teaching and the Passive Diffusion Model of Knowledge Transfer as described above are based in the theory of behaviourism, which was the dominant educational theory during the first half of the last century. Behaviourism interprets every human action (action, thinking, feeling, etc.) in terms of 'behaviour' (Skinner, 1976; Mills, 2000). According to the behaviouristic theory, every action is considered simply as a response to a stimulus; if the correct stimulus is provided the required behaviour will inevitably follow. Behaviourism stems from experiments with animals, e.g. Pavlovs well known experiment with the dog. From behaviourism, one can train an animal, or a human, provided one can identify a stimulus necessary to promote the desired response. In terms of learning a teacher wishes a student to learn something by simply providing the right stimulus, e.g. presenting the right pieces of information, in the right sequence, at the right moment.

Although the theory of behaviourism has been developed over time to account for a range of observations (Mills, 2000), in its principle it remained the same. It is suggested that giving the correct information to a student, will enable him to (a) store this information in his/her memory, (b) assign the intended meaning to this information, and (c) have this information readily available for future use. Unfortunately, evidence from educational research suggests, that none of the above three expectations is justified. Peterson and Peterson (1959) showed that about 85% of the information entering the short time memory is no longer available to a learner a mere 15 seconds later, if it has not been connected to any constructed meaning, or if no any additional stimuli are given to support memorisation in the meantime. While behaviourism can certainly be helpful in understanding the simple issues associated with basic training processes, like memorisation of facts or training simple psychomotoric skills, it has proved much less successful when it comes to comprehending the important issues of learning with understanding.

Today's understanding of effective learning of chemistry is highly based on the theory of constructivism (Bodner, 1986). Among other issues, constructivism suggests that science teaching should apply teaching methods making the learner the active player in their own learning process. Such methods should seek to encourage the learner to become cognitively engaged in developing understanding of the topic being taught. The more elaborated interpretations of constructivism not only seek to make students active thinkers, but to promote interaction between them. One of these elaborated interpretations is the socio-constructivist perspective on learning attributed to the Russian psychologist Lev Vygotsky (Hodson & Hodson, 1998).

One of the central ideas in the works of Vygotsky (1978) is the role of interpersonal communication and social interaction for learning. From this point of view, sustainable learning does not take place via the contemplation of content by an individual learner but by a process that mainly functions through cultural and social mediation about content (Driver & Oldham, 1986). Construction of meaning is understood as a process of negotiation in discussions with others. With a quote from Lazarowitz and Hertz-Lazarowitz (1998, p. 451) the social component of constructivist learning is described as:

> … cognitive construction is facilitated through the following activities, all of which are based on peer-interaction: students present their own ideas by explaining them to other group members; they think and talk about their experiences; they suggest and try out new ideas; they reflect on changes in their ideas; they negotiate and aid other students to clarify their thoughts; and they move ideas forward by making sense of new ones. Indeed, constructivist theory brings to light the significance of social-cognitive interaction, cooperation and collaboration to the science teaching-learning context.

This view on learning makes interaction between the student and the teacher, and also among the students between themselves important features for promoting effective learning in general and in learning chemistry in particular. Because interaction is mainly done through language considering linguistic issues for effective learning processes becomes an important issue too (see Chapter 5).

Cooperative learning to promote student-active learning

From the theory of social constructivism we know that chemistry education should apply methods fostering student activity and make learning a cooperative experience. Cooperative learning is an advanced mode of learning in groups. Lazarowitz and Hertz-Lazarowitz (1998, p. 449) describe the difference:

> Cooperative Learning brings to the school a different learning organisation in which the classroom is structured into cooperative teams of learners, thus making learning together a way of life. Students tutor each other, conduct group projects, practice mutual assistance by sharing and exchanging information, and create a collaborative-cooperative learning environment.

Far more than a mere exchange of ideas can take place in such cooperative learning environments. Instead of studying the mental content of individual minds, cooperative learning focuses on the processes of interaction, participation, discourse, and negotiation. Cooperative learning leads to co-constructing knowledge and to building up collaborative knowledge where the group is able to attain a level of understanding that could not have been achieved through the mental processing of any one individual from within the group alone (Johnson & Johnson, 1999).

Nevertheless, it is well known that merely putting students into a group does not necessarily lead to effective learning. The effective working of a group is often disrupted by a lack of structure within the group and differing interests among the group members (Johnson & Johnson, 1999). Thus, it is important that the group should have a clear structure, and sometimes it may even be preferable to leave it up to the students themselves to agree on the structure to be adopted. A lot of research on cooperative learning in general and in science education in particular is available today. The evidence gained from this can help to understand which factors must be fostered to enhance students' learning by high quality student cooperation (e.g. reviewed in Lazarowitz & Hertz-Lazarowitz, 1998; Johnson & Johnson, 1999).

The literature, in particular the five quality criteria for functioning cooperative learning as proposed by Johnson and Johnson (1999) has given us a useful and well-established basis for reflecting upon cooperative learning:

- *Positive interdependence*: Each member of the class understands and values the benefit of working together to achieve a common goal. The effort of each group member is required and is indispensable for the group's success and everyone has a unique contribution to make the group's task a success.
- *Face-to-face promotive interaction*: The students encourage and facilitate the other's efforts to complete their tasks in order to reach the common goals. Students providing each other with help and assistance. They exchange resources, such as information or materials, and process information efficiently by providing each other with feedback.
- *Individual accountability/personal responsibility*: The performance of each individual student is assessed and the results are given back to the individual and the group. All students are responsible for their group mates but also for themselves to contribute to the group's success.
- *Interpersonal and small group skills*: Students are able to or learn to trust and interact with each other, communicate accurately and unambiguously, accept and support each other, and resolve conflicts constructively.
- *Group processing*: A reflection on how well the group work functioned in an explicit and structured process. Reflection should include what member actions were helpful and unhelpful, and what actions should be continued or changed.

If these criteria for cooperative learning are considered and used, the classroom environment has high potential for effective learning, student motivation, and the development of skills beyond the learning of chemistry topics and theories. Such non-cognitive skills include team working abilities, organising and structuring of projects, and negotiating of consensus following conflict within the group. The use of cooperative learning activities has been found to result in higher cognitive achievement, better development of higher-level thinking skills, increased student self-confidence and satisfaction, and better attitudes towards subject matter (Lazarowitz & Hertz-Lazarowitz, 1998).

In the literature, several basic modes of cooperative learning are described. The basic models differ in their structure and the levels of guidance given to the students, who work in small groups. Some of the basic models are discussed below. In addition to the basic models of cooperative learning detailed below, there is also a wide variety of cooperative teaching techniques (Sharan, 2004). Some of these are also illustrated by examples from the chemistry classroom within the practice section of this chapter, e.g. how to introduce atomic structure within a cooperative learning scenario in secondary chemistry classes (Eilks & Leerhoff, 2001).

Group investigation. Group investigation (GI) based on the work by Sharan and Hertz-Lazarowitz (1980) is a model for conducting joint projects within a class (see also "*The Project Method*" by Frey, 1982). GI consists of six steps. In the beginning the whole class considers a joint project and then determines appropriate sub-topics. The class is split into sub-groups of 4-6 students each. Each sub-group plans their investigations for their part of the project. The planned activity is carried out as a group in the laboratory while the process is supported by a variety of resources which can be searched and analysed by the students working independently within their groups. The teacher acts as a mentor, convener and collaborator for the students' investigation. At the end, each group gives a presentation, poster, report or some other contribution to the whole class to bring the sub-topics back together. Finally, the results are assessed by the students and teachers.

