Chemie im Kontext – a symbiotic implementation of a context-based teaching and learning approach

Parchmann, Ilka; Gräsel, Cornelia; Baer, Anja; Demuth, Reinhard; Ralle, Bernd

Chemie im Kontext Â a symbiotic implementation of a context-based teaching and learning approach

Journal:	*International Journal of Science Education*
Manuscript ID:	TSED-2006-0058
Manuscript Type:	Special Issue Research Paper
Keywords:	chemistry education, curriculum
Keywords (user):	context-based

Chemie im Kontext – a symbiotic implementation of a context-based teaching and learning approach

Ilka Parchmann, University of Oldenburg, Cornelia Gräsel, University of Wuppertal,

Anja Baer, Reinhard Demuth, IPN Kiel, Bernd Ralle, University of Dortmund

and the project group ChiK

Correspondence to:
Ilka Parchmann University of Oldenburg, Germany
ilka.parchmann@uni-oldenburg.de

Abstract

Chemie im Kontext (ChiK) is a project which aims at the improvement of chemistry teaching at secondary school in Germany. Based on a framework, which was derived from theories and empirical data on the teaching and learning of science, science education researchers and teachers work together on learning communities to transform this framework into teaching and learning practice. Funded by the German Federal Ministry of Education and the participating federal states, such learning communities have developed and tried units for almost all topics for the upper and lower secondary education. The accompanying research studies show different effects on students´ motivation: The ChiK units point out the relevance of chemistry, but the student-oriented learning approach can also lead to a feeling of getting lost in the context. One reason might be seen in the result that teachers have put more emphasis on the realisation of a good context than on the second important principle of ChiK: the development of basic concepts. However, data also showed that the learning communities have indeed inspired and supported the teachers to change their teaching towards a more context-based and student-oriented teaching. The

continuing work will now especially focus on the improvement of facilitating the students with a better guideline, and on the development and assessment of different science competencies.

Introduction

After the publication of the results of the international TIMMS and PISA tests, the German school system has been criticised by a lot by experts, politicians and media. Topics of criticism have not just covered learning outcomes, but also organisational and structural aspects of the whole school system, like the modes of assessment, the early separation of students into different types of secondary schools, and the organisation of teacher education.

Any innovation, aiming at the improvement of learning outcomes, has to consider the complex structures of the school system. The German school system shows some important characteristics, which might be more hindering than fostering for the development and implementation of an innovation: (1) The school system is a federal system. This means, that every state has got its own syllabi and structure of school types (e.g. Gesamtschulen, where students are not separated according to their abilities, or Haupt-, Realschulen and Gymnasien, where students are separated after primary school). Additionally, the structure of science subjects is different: for example, in some states sciences are taught as an integrated subject up to year seven or nine, while they are taught as different subjects right from the beginning in other states. Therefore, every innovative curriculum has to produce syllabi for 16 states, the three main school types for secondary education, not to mention different demands and conditions in schools, e.g. equipment for students´ laboratory experiments. (2) Teacher education is also organised by state rules. In some states, in-service training is compulsory, while it is voluntary in others. Therefore, the implementation of an innovative approach might be left to some very ambitious teachers only in some states, while it could become compulsory for all teachers in other states. In many states co-operation between teachers is also left to personal activities and not really established in institutes.

Regarding these circumstances, the success of an innovation project will not only depend on the curriculum and material of the new course, but also on the effectiveness and flexibility of the accompanying implementation strategy.

Chemie im Kontext (ChiK) is a project aiming at the improvement of secondary chemistry teaching and learning on the one hand, and at the support of co-operation among teachers, as well as between teachers and science educators on the other hand.

The demand for a different science education, which regards the development of 'scientific literacy' for all future citizens as important as the development of a solid fundament of concepts and competences for future scientists, has been pointed out by many different studies and reports (e.g. Baumert et al., 2001; High Level Group, 2004). Context-based approaches such as ChiK claim to offer frameworks and exemplary units to realise such a different way of science education. However, these approaches and materials cannot simply be given to teachers to change their habits and traditional ways of teaching science. To bring about an innovation into the practical situation of the school, it has been shown that the involvement of teachers' existing situation (their beliefs, needs, working conditions etc.) in the process of developing an innovation seems to be relevant to making it successful (Pilling, Holman & Waddington, 2001; Eilks, Parchmann, Gräsel & Ralle, 2004; Gräsel & Parchmann, 2004). The implementation strategy of ChiK (which we call a 'symbiotic implementation', see below) builds up on a strong and continuous co-operation between teachers and science educators in 'learning communities' (Putnam & Borko, 2000). In this developmental process, both groups bring in their expertise and experience, and, as a result, both groups benefit for their own professional development.

This paper describes how the ChiK project developed - and still develops -, beginning with an idea of a different approach to teaching and learning chemistry and some theories about how this should be done, followed by the establishment of a 'symbiotic implementation strategy', up to the first review of where the project stands now. As a guideline for this paper, a model of curriculum representations described by Van den Akker will be used (see Van den Akker, 1998; Pilot & Bulte, this issue). First results of accompanying, mainly ongoing formative research studies are included in this model.

The organisational structure and development process of <u>Chemie im Kontext</u>

ChiK took its first steps in 1997, following the ideas of and experiences of the Salters courses in the UK (Pilling et al., 2001). Since 2002, an innovative implementation project based on ChiK has been funded by the German Federal Ministry of Education (BMBF) and the participating states. The central goal of this project is to implement the ideas of context-based learning into the school systems of the federal states and to gain further insight into fostering and hindering conditions for the implementation of school innovation. ChiK is a co-operative project between the IPN (Leibniz-Institute for Science Education) in Kiel and the universities of Dortmund, Oldenburg and Wuppertal. The project group consists of researchers (working in the areas of science education as well as in general educational research), research students, and teachers. Currently, 14 of the 16 federal states participate in this project. Additionally, ChiK co-operates with other German innovation projects (e.g. 'SINUS', 'piko' and 'BiK', see http://www.ipn.uni-kiel.de) and projects in other countries (e.g. the Salters projects in England and the context approaches in the Netherlands).

On the one hand, ChiK is still a developmental project, aiming at the development and dissemination of structures, exemplary units and teaching and learning material for upper and lower secondary education. On the other hand, several research topics are being investigated within this project, to enlarge knowledge about the design, effects and implementation of context-based teaching and learning in school. As shown above, the specific situation in Germany calls for innovations which can be adapted to the different demands, structures and conditions of schools in the 16 states, e.g. concerning syllabi, the number of chemistry lessons for secondary education, the financial support, and the structures of in-service training for teachers. However, a flexible course structure will lead to different realisations in states, schools and classrooms. Therefore, the research programme of ChiK cannot simply ask whether teaching and learning will be better or not, following the routes of ChiK. Instead, the main questions of interest accompanying the project look at different aspects of the developmental and implementation process and can be subsumed under the model of curriculum representations (described by Van den Akker, 1998):

(1) From goals and theories to an ideal framework. In a first phase, goals and theories about teaching and learning were analysed and transformed into a conceptual framework by researchers of the project group (Parchmann et al., 2000, 2001). This framework was then used as a guideline for the development of exemplary units. One important aspect, especially taking the German school system into consideration, is the demand for a flexible structure for the design and

teaching of units. Consequently, the framework can also be adapted to new guidelines for the school system (e.g. the introduction of national science education standards) or the experiences gained from trials and the learning communities.

Hence, the main question of interest in this first phase was:

> Which goals and theories of teaching and learning chemistry (science) at school should be used as a background for the ideal framework of ChiK?

<u>(2) From an ideal framework to a formal unit guide and the design of first operational units.</u> The conceptual framework was used to design exemplary units by members of the project group and some interested teachers (e.g. Huntemann, Honkomp, Parchmann & Jansen, 2001; Schmidt, Rebentisch & Parchmann, 2003). These units were tested in normal classroom situations. Case studies analysed some outcomes and effects, e.g. regarding students´ motivation and attitudes (Huntemann, Haarmann & Parchmann, 2000; Gräsel, Nentwig & Parchmann, 2005). Based on the results and feedback from classroom experience, descriptions for exemplary units were written and given to other teachers joining in the project.

The question leading this part of the project was:

> Can the ideal framework be transformed into exemplary units and teaching and learning material, which realise the theories and ideas of ChiK?

<u>(3) From first trials to a perceived and operational framework.</u> The next huge step was enabled through the implementation project, funded by the Federal Ministry of Education and the participating states. In 12 states initially, learning communities were established, consisting of teachers and science educators

(Fey, Gräsel, Puhl & Parchmann, 2004, see below). The means of support for these learning communities were the ideal framework as well as the tested exemplary units and a large portfolio of extra material, such as context-based experiments (e.g. Paschmann, Höffmann & Parchmann, 2001), a handout about teaching and learning methods in science and a handout about assessment tools (The ChiK project group, 2003).

The implementation project was and still is accompanied by several research studies, which regard several questions of interest, for example:

> Which elements of the ideal framework and which means, given to the groups, are being used successfully by teachers to design and to teach ChiK-units? Which are fostering or hindering conditions for the implementation of ChiK, regarding different conditions of systems, schools and participants?

<u>(4) From operational units to the experiential and attained curriculum</u>. The organisation of learning environments within the ChiK framework involves students much more than usual in the phases of planning and investigating a topic. Probably, the attained curriculum will be very different to what students (and teachers?) have experienced before: goals no longer refer to learning chemical knowledge dominantly. Different areas of competence are touched on and should be experienced by students, such as the application of knowledge on STS questions and the presentation of results.

To observe the attained curricula, research studies haven been set up, leading by the following questions:

What changes are reported by teachers and students as compared with prior teaching and learning experiences? Which effects can be measured regarding learning outcomes of students?

The processes described above have been carried out in the pilot phase and the implementation project of ChiK (2002-2005). In summer 2005, a follow-up project has begun, which is aiming at the transfer of context-based teaching and learning experiences to more schools and teachers, e.g. by the design of in-service training courses. Another focus will be set on the reflection and review of ChiK units and material regarding the new standards for science education in Germany. Consequently, two more processes can be described for the future:

<u>(5) From experiences back to the formal curriculum.</u> The framework of ChiK started with the design of exemplary units, to make sure that the general approach was teachable in the German school systems. Based on this developmental work and experiences, the learning communities are now a) revising their exemplary units and b) planning to design a whole curriculum, aiming at the continuous development of different competencies, as described in the new standards for chemistry education (KMK, 2004). Using an accompanying portfolio of context-based units, many groups have decided to have a closer look at tasks used for the initiation and diagnosis of learning processes.

<u>(6) From an implementation project towards a dissemination project.</u> To convert an innovation into the practical situation of the school, it has to loose its character as a project and instead become part of the normal school system. To support this last step, effective tools and structures have to be characterised and disseminated. Building on experiences of the learning communities, the use of different tools will be analysed and also tested in in-service training workshops as

part of the follow-up project. Additionally, accompanying research projects investigate co-operation structures at schools, for example, also trying to support processes by in-service training (Gräsel, Parchmann, Puhl, Baer, Fey & Demuth, 2004).

The following sections will offer a more detailed insight into the processes of curriculum innovation of the ChiK project and the first results of the accompanying research studies.

From goals and theories to an ideal framework

To address the first question of the previous section, the project group analysed and summarised several theories and empirical data about the goals of education, about teaching and learning and about implementation strategies (Gräsel & Parchmann, 2004; Nentwig, Parchmann, Demuth, Gräsel & Ralle, 2005). Based on findings and interpretations, we formed a conceptual framework for the design of an approach of chemistry teaching, in which the context for learning and the application of chemical knowledge play important roles. A 'context' should enable students to see the relevance and possible application of their learning results on the one hand, and to tie the new topic into their pre-knowledge, interests and ideas to enable successful learning processes (in the light of constructivistic learning theories). In traditional science frameworks, the systematic structure of concepts and principles are often separated from applications in relevant learning contexts for students. Therefore, one of the big challenges for ChiK was to combine context-based learning with a systematic development of basic chemistry concepts, such as matter and particles or structures and properties. To implement effective learning processes with the result of achieving applicable and transferable knowledge, the framework should also connect principles of student-oriented, situated learning with structures that enable the development of a systematic understanding.

The understanding of 'context'

Following the analysis of the meaning of context given by Gilbert, (this issue), three meanings of 'context' should be considered and connected, designing a context-based approach like ChiK:

<u>Context as content:</u> The design of teaching units must connect relevant contexts, from which questions are derived, and the basic concepts that can be applied to answer such questions. Other competencies, such as the research and presentation of necessary results or experimental investigations to develop such results are included by the design of the teacher's and the students´ activities.

<u>Context as learning stimulation:</u> Learning environments must stimulate students´ personal mental activities to enable successful learning processes.

<u>Context as frame for situated development and application of knowledge and competencies:</u> Learning processes in class must enhance and support the social development of competencies, especially the transfer of learning outcomes from one unit to another.

To realise these aims, theories and findings about teaching and learning haven been used, as described in the following sections.

The empirical and theoretical background of <u>Chemie im Kontext</u>

Many articles have been written about empirical findings, attesting to the unsatisfactory outcomes and structures of science education in Germany (e.g. Baumert et al., 2001; Seidel et al., 2002). A demand was made for more ´authentic science´ in class, for more application of science knowledge already as part of the learning process and for a greater variety of activities for students (Fischer, Klemm, Leutner, Sumfelth, Tiemann & Wirth, 2003; High Level Group, 2004). Of course, the demand for a more authentic, interesting and understandable science education is not easy to achieve: authentic phenomena and investigations are often complex, difficult to explain or cannot be carried out with school equipment. Additionally, they can raise a large number of questions, which will not all lead to scientific investigations and explanations. The latter reflects real life situations, of course, but might lead to problems with the level of available learning time for science education in school. The challenge, therefore, is to develop a curriculum, which offers examples of relevant authentic science (questions, knowledge and activities) that can be carried out in school, and that connects knowledge about students´ motivation and pre-conceptions to the development of basic and applicable knowledge and competences in science or especially chemistry.

Relevant science: a different question for scientists and members of a ´scientific literate society´

The question of relevance and authenticity is often raised and cannot be answered in the same way for all students. It surely depends on individual interests and activities within a ´community of practice´. For researchers, relevant questions arise from investigations and research studies, connecting theories to experiments and aiming at a better understanding and technical realisation of for example chemical processes. For non-scientists, questions might arise from daily-life activities, such as cleaning or eating and drinking. Natural or technical phenomena can also lead to relevant questions and to the motivation for dealing with science. Cultural and societal issues lead to more authentic questions and tasks for scientific investigations, but they are not always perceived as being important for the students´ daily-life experiences. Last but not least, career perspectives influence interests in scientific processes and understanding, but of course not for all students in the same way.

Therefore, learning environments aiming at offering an insight into authentic science questions and processes must consider different situations and levels of application and explanations. This is one criterion for the choice and combination of contexts and situations for the design of ChiK units.

Different domains for carrying out science involve similar activities and demand the development of similar competencies. These are the recognition of questions that are important and can be answered by scientific investigations, the understanding and application of scientific knowledge, the use of scientific methods, the interpretation of data or the exchange and discussion with other people (see the definition for scientific literacy given by the OECD-PISA-consortium in 1999). Hence, curricula, which place more emphasis on these competencies, especially on the understanding and application of scientific knowledge, should be able to achieve 'authentic science' in a more effective way. The four phases of a ChiK unit point out these different activities and steps of investigating a topic in a scientific way (see Figure 1).

Theories about interest and motivation

The importance of the context in which science is carried out was also pointed out by the IPN research study on interest in physics and chemistry (Gräber, 1995). The results describe students´ interest as a product of a context, a topic and an activity. Regarding many textbooks and teaching materials, the context seems to be neglected: often only tasks and topics are important for the teaching process, they cannot be related to any authentic question. This design of many traditional curricula delivers science in 'a world of its own' (High Level Group, 2004, p. x).

Following the different areas of authenticity, ChiK develops context-based units that pick up questions from the students´ daily life as well as from societal issues and science professions. Well-established activities, such as carrying out experiments, are integrated into such context-based units as necessary means to investigate the topic in the given situation.