Student teams and achievement divisions and teams games tournament. Student teams and achievement divisions (STAD) by Slavin (1978) and teams games tournament (TGT) by De Vries and Slavin (1978) use competition between groups as a framework to support cooperative learning. In STAD, for example, the class is assigned a specific set of information to be learned. Heterogeneous small groups of 4-6 students are formed. The joint aim is that students start learning as a team in order to prepare each other to be individually successful in a quiz, test or game. At the end everyone has to participate in the test individually. However, it is not only the student's individual score that is registered. The students' scores are also aggregated and contribute to the performance and mark of the students' group. Thus everyone has a vested interest in how the teammates perform and is aware that this is dependent on their mutual assistance and joint preparation.

The jigsaw classroom. The jigsaw classroom (JC) is considered to be one of the best known models for cooperative learning. The JC was originally suggested by Aronson, Stephan, Sikes, Blaney, and Snapp (1978). It is an approach to promote structured interdependence between members of a group, while still maintaining the need for individual accountability. For a JC the class is divided into small groups of 4-5 students who are asked to learn about a joint topic. The topic itself is divided into sub-units of similar size and responsibility, and each of these is assigned to one of the students. After having become familiar with their piece of information the students from all groups with responsibility for the same sub-unit are grouped together. This is called the expert round. These students now continue learning about their aspect of the topic together with classmates having the same piece to learn. The aim of the expert groups is to develop an explanation and teaching strategy of their sub-topic, to be later shared with the other classmates from the initial groups. The students eventually return to their starting groups and teach and learn from each other about the different pieces of the whole picture (teaching round, see Figure 2).

Subsequent developments of the JC led to different models, including its application to laboratory investigations. The idea of integrating laboratory work with the JC was developed with reference to the method of Group Investigation and was named Peer Tutoring in Small Investigative Group (PTSIG). PTSIG maintains the jigsaw structure as a framework, but includes the Group Investigation method for the work of the expert groups (Lazarowitz & Karsenty, 1990). In addition methods were developed in order to safe-guard the process. These safe-guards are directed at preventing issues with individual team members causing the system to fail. Examples of these safe guards are doubling-up in the expert groups or providing all individuals with optional basic helps of each topic underlying the joint task (Eilks & Leerhoff, 2001; Eilks, 2005).

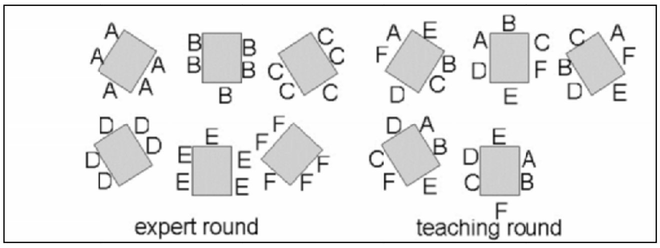


Figure 2. The Jigsaw Classroom

An analytical tool for reflecting on classroom interaction

As an analytical tool for reflecting classroom interaction, but also as a tool to help plan student interactive classrooms, Hertz-Lazarowitz (1992) suggested the six-mirrors of the classroom (SMC) model. This model can serve as a conceptual framework to guide classroom observation in behavioural categories such as "on-task" and "off-task" behaviours, levels of cooperation in the interactions between students, and in aiding the social events that take place during learning. It can be used to design classroom environments and move from traditional whole-classroom instruction to more active and then cooperative learning (Khalil, Lazarowitz, & Hertz-Lazarowitz, 2009).

The SMC model (Figure 3) includes six aspects (mirrors) of the classroom: (1) organisation, (2) learning tasks, (3) instructional behaviours of the teacher, (4) communicative behaviours of the teacher, (5) academic performance of the students, and (6) social behaviours of the student. Each mirror is described in terms of five levels of complexity from simple to complex. The conceptual dynamics between the six mirrors permits the formulation of predictions and the analysis of a range of variables – for example, quality of on-task cooperation as expressed by content, frequency of in-group communication, levels of reasoning, and predicted academic and social outcomes.

The use of the SMC will be briefly explained by comparing two different edges of effectively potential classroom environments. The one edge is considering the traditional teacher-centred classroom where the teacher is displaying information and tries to directly transmit information towards the students, also called frontal or expository instruction. The other edge serving as an example will be a classroom based on cooperative learning.

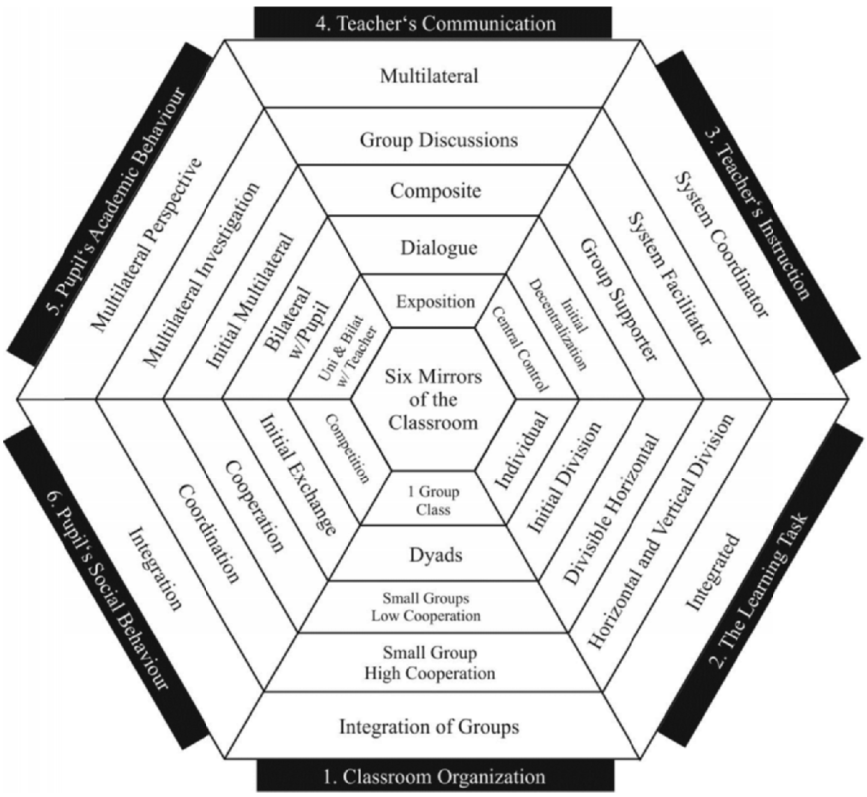


Figure 3. The Six-Mirrors of the Classroom (SMC) model

For the case of frontal instruction, in mirror 1 of the SMC, which examines the physical organisation of the classroom, there is a classroom with the class only forming one group. This is perceived as a fixed classroom with little or no movement of students around the room. The learning tasks (mirror 2) will be presented to the whole class and then, each student tackled the learning task individually. The teacher executes a centrally controlled and strongly guided instruction with the class as a whole (mirror 3), with a high frequency of expositing information by lecturing, demonstrating experiments or using the blackboard (mirror 4). Students' behaviour is limited to individual action or short term interaction with the teacher (mirror 5). Students' social behaviour often is individualistic and competitive (mirror 6). In all the six mirrors such a traditional teacher-centred approach will get low scores for a classroom environment with respect to its potential to support socio-constructivist learning.