The motivation to deal with chemistry in class is influenced by several situational aspects, too. Building up on the theory of motivation by Deci & Ryan (see Prenzel, 1997), six aspects are used in the ChiK framework to design and to analyse learning situations:

- The relevance of chemistry should be shown by a variety of authentic science questions, used to develop context-based units.
- The perception of autonomy should be considered by enabling students to integrate their own ideas and activities in different phases of a unit, e.g. during the planning and conduct of inquiries.
- The perception of competence should be fostered by using different tasks with a variety of activities, so that all students should be able to participate in a problem-solving process.

- The quality of instruction should be supported by a unit design, which follows a systematic sequence of scientific activities in each unit (Nentwig, Christiansen & Steinhoff, 2004, see also Figures 1 and 2) and which connects single units and learning outcomes with overall basic concepts revisited in every unit.
- The aspect of social embedding is covered through group learning activities within classes and by the application of learning outcomes outside school, e.g. by being able to participate in discussions and decision-making processes.
- Last but not least, the interest of the teacher is perhaps the most important aspect for students´ motivation. Comparable to students, teachers also have different interests and skills to initiate and to support students´ learning. Therefore, the ChiK framework offers different choices for the teachers too, to foster their motivation of context-based teaching.

Knowledge and competences

The definition of competence given by Weinert, 2001, points out an important aspect: competence is not just based on cognitive understanding and abilities, but also on motivation and willingness to apply these to different problems, interacting with other people. Following this definition, students´ motivation and the application of knowledge are not something that can be offered after the development of competence - they are parts of competence and must be considered already in the learning process also from the cognitive point of argumentation.

Leading back to the discussion of relevant science, we agree with others that the aim of science education must not be a replacement of daily-life concepts, but to use the adequate concept in each situation (Duit, Gropengießer & Kattmann, 2005).

Therefore, one goal of ChiK is to let students develop this ability to use different concepts and activities depending on the context and situation (Parchmann & Schmidt, 2003). They should be able to participate in different 'communities of practice', communicating with experts of chemistry as well as with non-experts, discussing a scientific matter. The importance of communication about science as well as the application in different contexts and situations have lately also been defined as standards for learning outcomes at the end of lower and upper secondary level (KMK, 2004). ChiK addresses all four claimed areas of competence of the new standards: understanding and applying basic concepts, methods of investigation, methods of communication and decision making processes.

The structure of Chemie im Kontext: design principles

Chemie im Kontext combines well-developed theories and goals of teaching and learning chemistry at school by describing a framework, which is based on three guiding principles (Parchmann, Demuth, Ralle, Paschmann & Huntemann, 2001; Gräsel et al., 2005):

1. All context-based units are based on relevant authentic topics and questions, which are the backbone and guideline for teaching and learning processes. For the design of learning environments, three areas of authentic relevant topics have been chosen: a) daily-life-situations (personal relationships), b) issues important for a society (relevance for a cultural community) and c) scientific and technical issues (insight into special communities and their role within a society).

2. A variety of teaching and learning methods enable students to integrate their ideas, competencies and interests, and to construct their own knowledge. They must also offer instruction to support individual learning processes and to carry out scientific investigations. The framework of ChiK describes four phases (see Figure 1), in which the roles of students and teachers change as well as the amount of instruction and self-directed learning activities carried out by the students.

****insert figure 1 about here****

3. Basic concepts and students´ competencies are developed through the investigation of relevant topics. ChiK describes six basic concepts as guidelines, which are now also mentioned in the German standards for lower and higher secondary education: the concept of matter and particles, the concept of structures and properties, the concept of energy, the concept of donor and acceptor processes, the concept of chemical equilibrium and the concept of reaction kinetics (the last three are sometimes combined to a frame of concepts of the chemical reaction). The idea of ChiK is not to develop a certain concept through one context-based unit only, but rather to pick up the same basic concepts again and again in each unit (see Figure 2). The use and development is guided by the questions and tasks of a relevant topic, but the aim is not to complete a concept in one unit. Only the combination of different units will lead to the development of such concepts, which must be connected and abstracted from the former learning context (see the fourth phase as a

summary). These abstract concepts can be used to explain and to investigate other phenomena and questions from a chemical perspective (see Figure 2).

insert figure about 2 here

Summarised, the framework of ChiK asks for the realisation of all three principles (context-based learning, the development of basic concepts and the design of student-oriented learning activities). The four phases illustrated in Figure 1 offer a structure to design the units and Figure 2 points out the necessity of combining different context-based units to define basic concepts and to develop science competencies.

Starting from this ideal framework of a curriculum, the next step was to design and to test exemplary units following these design principles.

From an ideal framework to a formal unit guide and to operational units: the design and test of exemplary units

The first units were designed by members of the project group and co-operating teachers. The contexts chosen dealt with societal issues (e.g. fuel problems), societal and technical questions (e.g. the development and evaluation of the hydrogen car) or daily-life topics (e.g. food or cleaning detergents). These units were tested in school, some of them accompanied by research studies about students´ perception of ChiK or the development of conceptual understanding (e.g. Huntemann et al., 2000; Schmidt et al., 2003). The results of these first studies showed a positive perception by teachers and students. Especially weaker students liked the different way of teaching (which is now reported controversial, see below). The perception of relevance and the quality of instruction were significantly more positive, compared to the teaching they were used to before (Gräsel et al., 2005). Reinforced by these results and experiences, the project of the 'symbiotic implementation' was initiated, which will now be described.

From first trials to a perceived and operational framework

While the first exemplary units were taught as designed for the trials, the ideal and formal framework of the implementation project leaves the final design, the choice and the combination of units to the teachers to adapt it to their conditions and expectations. Hence, the implementation process integrates the ideal framework, designed by science educators and teachers, and the different individual conditions and experiences of teachers and classes participating in the project. We call this approach a 'symbiotic approach' to point out the reciprocal dependency and profit of curriculum designers, researchers and practitioners (Gräsel & Parchmann, 2004).

This implementation approach of ChiK can be characterised by two important aspects: A) it is a co-operative and symbiotic process, in which teachers and researchers work together in learning communities, implementing and revising the ideal framework of ChiK. B) The process is a developing approach: changes and revisions of the ideal framework are not only allowed, they are regarded as important to adapt ChiK to different situations and conditions (Gräsel & Parchmann, 2004).

Consequently, as in all innovation processes, the implemented curriculum will only reflect parts of the ideal framework, and again, the attained curriculum will lead to some expected and other unexpected learning outcomes for students (Fullan &

Pomfret, 1977; Van den Akker, 1998). The implemented curriculum will be different for individual teachers, the attained curriculum different for individual students. Believing in theories about constructivism and situated learning, these processes of (individual) adaptation are necessary for effective learning environments. Of course, it will be important to make sure that the main characteristics of the ideal approach will survive (see Figures 1 and 2) and that the necessary adaptations to a specific situation and group will be carried out. The first should be taken care of by the project members in the learning communities, the latter by the participating teachers. Hence, the learning communities are the central instrument to enable the realisation of the ChiK design principles on the one hand and the necessary flexibility on the other.

In each of the participating states one or two learning communities of 8-12 teachers each were set up to elaborate the teaching material, to try it in their own classrooms and to reflect their experiences with it (see Figure 3).

***insert figure 3 about here ***

Each group is chaired by one person from their own ranks and one science educator of the project-group. A national communication network, occasional supra-regional meetings and in-service training inputs complete the support.

Initial research results

As mentioned before, the combination of both perspectives, those of the teachers and those of the researchers, lead to the design and testing of context-based teaching units and learning processes of students. Another important outcome should be a benefit for both sides and professions (Gräsel & Parchmann, 2004; Eilks et al., 2004). To follow up these goals and ideas, group meetings were documented by meeting protocols, and the designed units and materials were collected and distributed to other groups. Also the chairing science educators and teachers as well as a group of 37 teachers were interviewed at the end of the third year. Additionally, questionnaires were given to all participants to investigate effects of the attained curriculum (e.g. regarding the perception of chemistry teaching and learning or the co-operation in the learning communities, see Table 1).

insert table 1 about here

Even though the analysis of the material has not been completed yet, some conclusions can be drawn regarding the research questions mentioned earlier: Which elements of the ideal framework and which means given to the groups are used successfully by teachers to design and to teach ChiK-units? Which are fostering or hindering conditions for the implementation of ChiK, regarding different conditions of systems, schools and participants?

It was left to the groups to choose which units they wanted to teach or to develop and on which aspect of ChiK they wanted to put the main focus on. Many groups chose one of the given exemplary units to start with, but they adapted them as a group or even individually to their expectations and teaching conditions. These adaptations concerned the variety of topics and activities as well as the amount of self-directed learning, for example. After their first trials, most groups decided to develop their own units, which were given to other learning communities after they were tested and commented. In the second year, these units were often picked up and again adapted by the other learning communities, and they were regarded as a very effective tool to support the implementation of ChiK by teachers and the participating science educators. On the whole, the interviews as well as personal feedback show that the exemplary units, the units developed by other groups and the exchange and co-operative development and adaptation processes in learning communities were regarded as the most effective means to support the realisation of the ChiK approach (see Figure 4). The importance of ownership was also pointed out in other studies (Eilks et al., 2004).

insert figure 4 about here

The results of the interview analysis and of the designed units and material have shown another important aspect. The emphasis in the first two years has clearly been laid on two aspects of the framework only: all groups have put a focus on finding a good context, estimated as being relevant for students and also suitable to teach the chemical content asked for in the state syllabus. The second aspect achieved by the groups has been the integration of different and more student-oriented teaching and learning methods, enabling the students a greater participation in the phases of planning and investigation (see Figures 5 and 6). However, the third design principle, the abstraction of general basic concepts, has not been achieved in the same way yet. We suppose that the teachers at first picked up those aspects that were rather innovative and unusual for them and which they connected most with the ChiK approach. Still, after three years, more groups report problems, especially with their weaker students, and they have asked for more guidelines and structures. Some of them have started to use basic concepts explicitly and report about positive effects for their students.

insert figures 5 and 6 about here

Almost all groups reported difficulties with the length of the units. Therefore, many units were shortened by reducing open-ended student activities and placing greater emphasis on central points.

To find hindering and fostering conditions, the data collected by interviews and by questionnaires given to teachers and students were analysed too. In the perception of the teachers, their syllabi and freedom of choice for topics and activities are the most important factor for a successful implementation of an innovation. The next important aspect was the equipment of their schools, which is understandable regarding the demands of different activities in the ChiK framework. The analysis of the questionnaires about the teachers perception of their teaching and the questionnaires about the work in their learning communities showed significant effects: the more positive the perception of the support offered by the learning communities was, the higher were the reported changes towards a 'ChiK-like teaching' (Fey et al., 2004; Eilks et al., 2004).

From the operational curriculum to the experiential and attained curriculum

The perceived and attained curriculum should be different according to the teachers´ and students´ beliefs, expectations, abilities, etc. To gather this information, the questionnaire was given to students and teachers at the beginning of the project and after each year. Currently, the first two points of data collection have been analysed. We focus on the following question:

What changes are reported by teachers and students as compared with prior teaching and learning experiences?

The results of the pre-ChiK questionnaire were coherent with those of other studies but also showed some interesting results for researchers and teachers. For example, students perceived the learning of subject matter as the main goal of chemistry classes, while teachers had a much broader view (of what they thought they had done?). The teachers´ main expectations for participating in ChiK were the rise of students' motivation and student-oriented learning (Fey et al., 2004). Many teachers worried about the quality of subject matter learning, which has also been described for other context-based curricula (Bennett, Gräsel, Parchmann & Waddington, 2005). However, these expectations varied enormously between the groups, probably referring to different teaching traditions in different states (see Figure 7).

Findings after the first year show that these worries – probably based on critical attitudes towards context-based learning on the one hand and on traditional beliefs of 'good chemistry teaching' on the other – influenced the implementation of the curriculum: In one state, where these beliefs have a particularly strong tradition, protocols and materials show that the teachers used the context as a mere introduction of a unit, not as a guideline. Only after evaluating the learning outcomes of ChiK as positive - which was another result of our questionnaires - they opened up and tried to use the context as a real guideline for a teaching unit. Other groups showed a larger variety of design principles realised in their units right from the beginning.

insert figure 7 about here

One important goal of ChiK was to enhance the students´ motivation for chemistry. Therefore this was question was investigated in the trials as well as in the main study. Exemplary items are given in Table 2.

insert table 2 about here

Regarding the development of the students´ motivation, first results show positive effects: A comparison between the motivation to learn chemistry of ChiK-students and students learning within a conventional curriculum (n1 = 216; n2 = 183) shows that at the beginning of the school year the two groups were comparable in their motivation towards learning chemistry as well as in their overall evaluation of the chemical education they had experienced until then. At the end of the school year the motivation of students following a conventional curriculum decreased significantly more compared to the ChiK-group. After two years, the interest of all students participating in ChiK was significantly higher than at the beginning of the project. Further, after two years of the project more than 60% of the ChiK students at the end of 10^{th} and 11^{th} grade stated that they liked to choose chemistry in upper secondary level. Especially the application of knowledge and the perceived personal relevance of chemistry were important for the positive development of students' interest. Also, the influence of the teacher was found to be crucial for the development of interest.

The questionnaires were followed up by an interview study with a limited number of students, using a reduced form of the questionnaire as interview-guide. The outcomes of the survey were confirmed in detail, including the influence of the person of the teacher, which cannot be overlooked. The motivation of the students was definitely raised both by the fact that the issues dealt with in their chemistry class were not just academic but had to do with their real life and that, within feasible limits, they were allowed to follow their own interests in pursuing the theme. They were, however, not uncritical towards their new learning experience. The feelings of getting lost in the complexity of a context and of loosing the clear learning goal were evaluated by students as not encouraging.

Which effects can be measured regarding learning outcomes of students?

As the implementation of the framework was different in different classes, problems occur when the success of a new curriculum is analysed and documented: the same ideal framework might be and will be highly successful in some classes and not successful at all in others (Lange & Parchmann, 2003). Nevertheless, it will be very important to be able to give information about positive effects and also about difficulties in teaching the ChiK framework. Hence, in the first phase of the project, we have developed and tested several instruments to diagnose students´ interests and learning outcomes in different areas of knowledge and competences. We will use these instruments in the follow-up project to carry out design experiments. If possible, exemplary video-studies might offer a closer look into lesson design and resulting teaching and learning processes.

The first study carried out was looking at the learning outcomes concerning the understanding of a context as well as the basic concept. Additionally, an analysis was done of cognitive skills and the transfer of knowledge to another context (Lange & Parchmann, 2003). The first important result was that a great diversity between classes could be observed, so it was impossible to say whether the unit was effective or not effective in general. No effects were found between the understanding of the context (polymers in cars) and the underlying concept (polymers). As expected, the average results were lower for the transfer context (clothes). The perhaps most interesting finding was that the length of the unit showed positive effects for the advanced courses and negative effects for basic courses. One assumption is a loss of motivation for the less interested or less able students.

Another study was investigating the development of students´ explanations, beginning with pre-conceptions and analysing the use of scientific or very often mixed conceptions (Parchmann & Schmidt, 2003). The diversity between classes was also found in this study, though for the phenomena also taught during a context-based unit, the changes towards the application of particle models were rather high (up to 70%).

Three other studies developed and analysed test instruments, which were designed to investigate different areas of competence, e.g. the design of experiments, the use of mental models or the use of chemical knowledge for decision making processes (Menthe, 2005). For a test on acids and bases (n=359 students), the only comparative study, the results showed slightly better results (significant, but low effect) for ChiK classes.

Conclusions and implications

First observations and results of research studies show that teachers have started teaching units, following the characteristics of the ideal ChiK framework, and that they have implemented the units according to their specific needs and circumstances. The results of the investigation of the experienced and attained curriculum show positive effects as well as challenges to be responded to. One explanation for observed problems might be the neglect of one important design principle of ChiK: while all groups designed context-based teaching units and integrated a greater variety of teaching and learning methods, almost no group has yet found a good way to integrate the basic concepts as a necessary abstraction for the transfer of knowledge. This will be one important point to improve in the next phase of the project.