In contrast to the frontal instruction, cooperative learning environments will receive higher scores in the SMC. In cooperative learning environments students work in small groups which do interact and are integrated with one another in the fashion suggested in the Jigsaw Classroom (JC) (mirror 1). Learning tasks (mirror 2) are divided horizontally, as in a JC, or vertically and integrated, as in the Group Investigation (GI). These cooperative learning tasks involve peer learning and peer teaching, were designed to increase interdependence and personal as well as collective responsibility and thus form integrated tasks for all learners. The pattern of teacher's communication and instructional behaviours include communication with the whole class for a short period of time, then with each of the groups as well as with individuals who needed help. The teacher becomes the organiser and coordinator of the cooperative classroom (mirror 3). The teachers' communication (mirror 4) becomes multilateral while moving between the groups and helping the students individually or within their groups. The students' communication has a multilateral perspective and their social behaviour is supported by the structured formation of the group and they become socially integrated within the group by feeling their individual accountability together with their positive inter-dependence and the need for cooperation and communication (mirrors 5 and 6).

Thus, using the SMC as a Spider Web (see the example of using Spider Webs to analyse classroom activities in Chapter 1), the area within the spider will give a measure for the classroom learning environments' potential to support socio-constructivist learning. But it also can help to reflect on lesson planning in advance to apply instructional methods.

The variety of methods for making students active – Hands on and minds on

As we saw in the previous section, the dimensions of making the classroom student-centred using appropriate teaching methods offers a wide variety of activities. As the dimensions differ so too do the methods, with the various methods offering a distinct variety of strategies for making the student more active in chemistry teaching, in a hands-on and minds-on fashion. Table 1 provides a selection from the variety of potential methods for the teaching of chemistry. Illustration will be given in the practice part of this chapter. Further examples which work well and have been proved in practice for all of these methods can be found on the Internet or in the literature.

Insights into other methods and their implementation in chemistry teaching can be found in Chapters 1 and 6. The connection of cooperative learning with the use of modern ICT (CSCL, Computer Supported Cooperative Learning) is discussed in

Chapter 8. More methods can be found in the section on hints below for further reading and the Internet.

Table 1. Potential strategies to make students active participants – hands on and minds on

Challenging students' pre-knowledge and ideas, or help to structure and organise them
– Brainstorming and clustering
– Drawings of students' imagination and ideas
– Mind and concept mapping
– Preparing posters, organisers, or digital presentations
– …
Making students' communication the basis for effective learning
– Reciprocal explanations
– Think-pair-share (1-2-4-All)
– The ball-bearing method (Inside-outside-circle)
– Jigsaw Classroom
– …
Using cooperative learning for whole lesson plans
– Peer Tutoring in Small Investigative Groups (PTSIG)
– Students' Teams and Achievement Divisions (STAD)
– Teams Games Tournament (TGT)
– Learning Companies
– …
Allowing students' creativity, play, and everyday life acting in lessons
– Using or inventing card or board games
– Scenic interpretations, drama, or role play
– Making opinion surveys or expert interviews
– Writing newspaper articles or inventing news-spots for TV
– …

THE PRACTICE OF CHEMISTRY TEACHING

Methods for activating and structuring students' thoughts

Based on the theory of constructivism we know that one of the most important factors that affects learning is the students' prior knowledge (see Chapter 4). The construction and reconstruction of meaning by learners requires them to actively form integrated knowledge structures, building on prior knowledge and relevant experiences. Teachers need to apply instructional techniques that help to activate students' existing knowledge structures in order to accommodate new knowledge, but also to allow for exchange in the fashion intended by social constructivism. In the following section, we will present a number of methods to activate, make explicit, and present students' ideas and their existing knowledge structures.

Brainstorming. Brainstorming is a technique used to foster creative thinking for a specific problem or topic (Fisher, 2005). While brainstorming, a group tries to find a solution to a problem or to collect potential ideas on a joint issue by collecting spontaneous contributions associated with the problem or issue, e.g. how to start a practical investigation on a specific topic or which apparatus, set-up, or equipment might be used. Brainstorming can be also used to orient oneself towards a new topic or domain, e.g. to ask the students for their spontaneous associations or prior knowledge of introducing a new topic like salts, acids and bases, or alcohols.

Originally, brainstorming was developed as a group technique. However, it can also be put in practice on a solitary basis. A prerequisite for brainstorming is that it should address one specific question or topic. Sessions that address multiple questions tend to be rather inefficient.

In practice brainstorming can be guided by the following four steps:

- *Strive for a heterogeneous group composition*: Place members with different backgrounds and/or experiences in one group to enhance looking at the problem from multiple perspectives and suspending assumptions. Heterogeneity fosters the generation of a long list of divergent ideas.
- *Start open-ended*: Generate as a long list of ideas as possible for facilitating problem solving. The greater the number of ideas is, the greater the chance for an effective solution will be (quantity breeds quality).
- *Associate and postpone critic*: Association will stimulate the building of ideas. Participants should extend and add to ideas freely. Analysis and criticism should be reserved for a later stage in the process.
- *Combine and integrate*: Eventually, combine and integrate the ideas to form a lower number of categories, and in the end one single (improved) idea might be developed or selected. One way to do this is clustering (see below).

In the last decade numerous variations on the brainstorming technique were developed, aimed at enhancing the creative output, encouraging all participants to have an equal say and reducing social inhibition in the group. In the context of chemical education, brainstorming is mainly used to activate students' thoughts in order to initiate problem-solving activities, or is related to understanding key concepts, such as diffusion (Van Rens, Van der Schee, & Pilot, 2009). Brainstorming sessions are often followed by a class discussion chaired by the teacher. The proposed ideas are shared, reflected upon, classified, and ranked.

Clustering. Clustering is a technique used to classify objects, and thereby offering richer information about relationships by grouping them. Clustering can start from any collection of ideas, words or pictures, but also can be a form of brainstorming.

Rico (2000) suggests clustering as being a technique of brainstorming. One can ask the students to start with a word. They should circle the word and write down each new word or phrase that comes to their mind, circling them too, and connecting them with a line to the word in the centre if it seems like an entirely new direction. But, the students can also make connections between the different circles, so that one big cluster of words and ideas is formed, but also the ideas near to one another form sub-clusters in themselves.

Another technique of clustering is the sorting of words or phrases already set up and documented on pieces of papers or cards (Stanfield, 2002). The clustering starts by sorting related cards together following distinctive criteria, e.g. specific relationships, properties or similarities. Smaller and bigger clusters of cards (and thus of information) are formed and information is organised in a qualitative and quantitative way. Clustering puts students in the position to review their existing knowledge structures and to come up with new patterns, thereby contributing to a flexible use of different representations of their knowledge structures. The outcomes of a clustering can be presented in different ways. The most common way is a one-dimensional depiction of elements obeying a specific criterion. However, the use of two (or higher) dimensional patterns offers the opportunity to classify objects according to two (or more) criteria.

In the chemistry classroom the periodic system of elements offers rich opportunities for performing clustering (Chen, 2010). The teacher can give cards to the students with pictures and names of different chemical elements, e.g. each four of the alkaline metals, the alkaline earth metals, halogens, and inert gases. In addition to the name and a picture of the element, the cards also encompass the GHS-risk pictograms (Figure 4). Students analyse the safety symbols and search for any risk and safety specifications. The cards are then clustered with respect to similar behavior. This may have potential as an initial approach towards learning how the periodic system of the elements is structured.