To make the framework of ChiK more robust against problems, more guidelines might be necessary. Two have been developed already, again in a symbiotic way by teachers and researchers, and will be given to the groups shortly: one describes steps towards the design of a successful context-based unit, the other connects the ideas and design principles of ChiK with the new standards for chemistry education in Germany. The later guideline also contains a matrix to plan and to analyse the units, e.g. check the 'need-to-know' basis for basic concepts and competencies from the experts´ point of view and from the point of view of the students in class. The assessment of the students´ ideas and learning outcomes will be supported by the systematic design of competence-based tasks.

More important answers will be given after a longer period of time, when the new approach will have to become 'normal', when occurring problems will have to be solved and when the groups of teachers will become more and more self-directed in their work with ChiK.

References

Baumert, J., et al. (Eds.) (2001). *PISA 2000. Basiskompetenzen von Schülerinnen und Schülern im internationalen Vergleich [Basic Competencies of students internationally compared]*. Opladen, Leske + Budrich.

Bennett, J., Gräsel, C., Parchmann, I., & Waddington, D. (2005). Context-based and Conventional Approaches to Teaching Chemistry: Comparing teachers' views. *International Journal of Science Education*, 27, 1521-1547.

Duit, R., Gropengießer, H., & Kattmann, U. (2005). Towards science education research that is relevant for improving practice: The model of educational reconstruction. In H.E. Fischer (Eds.) Developing Standards in Research on Science Education (pp. 1-10). London, Taylor & Francis.

Eilks, I., Parchmann, I., Gräsel, C., & Ralle, B. (2004). Changing teachers´ attitudes and professional skills by involving them into projects of curriculum innovation in Germany. In I. Eilks & B. Ralle (Eds.) Quality in Practice-oriented Research in Science Education (pp. 29-40). Aachen, Shaker.

Fey, A., Gräsel, C. Puhl, T., & Parchmann, I. (2004). Implementation einer kontextorientierten Unterrichtskonzeption für den Chemieunterricht [Implementation of a context-based instructional concept for Chemical Education]. *Unterrichtswissenschaft,* 32, 238-256.

Fischer, H., Klemm, K., Leutner, D., Sumfelth, E., Tiemann, R., & Wirth, J. (2003). Naturwissenschaftsdidaktische Lehr-Lernforschung: Defizite und Desiderata

[Learning-teaching research in science pedagogy]. *Zeitschrift für Didaktik der Naturwissenschaften*, 9, 179-209.

Fullan, M., & Pomfret, A. (1977). Research on curriculum and instruction implementation. *Review of Educational Research*, 47, 335-397.

Gilbert, J. K. (this issue). On the nature of 'context' in chemical education. *International Journal of Science Education.*

Gräber, W. (1995). Schülerinteressen und deren Berücksichtigung im STS-Unterricht: Ergebnisse einer empirischen Studie zum Chemieunterricht [Interests of students and accounting for that in STS education: Results of an empirical study in chemical education]. *Empirische Pädagogik*, 9, 221-238.

Gräsel, C., & Parchmann, I. (2004). Implementationsforschung [Research on implementation]. *Unterrichtswissenschaft* 32, 196-214.

Gräsel, C., Parchmann, I., Puhl, T., Baer, A., Fey, A., & Demuth, R. (2004). Lehrerfortbildungen und ihre Wirkungen auf die Zusammenarbeit von Lehrkräften und die Unterrichtsqualität [Development of students and the effects on the co-operation of teachers and the quality of instruction]. In J. Doll, M. Prenzel (Eds.) Bildungsqualität von Schule (pp. 133-151). Münster, Waxmann.

Gräsel, C., Nentwig, P., & Parchmann, I. (2005). Chemie im Kontext: Curriculum development and evaluation strategies. In J. Bennett, J. Holman, R. Millar, & D. Waddington (Eds.) Evaluation as a tool for improving science education (pp. 53-66). Münster, Waxmann.

High Level Group on Human Resources for Science and Technology in Europe (2004). *Report on Increasing Human Resources for Science and Technology in Europe*. Brussels, European Communities.

Huntemann, H., Haarmann, E., & Parchmann, I. (2000). Schüleraussagen zur Unterrichtsreihe „Treibstoffe in der Diskussion“: Eine erste Untersuchung zur Wirksamkeit von Chemie im Kontext [What students say about the lesson series „Fuels in discussion“: A first study into the effectivity of Chemie im Kontext]. *CHEMKON,* 7, 131-136.

Huntemann, H., Honkomp, H., Parchmann, I., & Jansen, W. (2001). Die Wasserstoff/Luft-Brennstoffzelle mit Methanolspaltung zur Gewinnung des Wasserstoffs – Der Fahrzeugantrieb der Zukunft? [The Hydrogen/Air cell with separation of methanol for the production of hydrogen – The propulsion for cars in the future?] *CHEMKON,* 8, 15-21.

KMK (Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland) (2004). *Bildungsstandards im Fach Chemie für den Mittleren Schulabschluss [Educational standards in Chemistry for secondary school exams]*. München, Wolters Kluwer.

Lange, B., & Parchmann, I. (2003). Untersuchung zur Entwicklung fachspezifischen Wissens bei Schülerinnen und Schülern in einem Unterricht nach Chemie im Kontext [Research to develop subject specific knowledge at students in instruction based on Chemie im Kontext]. In A. Pitton (Ed.) Außerschulisches Lernen in Physik und Chemie, Proceedings of the GDCP meeting 2002 (pp. 269-271). Münster, LIT Verlag.

Menthe, J. (2005). Acquisition and encouragement of decision making processes in science classes. In H.E. Fischer (Ed.) Developing Standards in Research on Science Education (pp. 155-164). London, Taylor & Francis.

Nentwig, P., Christiansen, D., & Steinhoff, B. (2004). Aufgaben zur Kompetenzentwicklung – Kriterien und Beispiele der Aufgabengestaltung nach

Chemie im Kontext [Tasks for development of competence – Criteria and examples for the construction of tasks based on Chemie im Kontext]. *Praxis der Naturwissenschaften-Chemie – Chemie in der Schule*, 53, 21-24.

Nentwig, P., Parchmann, I., Demuth, R., Gräsel, C., & Ralle, B. (2005). *Chemie im Kontext - From situated learning in relevant contexts to a systematic development of basic chemical concepts*. Paper presented at the International Symposium on Context-based learning, Kiel 2002. Münster: Waxmann, 2005.

Parchmann, I., Ralle, B., & Demuth, R. (2000). Chemie im Kontext - eine Konzeption zum Aufbau und zur Aktivierung fachsystematischer Strukturen in lebensweltlichen Kontexten [Chemie im Kontext – a concept for the construction and elaboration of subject specific structures in contexts related to the world students live in]. *MNU* 53, 132-136.

Parchmann, I., Demuth, R., Ralle, B., Paschmann, A., & Huntemann, H. (2001). Chemie im Kontext - Begründung und Realisierung eines Lernens in sinnstiftenden Kontexten [Chemie im Kontext – Arguments and realisation of learning in meaningful contexts. *Praxis der Naturwissenschaften-Chemie*, 50, 2-7.

Parchmann, I., & Schmidt, S. (2003). Students´ pre-conceptions as a tool to reflect and to design teaching and learning processes - a study from the project Chemie im Kontext. Paper presented at the ESERA conference 2003.

Paschmann, A., Höffmann, B., & Parchmann, I. (2001). Die Gewinnung von Magnesium aus dem Salz des Toten Meeres The production of magnesium from the salt of the Dead Sea]. *CHEMKON* 8, 30-31.

Pilling, G., Holman, J., & Waddington, D. (2001). The Salters´ experience. *Education in Chemistry*, 38, 131-137.

Pilot, A., & Bulte, A.M.W. (this issue). The use of 'contexts' as a challenge for the chemistry curriculum: its successes & the need for further development and understanding. *International Journal of Science Education*.

Prenzel, M. (1997). Sechs Möglichkeiten Lernende zu demotivieren. Wege zum Können. Derterminanten des Kompetenzerwerbs [Six possibilities to motivate students. Ways to knowledge]. In H. Gruber & A. Renkl (pp. 2-10). Bern, Huber.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29, 4-15.

Schmidt, S., Rebentisch, D., & Parchmann, I. (2003). Chemie im Kontext auch für die Sekundarstufe I – Cola und Ketchup im Anfangsunterricht [Chemie im Kontext also for the phase I in secondary education – Cola and ketchup in introductory science education]. *CHEMKON* 10, 6-17.