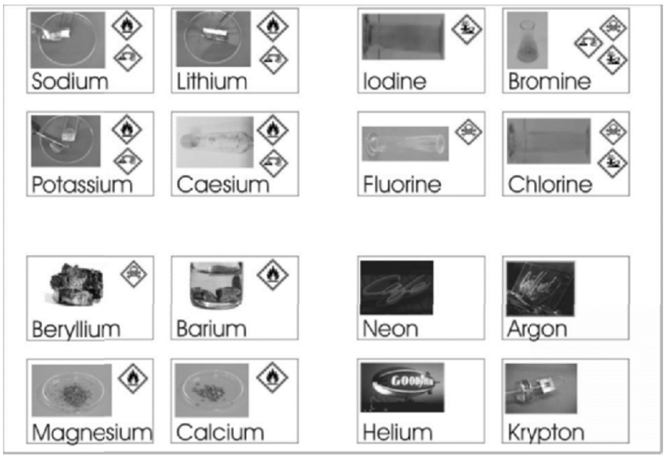


Figure 4. Cards of selected elements for a playful approach towards the periodic system of the elements

Mind and concept mapping. Mind mapping is a technique to represent words, ideas, tasks or other items linked to and arranged around a central key word or idea developed by Buzan in the 1970s. By presenting ideas in a radial, graphical, non-linear manner, mind maps encourage a brainstorming approach to planning and organisational tasks. Mind maps are used to generate, visualise, structure, and classify ideas one has in mind and thus helps to re-organise and reflect already captured information. Mind maps serve as an aid to studying and organising information, solving problems, and making decisions (Buzan, 1996). An example of a mind map on atoms and bonding is given in Figure 5.

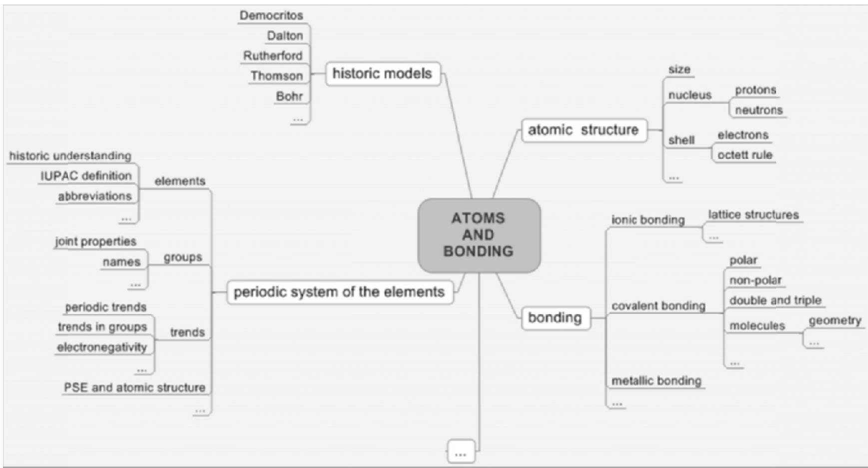


Figure 5. Example of mind map developed by mind mapping software

Related to mind mapping is the technique of concept mapping. A concept map is a diagram showing the relationships between ideas, images, or words. Concept maps differ from mind maps in that concept maps make "*concepts, and propositions composed of concepts, the central elements in the structure of knowledge and construction of meaning*" (Novak & Gowin, 1996). Concept maps consist of nodes (terms or concepts represented as boxes or circles), linking lines (uni- or bi-directional arrows from one node to another), and linking phrases describing the relationship between nodes, such as "gives rise to," "results in," "is required by" or "contributes to." Two nodes connected with a labeled line are called a proposition. Moreover, concept arrangement and linking line orientation determine the map's structure (e.g. hierarchical or non-hierarchical). An example of a concept map on atomic structure is given in Figure 6.

Basically, two different types of concept mapping tasks exist, namely 'fill in the map' and 'construct a map.' In 'fill in the map' students are provided with a concept map in which some of the concepts or linking words are missing. Students are supposed to fill in the blanks (Figure 7). In 'construct a map' students are asked to create their own concept map on a given topic. The question of how much information is provided depends on the teacher. He might give the concepts or linking words or a selection of both.

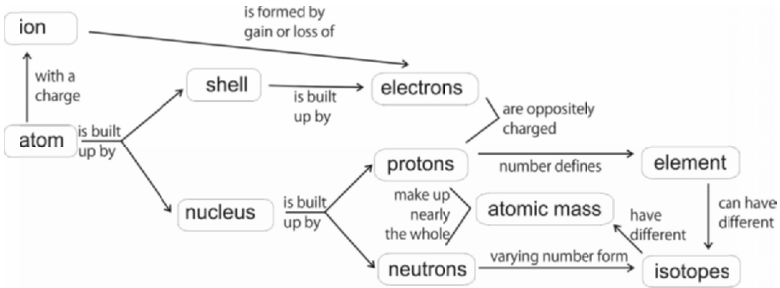


Figure 6. Example of a concept map

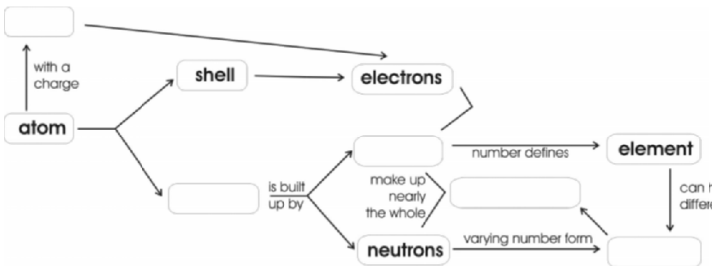


Figure 7. Example of 'fill in' concept map

Before using concept mapping as activity it is needed to familiarise students with the operational definitions of terms applied, such as concept, label, node, linking relationship, proposition, cross-link. In general, the procedure for constructing new concept maps can be described in terms of four (partly overlapping) phases:

– *Brain storming*: Students identify facts, terms and ideas associated with the topic at hand. At this stage, students should not worry about redundancy, relative importance or relationships.
– *Organisation*: All items are classified in groups and subgroups. Students should emphasise hierarchies of the items within groups. Students are free to rearrange items and to introduce new items.
– *Lay-out*: Students make an arrangement that best represents their collective understanding of relationships and connections among groups of items. Students are free to rearrange things at any time during this phase. It should be emphasised that they must pay attention on using a consistent hierarchy in which the most important concepts are placed in the centre or at the top. Related items should be positioned near to each other. The relationships can be made visible using lines or arrows accompanied with a words or small phrases.
– *Finalising*: After the students have agreed on the arrangement that covers their present understanding, the concept map needs to be preserved that others can view and discuss. The creativity of the students is encouraged to use different

colours, fonts, shapes, border thickness, etc. to construct a map. Also ICT-tools might be used.

Finally, the produced concepts maps should be discussed in class. The discussion might be directed by paying attention to the following attributes.

- *Accuracy and thoroughness*: Are the concepts and relationships correct? Are important concepts missing?
- *Organisation*: Was the concept map laid out in such a way that higher order relationships are apparent and easy to follow?
- *Appearance*: Was the assignment done with care showing attention to details such as spelling and penmanship? Is it neat and orderly or is it chaotic and messy?
- *Creativity*: Are there unusual elements that aid communication or stimulate interest without being distracting?