Seidel, T. et al. (2002). „Jetzt bitte alle nach vorne schauen!" – Lehr-Lernskripts im Physikunterricht und damit verbundene Bedingungen für individuelle Lernprozesse [„Now all should look to the front side" – Learning-teaching scripts in physics education and related conditions for individual learning processes]. *Unterrichtswissenschaft*, 30, 52-77.

The ChiK-project group (2003). *Materialien-CD: Unterrichtsmaterial – Konzeption – Hilfsmittel [Materials on CD: Teaching materials – Concept of the units – Additional materials]*. Project material on CD ROM.

Van den Akker, J. (1998). The science curriculum: between ideals and outcomes. In: B. Fraser and K. Tobin (Eds.) International Handbook of Science Education (pp 421 – 447). Dordrecht, Kluwer.

Weinert, F. E. (2001). *Leistungsmessungen in Schulen [Assessments in schools]*. Weinheim & Basel, Beltz.

Tables and figures for the paper

Chemie im Kontext – a symbiotic implementation of a context-based teaching and learning approach

Ilka Parchmann, University of Oldenburg, Cornelia Gräsel, University of Wuppertal, Anja Baer, Reinhard Demuth, IPN Kiel, Bernd Ralle, University of Dortmund and the project group ChiK

Table 1: Names of variables, number of items, Cronbach's alpha and examples of items used to evaluate the teachers' views of their teaching used in Figures 6 and 7.

Names of variables	*Number of Items*	*Cronbach's alpha*	*Examples of items*
Variety of teaching methods	5	.67	I used a broad variety of teaching methods.
Students' participation	5	.74	The contents and learning activities were chosen together with the students.
Teacher control	5	.62	In the process of teaching and learning I realised exactly my planning.
Feasability	6	.73	It is difficult to integrate 'Chemie im Kontext' in our syllabus.
Content knowledge of students	3	.78	Students were able to apply their knowledge on the solution of everyday problems.
Classroom management	3	.67	Students often talked together about private things.

Table 2: Names of variables, number of items, Cronbach's alpha and examples of items used to evaluate the students' motivation and interest.

Names of variables	*Number of Items*	*Cronbach's alpha*	*Examples of items*
Motivation	4	.81	Learning chemistry is fun.
Relevance	5	.70	In chemistry, I learn contents which are personally meaningful.
Interest	6	.83	If I see something written about chemistry in magazines or books, I start reading.

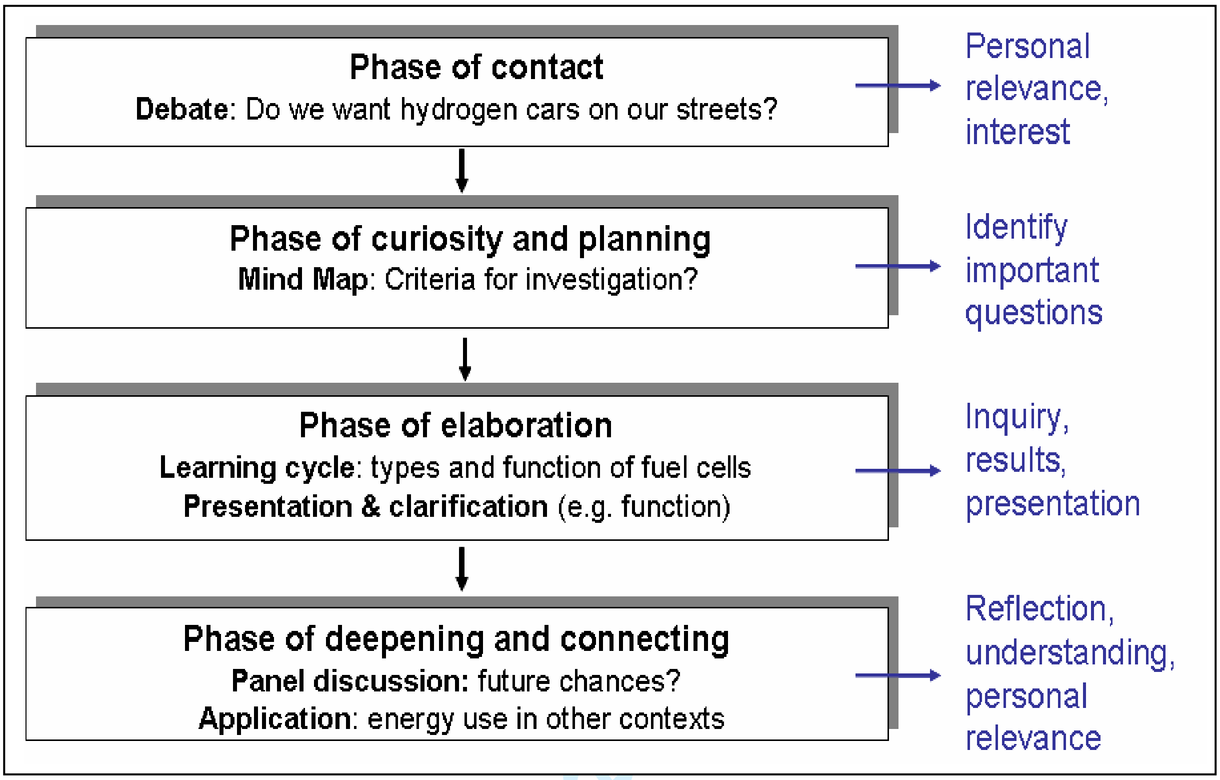

Figure 1: Four phases of an exemplary ChiK-unit.

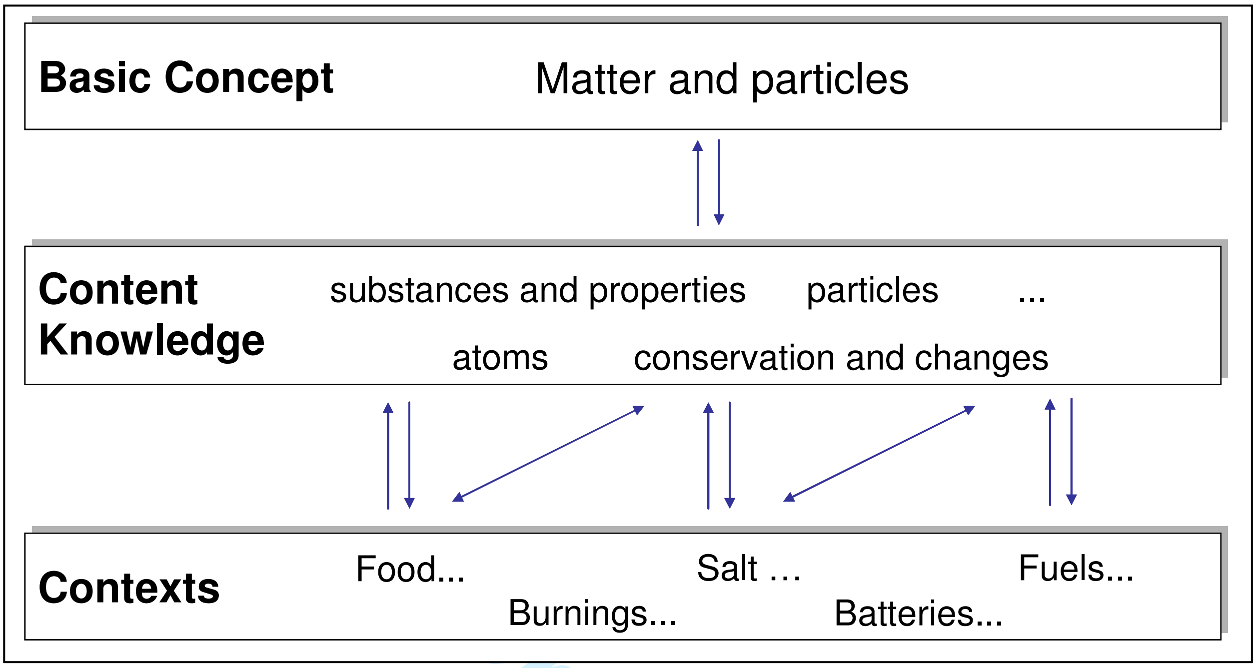

Figure 2: Basic concepts are developed through the combination of different context-based units and used for the explanation of new topics.