Research has shown that mind and concepts maps are useful tools that reveal students' existing notions and ideas. There are many examples described in which mind and concept maps are used in chemistry education, for instance for the meaningful learning of atoms, bonding, electrons and solutions (Regis, Albertazzi, & Roletto, 1996).

Methods for stimulating communication for more effective chemistry learning

From the theory part in this chapter we know how important communication is for learning (see also Chapter 5). Therefore, in the following section two methods of cooperative learning and associated examples from the chemistry classroom, which place a strong focus on communication, will be discussed.

Think-pair-share (1-2-4-All). This method developed by Lyman in the 1980s looks at joint learning by an iterative comparison of individual solutions (Lyman, 1981). The method focuses on learning as a process of negotiation. It aims to negotiate a common (better) result step by step. Starting from an individual draft, result or piece of work it leads to a common result for a pair of learners and maybe the whole class later on. The method starts by asking students to solve a given task on a sheet of paper. In a second round each a pair of students compares their two drafts and negotiates a joint solution on a new sheet of paper. In the interpretation of *1-2-4-All* (Witteck & Eilks, 2005), each two pairs of students compare their drafts and work out a joint solution. In the end, the whole class selects the best solution or re-organises components of all the solutions into a joint product. In chemistry education, the method can be used in a variety of ways, for example it could potentially be used for the joint development of write-ups of experiments.

A write-up always should be structured by a scheme, making a clear distinction between different parts including: title and date, aims, safety aspects and risk assessment, sketch of the experiment, procedure, observation and results, and finally interpretations and conclusions. Unfortunately, students often (a) do not focus on the most important points of the experiment (from a science perspective) while observing them or writing them up, (b) do not distinguish clearly between procedure, observation, and interpretation/conclusion, and (c) do not see the connection between their experimentation and the theory behind it. This causes problems in the evaluation of the experiments itself but also means that students frequently miss a central point of scientific work. Often it is not clear to the students that carrying out an experiment is essentially proposing a question to nature by the person doing the experiment, whereas the observation is the answer from nature. The interpretation of the finding is a different step while doing practical work. The interpretation can change in the light of new theoretical knowledge, while an observation can never be changed after it has been made. An observation can only be seen differently if the conditions under which the observation has been made have not been clear or unless new experiments are carried out leading to different observations. The pairs-to-share method can help to clarify the role of the different steps in doing an experiment and explain why these steps are divided into different parts in the write-up. Potential steps of writing up the experiment using the think-pair-share are given in Figure 8.

Develop *one* write-up of the experiment!

1. After a demonstration by the teacher, or after carrying out the experiment by the students, all students individually write up the experiment following a given scheme of steps.

2. Pairs of students sitting next to each other agree on a common solution to the given task based on their answers. They write down their solution on a *new* sheet of paper.

3. Each two pairs of students work out a common answer or solution on the given task, based on the pairs' answers. They have to write down their solution on a *new* sheet of paper.
   A scheme following the steps of the write-up is copied on a transparency and cut into pieces containing the single sub-issues.

4. Version a: All groups receive the whole set of pieces from the transparency. They can then copy their solution on the parts of the transparency. The results of each group are presented on the overhead projector. The whole learning group decides about the best solution for each sub-issue. The write-up of the whole group is puzzled together, presented on the overhead projector and copied by the students.
   Version b: Categories 1-4 are filled out by all groups. Categories 5-7 are prepared in divided labor by different groups on the parts of the transparency. The results are presented on the overhead projector, discussed, pieced together and copied by the students.

Figure 8. Writing up an experiment using the 1-2-4-All-Method. To make the work faster steps 2 and 3 can be focused on the description of procedure observation, and interpretation without writing up the other points again. A second way is to give the transparency to the students in advance of step 3. Thus step 3 can be directly done on the pieces of the transparency.

Think-Pair-Share can be used to introduce the writing-up of an experiment, but also can be applied to train the students. Time spent while writing up the experiment in this way will be full of intense discussion and on-task activity. It will lead to several modifications in the write-ups; initial mistakes and weaknesses will be recognised by the students themselves. A better version of the write-up will be generated step by step. But, the method also will help the students to better connect the experiment to their prior knowledge and this may lead to new questions. The method can be also applied to find a joint solution for a theoretical task, e.g. forming a complex reaction equation or mechanism.

The ball-bearing (inside-outside-circle) method. The ball-bearing is a method of cooperative learning developed by Kagan in the 1990s. The method asks the students to explain to each other a newly learned theory in a sequence of different pairs (Kagan, 1994). The ball-bearing employs the idea of reciprocal explanations and each student has to explain the content that they have just heard to an expert, who is there for control, in order to test whether the students' understanding was correct. By forming different pairs of students ball-bearings enable control and assure sufficient support for each learner.

In the interpretation of Witteck, Most, Leerhoff, and Eilks (2004) for the case of chemistry teaching, the whole learning group is divided into two groups of similar size. Both groups work on a specific issue. The issues given to the two groups of students are related to each other, but do not overlap and do not build upon each other. The work can be supported by use of appropriate materials and tasks and should be organised in pairs or small groups. Informative material could be provided, e.g. a few pages from a textbook, different URLs from the Internet, or two experimental tasks. The central task for each group is to understand their issue, and to develop a small presentation of five minutes about their topic. Initially, it is made clear to the students that they will have to explain their part of information as 'experts' individually to one of the students from the other group at a later stage. Questions for self-control can be made available for the students, as well as offering help to explain techniques.

After working on their topics the students form two circles with each two of the learners sitting face to face to one another (Figure 9). One after the other, both experts presents the part of the topic that they have learned. The other person is asked one after the others to listen, to understand, and to make notes during the phase where the partner is presenting his or her topic. This phase should take about 10 minutes. Then the circles are rotated. One circle is rotated clockwise, one counter clockwise by one or two chairs. New pairs of students are generated and are asked to repeat the explanation of the topic presented to them in the first round. The opponent now listens, expands, and corrects. In this second phase all students have also the chance to ask comprehension questions if the explanation in the first round has not been sufficient. In this case, all learners now have new partners who may be better able to explain their topic. Perhaps this is done in another way compared with the initial partner in the previous round. This phase again takes some 10 minutes. After another rotation of the ball bearing both learners in each new pair are asked to look for parallels, differences, and relationships within the two topics.

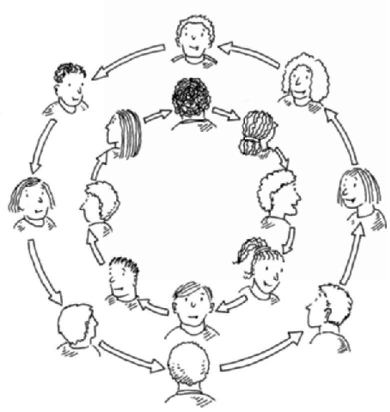


Figure 9. Grouping the students within a ball-bearing

For chemistry education Witteck et al. (2004) suggested different examples. One is, for example the formation, exploration, and refining of crude oil. Different oil companies have websites about their sources of crude oil and their technical processes. One group of students is asked to learn from a selection of Internet URLs about the formation of and prospecting for crude oil, the other group learns about the refining of crude oil and oil-based products. Potential tasks are outlined in Figure 10. After preparing themselves the students are asked to explain to each other the two issues, utilising the ball-bearing method as described above. After the final rotation the students should recognise the relationship of both parts to the whole process of processing of crude oil.