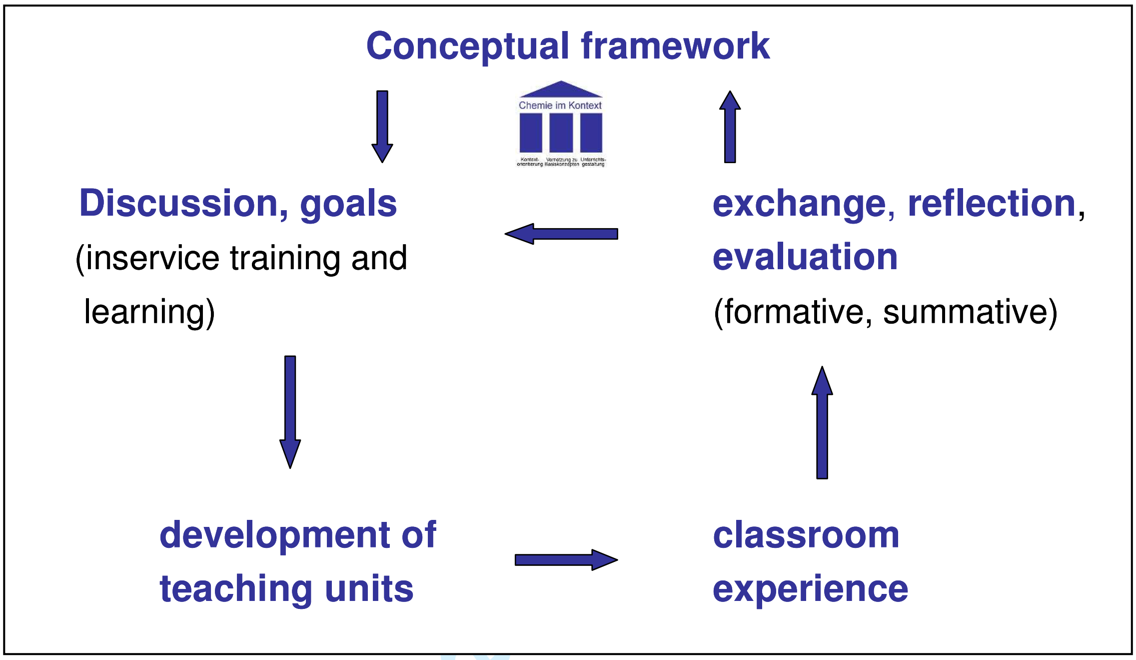

Figure 3: Activities in a learning community.

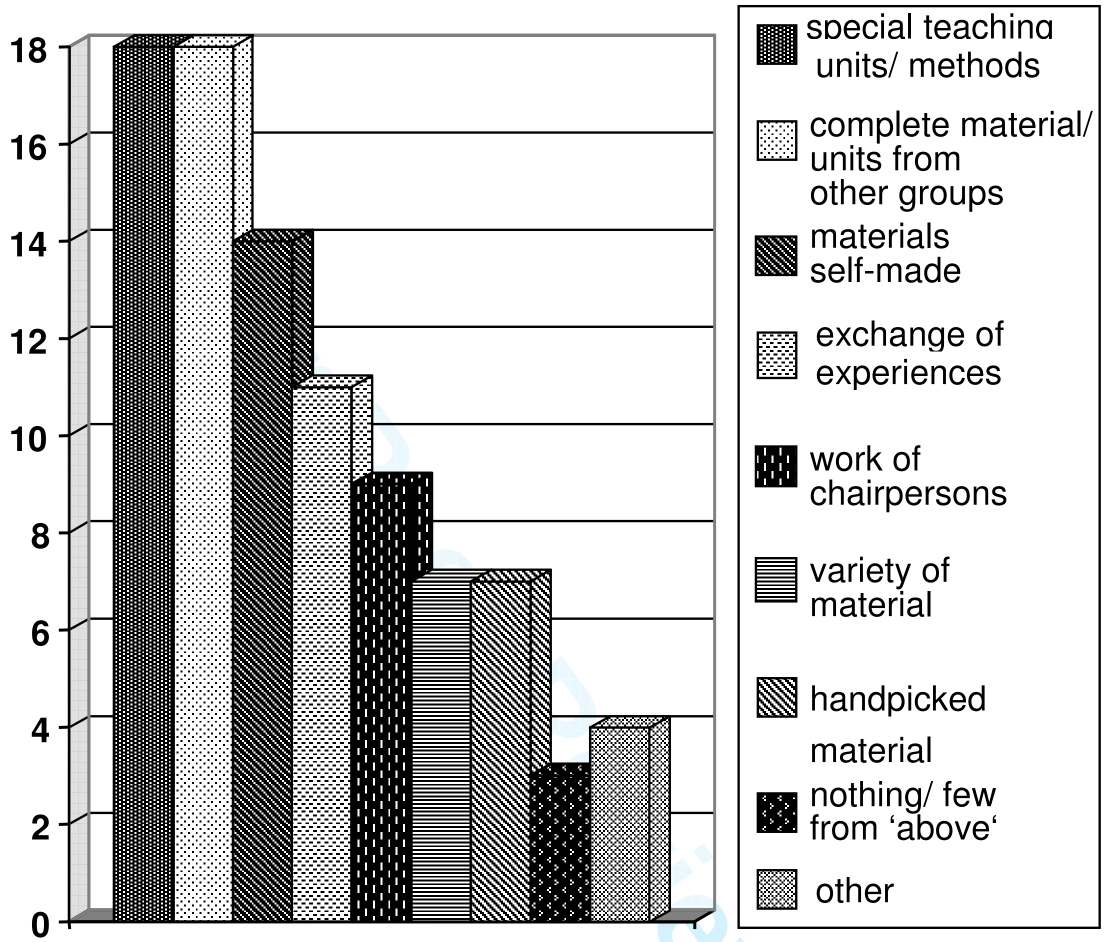

Figure 4: Evaluation of useful means given to the groups to support the implementation of ChiK. Results from the interview study with the chairing science educators (n=18) and teachers (n=37) (Baer et al., in press). The graph shows how often a certain tool was mentioned as being useful.

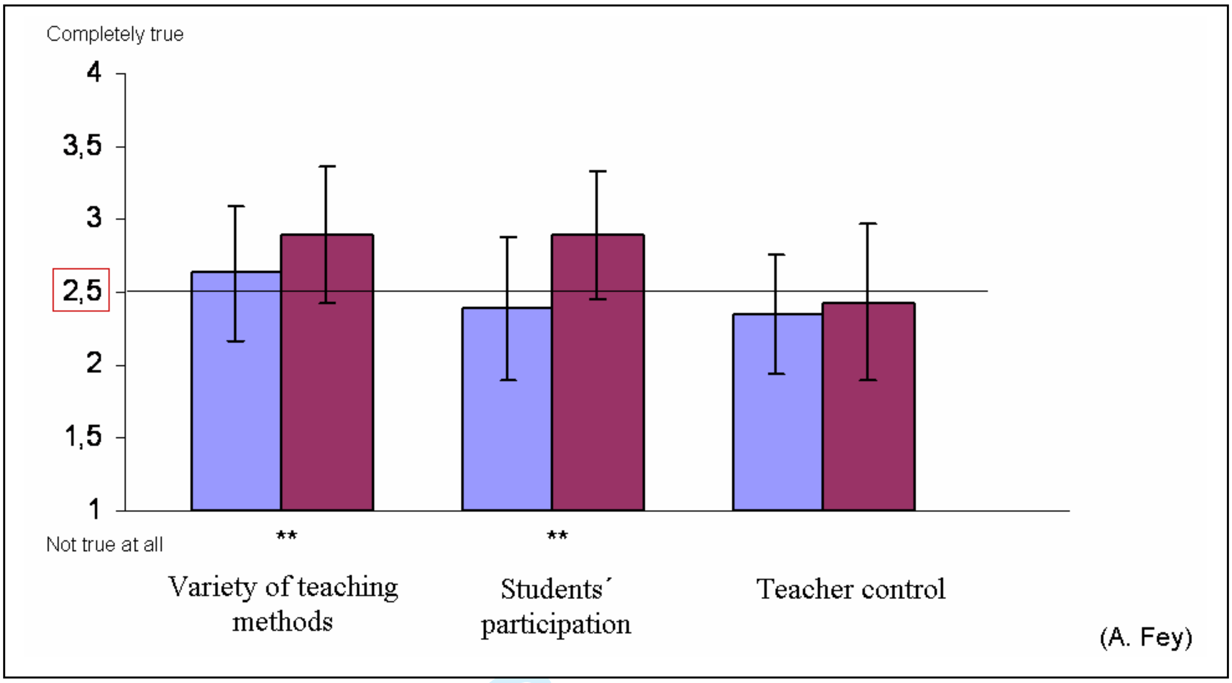

Figure 5: Enhancement of the variety of student-oriented teaching methods, results of the teachers´ questionnaire (light: before beginning with the project, dark: after the first year; **: significant differences; Fey et al., 2004).