- *Formation and prospecting: Which chemical substances form crude oil? When, how, and from what materials did crude oil evolve? In which regions of the world is crude oil prospected? How much crude oil is prospected per day resp. per year?*
- *Refining: Out of which chemical substances does crude oil consist? What happens in the refinery? What happens in the processes of cracking, hydrogenation, and reforming? What are the most important products coming out of the refinery? How much crude oil is refined per day resp. per year in your country?*

Figure 10. Potential tasks for a Ball-Bearing on crude oil chemistry

The combination of the guided search on the Internet with the ball bearing proved to be an interesting and motivating method. The method helped the students to become clear about what they have to do. Although the evaluation of information is not an easy task and students sometimes feel uncertain about learning information coming exclusively from their classmates, these considerations diminish after applying respective techniques several times. In the end, the students enjoyed working in this way and their achievement improved.

Methods for learning chemistry in a cooperative mode

The literature (e.g. Sharan, 2004) suggests a lot of different techniques to promote cooperative learning. Think-Pair-Share and the Ball-Bearing method presented above are two of the methods. In the following section two examples for organizing a whole lesson plan in a cooperative mode will be presented and illustrated by examples from chemistry teaching.

Introducing atomic structure in a jigsaw classroom. In the jigsaw classroom (JC) by Aronson et al. (1978) a topic of interest is divided into several pieces of similar size and complexity. The students are grouped into groups of equal size. The number of students in each group should not differ much from the number of the groups. So for a class of 30 students a group size of 5 or 6 students is a good option. Each student gets one part of the materials. The students start to individually work through the material, to try to understand and in some cases to solve respective problems. Following that, all those students working on the same task form an expert group. In the expert groups they continue working on the content and to clarify any lack in understanding. They jointly prepare a teaching strategy to later on explain the information to the other students. Following on from this work, the groups are rearranged in such a way that new groups are formed with each new group consisting of one student from each of the expert groups. In this fashion the students teach each other, following the strategy they planned in the expert groups' work (see above and Figure 2).

The teacher should be aware that this is an ideal description. A lot of communicative as well as social abilities are necessary to lead to successful performance. The objective, to let the students plan the teaching strategy for the second part of the work, is rather cognitively demanding. Younger students are often not able to do this, particularly if they are not trained properly. This causes dangers for learning especially in cases where new and essential tasks have to be worked out. It is recommended that help in the form of guidance and specific tasks should be provided by the teacher to ensure the smooth dynamics of the method. Another method to alleviate issues is to double the expert groups (Eilks & Leerhoff, 2001). A doubling of the expert groups makes the system more secure because it gives each teaching group two experts who prepared themselves independently (Figure 11).

An example for the latter case is introducing atomic structure by a JC (Eilks & Leerhoff, 2001). The JC itself contains three different areas each carried out by two expert groups. In the expert groups the students work out (a) Rutherford's experiment and the nucleus-shell-structure, (b) the structure of the atomic nucleus,

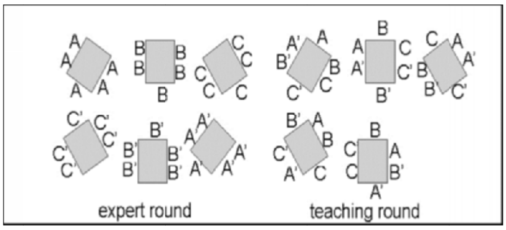


Figure 11. Rearrangement of the groups from doubled expert to teaching groups

and (c) structure of the atomic shell. Potential tasks are given in Figure 12. Different texts, questions and small experiments aid the students in solving their task.

Group A/A'

Rutherfords experiment and the nucleus-shell-structure of the atom
Radio activity
Charges and their behaviour
Rutherfords experiment in a shoe box
Rutherfords experiment
The relation between nucleus and atom
Diff.: The life of E. Rutherford

Group B/B'

Structure of the atomic nucleus
Electrostatic distraction
Model on distraction with magnets
Sructure of the atomic nucleus
Atomic masses, isotopes
Diff.: Radio carbon method

Group C/C'

Structure of the atomic shell
Electrostatics and frictional electricity
Structure of the atomic shell
Shell occupation and octet rule
Electron configuration of different atoms
Ionisation energy and investigating the shell
Diff.: Rare gases as inert gases in bulbs

Figure 12. Tasks for the expert groups in a jigsaw classroom on atomic structure

After working out the experts' tasks the groups are rearranged as described above. The teaching round includes a report about the work done in the expert groups as well as an exchange and shared clarification of the main terms and rules, with the objective that every students must be able to provide all of them afterwards. Additionally the students have to solve different tasks on the structure of atoms of different elements together. This means adding all possible information about several element atoms from the given information (number of protons, neutrons, electrons, atomic mass, and structure of the atomic shell). At the end the students are asked to compare the atoms from different groups from within the periodic system of the elements and to search for parallels and trends.

Introducing the structure of atoms by the JC has the potential to make the teaching of this theoretical and demanding phase student-active. From the classrooms we know that the students develop a positive attitude towards their learning of chemistry and the gained concepts while learning about them in the JC. Research revealed that this way of introducing atomic structure worked well and helped to reduce deficits in learning, while also keeping students motivated throughout this difficult phase of chemistry education (Eilks, 2005).

A learning company on acid-base-chemistry. The learning company method (LC) by Witteck and Eilks (2006) is a didactically-constructed classroom structure, analogous to existing or "ideal" companies. Originally, the LC idea was thought to simulate practical, profession-oriented tasks in vocational education. Through a model based on already-existing or idealised companies, students were supposed to learn how processes in a company occur. This is not the in the core of chemistry teaching. However, there are possibilities of using learning companies for the motivation and the encouragement of student-active and cooperative learning also in the chemistry classroom.

Witteck and Eilks (2006) adopted the idea of the LC for chemistry education. Within a chemistry LC it is intended that all necessary steps of learning chemistry should be performed by the pupils on their own, based in small learning groups, starting from open-ended tasks and based on experimental work. Open experimental tasks are assigned to the students instead of prescribed "cookbook recipes" being provided to the students (see Chapter 6). These open tasks are framed within a fictional story of a company with different departments. The assigned experimental problems must be conquered through self-organised and self-responsible learning within groups of students (the departments). The problems are presented so that no experimental direction is to be given. Instead, goal-oriented work orders and a folder of materials are provided so that the exercise can be solved without resorting to a prescribed path.

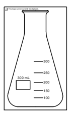
The LC should be illustrated by an example from the chemistry of acids and bases: The *Max Sour Ltd. Learning Company* (Witteck & Eilks, 2006). The objective of the Max Sour LC is to include all relevant aspects of acid-base chemistry into the LC lesson plan, theoretically as well as in the hands-on aspects. Initially, students are divided into small groups (departments of the Max Sour Company). Each group is composed of 4-5 students as a mix of different achieving learners. A folder is provided for their particular department. Max Sour Ltd. has up to seven different departments. E.g. the research department "Synthetic Indicators" is ordered to produce an optimal universal indicator by mixing several different indicator solutions. A large number of indicators are provided for the task. The pupils must discover a good combination of the solutions so that they can differentiate between a pre-set range of pH-values (1, 4, 7, 10, 14). A second example is the research division "Plant-based Indicators." They are ordered to produce a new, natural indicator from radish peels. An indicator handbook must be written, including a colour scale which makes predetermined pH-change points visible. But there are also analytical departments, or a group for the canteen (being ordered to find out why red cabbage sometimes turns blue and how to make a business out of it), or a group of janitors (being asked to find a way for the company's canteen to clean calcified heating-elements in the dishwasher and to free a plugged drainpipe using acid-base-chemistry).