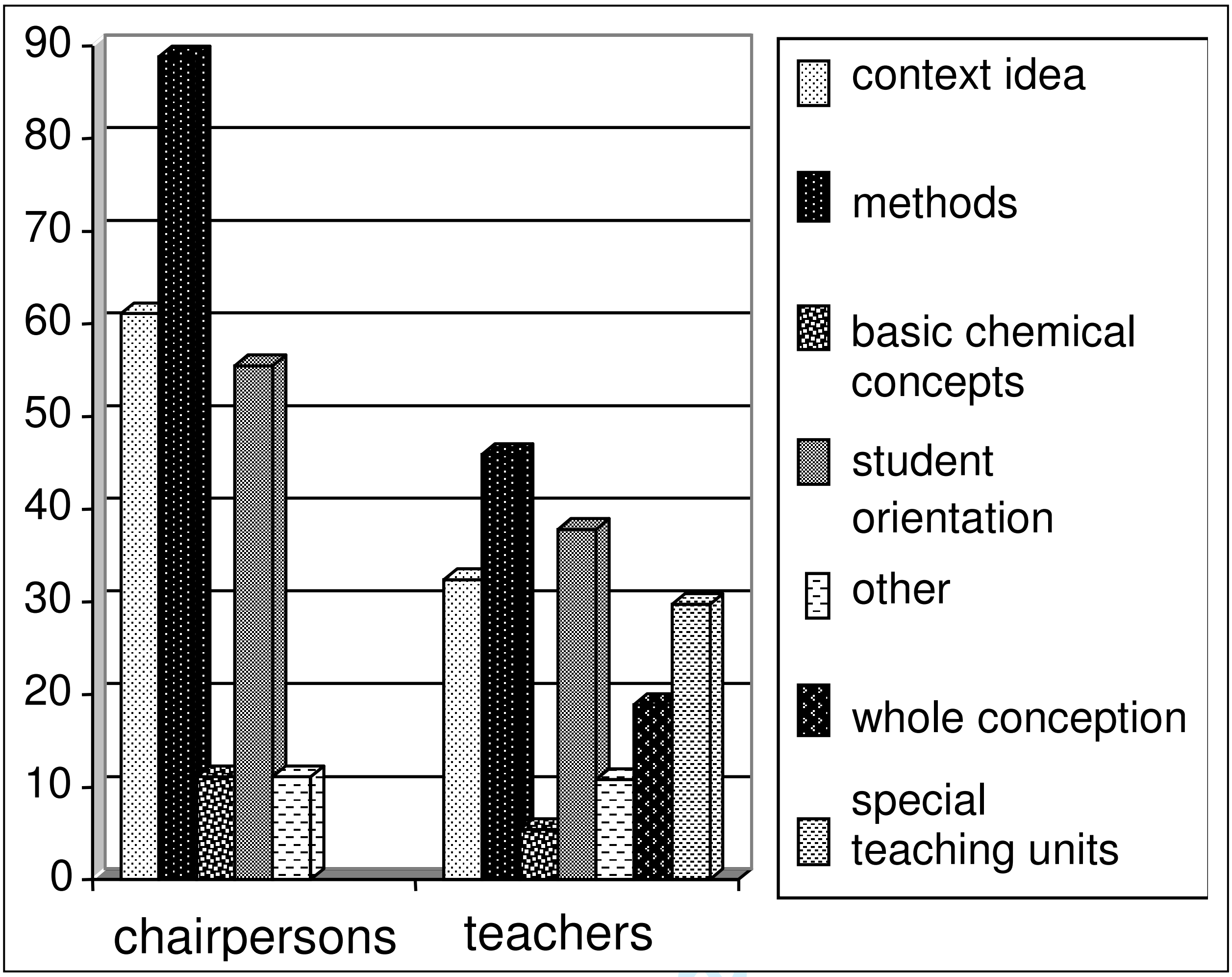

Figure 6: Realisation of the different principles of the ideal framework of ChiK as perceived by the chairing science educators and teachers: Results of the interview study (Baer et al., in press). The graph shows how often a certain tool was mentioned as being useful.

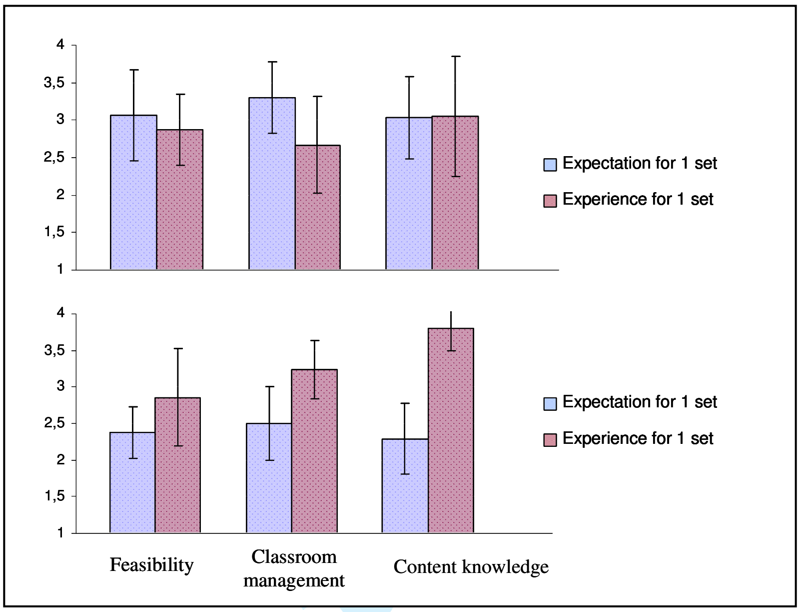

Figure 7: Case studies of perceptions by two groups of teachers (called a set of teachers) in two different states, regarding their expectations before doing ChiK and their experiences after the first year of ChiK. Results from the teachers´ questionnaire (n=13/16 for expectations and n=5/7 for experiences).

Table 1: Names of variables, number of items, Cronbach's alpha and examples of items used to evaluate the teachers' views of their teaching used in Figures 6 and 7.

Table 2: Names of variables, number of items, Cronbach's alpha and examples of items used to evaluate the students' motivation and interest.

Figure 1: Four phases of an exemplary ChiK-unit.

Figure 2: Basic concepts are developed through the combination of different context-based units and used for the explanation of new topics.

Figure 3: Activities in a learning community.

Figure 4: Evaluation of useful means given to the groups to support the implementation of ChiK. Results from the interview study with the chairing science educators (n=18) and teachers (n=37) (Baer et al., in press). The graph shows how often a certain tool was mentioned as being useful.

Figure 5: Enhancement of the variety of student-oriented teaching methods, results of the teachers´ questionnaire (light: before beginning with the project, dark: after the first year; **: significant differences; Fey et al., 2004).

Figure 6: Realisation of the different principles of the ideal framework of ChiK as perceived by the chairing science educators and teachers: Results of the interview study (Baer et al., in press). The graph shows how often a certain tool was mentioned as being useful.

Figure 7: Case studies of perceptions by two groups of teachers (called a set of teachers) in two different states, regarding their expectations before doing ChiK and their experiences after the first year of ChiK. Results from the teachers´ questionnaire (n=13/16 for expectations and n=5/7 for experiences).