In all departments, the pupils receive instructions from a fictitious "executive department" member allegedly in charge of the various departments (the teacher). All orders include a small story related to a possible problem which might occur in a company. The stories instigate the investigation of and the products surrounding acids and basis. The student groups receive their work orders, including equipment and chemicals. Each work order is to be solved through experimentation. Only the stated problem and the materials which are available for the various departments are listed on the work order. They do not contain instructions for experimental procedures or apparatus construction. Pupils are supposed to plan and execute the experiments using their own initiative. Figure 13 gives an overview of the lesson plan.

The Max Sour Learning Company

The Max Sour Company has seven departments. You will form these departments. You will receive work orders from the "boss," which you must complete.

Form groups (departments) of 4-5 students. You will work in these groups for the next few periods and display your findings at the end in a fair. Each pupil will receive an identification tag showing his or her department and name.



You have approximately 1-2 hours for the planning and preparation of your experimental doing and another 4-5 periods for conducting them, to learn about acids and bases, and to create a poster. All experiments must be discussed with your teacher before you carry them out. Every activity must be carefully documented. Every experiment must be written up using correct scientific terminology.

Aside from working on your experimental tasks, answer the questions for your specific area in the general question catalogue with the help of the computer learning environment, your textbook, or the Internet.

Create a poster which summarises all of the work and experimental results from your particular department.

Note: The work of the entire department is the most important factor!

Figure 13. The Max Sour learning company

Due to the open-formatted, independent nature of the students' experimentation, they must carefully plan and discuss exactly how they want to perform their experiments. But, the students are also guided through learning by different sets of questions for the theory and everyday life applications. The textbook can be used, as can a specific learning environment on the internet (The Max Sour Ltd. Intranet), which provides help where needed. Finally, the students have to present their department, their experimental solutions and the theory that they used at a fair showing up the potential of their department and of Max Sour Ltd. as a whole.

The learning company approach clearly proved that it encouraged students to work actively, flexibly, and with more self-direction on their experimental tasks. The pupils planned, worked and thought independently and carefully organised their work. Self-organisation was provoked by use of the open-ended work orders, which could only be solved through discussion, inquiry, and the exchange of information within the groups. Another example is described in Witteck, Most, Kienast, and Eilks (2007).

Scenic interpretations, drama, role-play, and the mimicking authentic practices in chemistry education

In the last section of this chapter we shall present quite unconventional methods for the learning of chemistry. Examples will be outlined illustrating how these methods can be used to activate the students learning of essential chemistry. In the first two examples we will discuss how physical interpretations can help students to better understand the particulate nature of matter, and how drama can be used to learn about the nature of science. The other two examples will discuss the idea of role-playing and mimicking authentic social practices to understand about how chemistry is handled in and by the society.

Using drama to understand ptarticle concepts. Understanding the different representations of chemistry is one of the most difficult parts in chemistry education, for example, understanding chemical phenomena on the particulate level is challenging for students (see Chapter 4). Using a drama interpretation of the particulate level can help students through making physical experiences about the particulate level. This experience has the potential to promote understanding and can serve as an anchor for transferring knowledge in the long-term memory.

An example concerning the states of matter may illustrate this. The states of matter (solid, liquid, and gaseous) are differentiated by the motion of the particles which they are composed of and the distance between them. In the solid state particles have fixed places in a lattice structure. They are near to each other and move only slightly. In the liquid state particles are still near to each other, but can move freely. In the gaseous state there is free movement and a lot of empty space between the particles.

To promote understanding, one idea is to take the group of students and to ask them to stand close to each other. With 'growing temperature' the students are asked to increase their movement step by step. They will find out that it becomes difficult to keep their fixed places. By another raise in motion the students will see that the distance between them will increase, and in the end by nudging each other students will leave the 'particle formation.' The matter will start to 'evaporate' (Figure 14). The experience of this motion will serve as an aid for understanding the states of matter and their changes and will act as an anchor for the students' memory.

Figure 14. Students interpreting the states of matter the solid state (left), via liquid (middle), to the gaseous state (right) (Eilks & Bolte, 2008)

For more ideas see Sciencelearn (2012). A related example on introducing different types of chemical bonding was recently described by Ozden (2007).

Using theatre play to learn about the nature of science. For more personalised topics a theatre or role play can be used. Atomic structure is a good example. Throughout the history of chemistry different models for atoms and atomic structure were available. For true understanding of the nature of science (see Chapter 1), it is important that the students learn about the tentativeness of these models. The students should learn that the creation of models is usually bound to individual chemists and that models can replace each other in the light of new evidence. Forming a theatre play between big chemists from history (Democritus, Dalton, Rutherford, Thomson, & Bohr) can help students to understand, that all these ideas were brilliant at that particular point in time, but also that all these models are tentative in nature and were replaced at some point in the light of new findings (Craft, 2007).

Using theatre plays to learn about the different models and the history of chemistry can be carried out in a variety of different ways. If time and the students' skills allow for it, the students can write their own storybook of a fictitious meeting of the different representatives of atomic models. A dialogue between the chemists can be written, with the one for each individual explaining and justifying his model leading to a reflection on the different proposals, their power with respect to their time but also their limitations in the foreground of our current understanding. Students can create costumes to make clear, whose role they are playing. Students with good knowledge in the content and skills involved in argumentation might be allowed to add a phase where they start debating without the pre-scribed storybook. For those students who are not able to write the storybook themselves, the teacher can prepare it and ask the students to play and interpret it.

While acting out the drama better understanding will develop. The role play and the preparation for it can offer students good motivation for comparing the different models (in their potentials and limitations), but also will enable learning processes about the tentative nature of models and their connection to the time their 'inventors' lived in.

Role-play about the handling of chemistry issues in society. Learning chemistry is more than only memorizing chemical facts and theory. Chemistry education also encompasses an understanding of the interplay of chemistry, technology, and society (see also Chapter 1). A role-play or business game can help offer an insight into the different roles individuals within society have when decisions about chemistry and chemical technologies are made.

The role of renewable energy sources can serve as a good example. In the case of bioethanol we face a controversial situation. Renewable energies are of value to reduce the emission of greenhouse gases and to protect crude oil resources for the future. However, the decision is made within a framework of scientific, economical, ecological, and social questions and issues. After learning about the science background, role play can help students to better understand that the decision about the use of bioethanol is not only a scientific one. Based on role-cards, texts and internet pages groups of students prepare themselves for a discussion about the use of bioethanol. Role-experts might come from the car manufacturers, environmental and climate protection groups, the agricultural industry, development assistance groups, or the consumers. After having prepared each one of them, the students in a role play can mimic a TV talk show or a parliaments hearing to whether the use of bioethanol in cars should be promoted by the politics. An example is described in Feierabend and Eilks (2011).

Also in the context of industrial-chemistry oriented teaching (see Chapter 1) role plays and society-oriented discussions can be used (Reid, 2000). Several projects in different countries introduced such topics into the regular secondary chemistry teaching. The respective lessons were usually interdisciplinary in nature to integrate learning of chemistry concepts with its related societal and technological applications, e.g. the industrial chemistry units developed in Israel by Hofstein and Kesner (2006). Also in these projects, the students are involved in debates about the location of an industrial plant. They have to consider many criteria such as natural resources (availability of raw materials), geology, environment, labour, economical and all kind of technological applications

While discussing in the role plays the students will learn about the different arguments which are held by the different interest groups in society. But, they will also learn that decisions on the use of a new technology nearly always have to be made in a field of contradictory opinions and effects (see Chapter 1).

Mimicking authentic societal practices in chemistry education. To learn about how scientific information is handled in society the mimicking of societal practices proved to be educationally effective. Role-plays and business games (see above) or playing out the evaluation process in a consumer test (see Chapter 1) are options. But also dealing with media reports or advertisements can lead to a reflection on the multidimensional character of evaluations processes about chemistry within society.

For this purpose, Marks, Otten, and Eilks (2010) suggested the idea of working as a journalist. Among the different examples that this method illustrated it was indicated that it always is the individual that changes information while transmitting it (Eilks et al., 2012). One of their examples deals with the problematic nature of musk fragrances in cosmetics. Having learned about the chemistry behind this topic the students form different groups. Every group gets a 'newsticker' (Figure 15). A newsticker is one page of quotes taken from the internet. The newstickers were made by utilising a Google search. For each newsticker a different search was made. The search is always combining two terms, one of them in all the four cases within this example was 'musk fragrances,' but the second terms differed. In the end the separate newstickers reflect the following perspectives: (a) consumer protection (concerns about potentially hormone-activating or carcinogenic substances), (b) innovative products (cost and sales pressure to market a competitive product), (c) wastewater treatment (problems and costs for local authorities), and (d) environmental protection (effects of synthetic musks on the environment).

news ticker Group A

Imagine that you are journalists at RTL News and receive the following messages in the editorial department! Use them to make a news report approximately 60 seconds long!

News messages:

Source: www.greenpeace.at Greenpeace Austria
11.11.5 4:03
… Humans can assimilate musk fragrances through the foods they eat. Musks are especially prevalent in fatty fishes. Human breast milk can also contain musk fragrances….

Source: www.greenpeace.at Greenpeace Austria
11.11.05 2:28
…Consumers have no way of confirming whether artificial musks are in a product or not. It is not mandatory for producers to provide a legally-binding declaration of exactly what is in their products.

Source: www.verbraucherschutz.de consumer protection agency Germany
Datum: 28.02.06
….Musk compounds exist in almost every product, whether we are talking about soaps, perfumes, or other detergents which spray fragrances into the air. Most consumers these days are not willing to abstain from the use of certain scents. Oftentimes, they do not even realize which dangers are involved and, even then, accept them as par for the course…

Source: www.verbraucherschutz.de consumer protection agency Germany
Datum: 02.03.06
..Breast milk samples were tested for musk compounds, because such

Figure 15. Start of a news ticker for the journalist method

The class is divided into eight groups consisting of 2-4 students per group. Each two separate groups of students receive identical newstickers, so that each of the four perspectives is repeated in a double format. The students are asked to write a 45 second report for the evening news on TV. The students are given about 30-45 minutes time to complete this task. The doubling of the groups for each of the newstickers is done so that it becomes clearly visible that totally divergent presentations can arise from using exactly the same information sources.

In the final phase, the pupils present their news spots. The role of the journalist/editor becomes explicitly clear in this exercise. The pupils generally recognise the problematic nature of the exercise early on and quickly connect, not merely to the ulterior motives behind the various interest groups, but also to the exaggerations and omissions frequently used in media reports. The learners show evidence of wide-ranging cognitive levels of reasoning ability, especially when the conversation is steered in a direction suggesting solutions to the problem.

SUMMARY: KEY SENTENCES

- Social constructivism suggests that learning is a process mainly built on student-activity (hands-on and minds-on) and communication.
- Student-centred teaching methods are essential to provoke effective thinking among students and to provide structured frameworks for communication and cooperation, which will ultimately help to enhance effective learning in the chemistry classroom.
- Teaching methods provoking the explication of thoughts, promoting communication and supporting mutual assistance between the learners proved to be more successful for the learning of chemistry than the pure dissemination of facts and theories which takes place in frontal teaching.
- In the core of student-centred methods is cooperative learning. Cooperative learning means the structured interdependence and collaboration of the learners towards each other. Quality criteria for cooperative learning are individual accountability, positive interdependence, face-to-face promotion of interaction, group processing, and interpersonal and small group skills.
- Varying the teaching methods allows for enabling the students to become active learners. Brainstorming, mind and concept mapping, or clustering help for organising and exchanging thoughts. Methods like Ball-Bearing, Think-Pair-Share, the Jigsaw Classroom or the Learning Company proved to provoke class cooperation, promote motivation, and raise achievement in chemistry learning. Scenic interpretations, drama, or role-play can help to enrich the chemistry classroom, motivating students and achieving a broader range of goals.

ASK YOURSELF

1. Explain: What is the ‘social’ dimension within social constructivism?

2. Repeat the quality criteria for cooperative learning as outlined by Johnson and Johnson (1999).
3. Think about a mind map and a concept-map on the topic of acid-base-chemistry. List advantages and disadvantages for both forms of visual representation.
4. Outline a sketch of how you would organise a lesson on the topic of alcohols utilising the ball-bearing method.
5. Draw a sketch outlining a jigsaw classroom for the teaching of carbohydrates in a secondary chemistry classroom.
6. Remember the scenic interpretation for the states of matter and their change. Outline a scenic interpretation for the process of dissolution of sugar in water.

HINTS FOR FURTHER READING

Johnson, D. W., & Johnson, R. T. (1999). *Learning together and alone: Cooperative, competitive, and individualistic learning*. Boston: Allyn & Bacon. The book sums up the theory and interpretations of different social structures for learning, i.e. in the means of collaborative and cooperative learning.

Lazarowitz, R., & Hertz-Lazarowitz, R (1998). Co-operative learning in the science curriculum. In B. J. Fraser & K. G. Tobin (eds.), *International handbook of science education* (pp. 449-470). Dordrecht: Kluwer. This handbook chapter gives an overview about the evidence science education research gained in the field of cooperative learning.

Sharan, S. (ed.) (2004). *Handbook of cooperative learning methods*. Westport: Praeger. This handbook gives an overview about a large variety of methods how to apply cooperative learning in the classroom.

Ginnis, P. (2002). *The teacher's toolkit: Raise classroom achievement with strategies for every learner*. Camarthen: Crown Publishing. The book offers a plenty of different methods how to organise the classroom by a variety of different methods.

Naylor, S., Keogh, S., & Goldworthy, A. (2004). *Active assessment: Thinking, learning and assessment in science.* Sandbach: Millgate House. The book focuses tools and examples for student-active learning and assessment in the science classroom.

Herr, N. (2007). *The sourcebook for science teachers*. San Francisco: Jossey Bass. The book offers a variety of methods and examples to enrich science teaching. See also the online offers accompanying the book at sciencesourcebook.com.

RESOURCES FROM THE INTERNET

Jigsaw Classroom: *www.jigsaw.org*. The official site explaining everything around the jigsaw classroom technique.

Kagan Online: *www.kaganonline.com*. The site of S. Kagan offers tips and access to a lot of materials for student-active learning and professional development of teachers.

Methodpedia: *de.methopedia.eu*. Methopedia is a collection of teaching and assessment methods that can be used in chemistry classrooms on all levels.

Sciencelearn: *www.sciencelearn.org.nz*. This website from New Zealand offers a big variety for alternative teaching ideas in all fields of the sciences.

NSTA: *www.nsta.org*. The site of the National Science Teachers Association from the USA offers a lot of materials and publications for enriching the pedagogies in all fields of science teaching

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