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Chemie im Kontext

One approach to realize science standards in chemistry classes?

“Química en context”
Una proposta per assolir els objectius del currículum a les classes de química?

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resum

Química en context (CHiK) és una proposta per fer realitat l’assoliment dels “Science standards” (objectius i competències bàsiques) a les classes de química a Alemanya. És un projecte que va ser desenvolupat i implementat per “comunitats d’aprenentatge” formades per investigadors universitaris de didàctica de la química i per professors, creades pel Ministeri d’Educació d’Alemanya (BMBF). El procés d’implementació va anar acompanyat de molts estudis de recerca empírica, com per exemple sobre la percepció del projecte CHiK pels professors i els alumnes. Junt amb els resultats de la recerca, es va desenvolupar un marc curricular per a tots els nivells de l’ensenyament secundari i es van elaborar i oferir als altres professors els corresponents materials d’ensenyament-aprenentatge

paraules clau
Aprenentatge basat contextos, competències bàsiques, implementació, avaluació, cel·les de combustible

abstract

Chemie im Kontext (CHiK) is one approach to realize science standards in chemistry classes in Germany. It was developed and implemented by “learning communities” of university researchers in chemistry education and teachers, funded by the German Ministry of Education (BMBF). The implementation process was accompanied by several empirical research studies, e.g. on the perception of CHiK by teachers and students. Next to the research findings, a curriculum framework for all age groups of secondary education and tested teaching and learning material were developed and offered to other teachers.

key words
Context-based learning, science standards, implementation, evaluation, fuel cells.

Introduction

How can subject matter teaching react to the unsatisfying results of international studies, such as TIMSS (TIMSS, 1996), PISA (Pisa, 2007) or ROSE (ROSE, 2008)? This was a leading question for the research and development project *Chemie im Kontext* (CHiK). Regarding the decreasing interest and a rather low motivation for science classes – especially physics and chemistry – and the difficulties that many students show in the application of scientific concepts for the explanation of real-life contexts (e.g. High Level Group, 2004, Gräber, 1995), we were looking for alternative approaches towards the teaching and learning of sciences and chemistry in particular. While the traditional curricula in Germany are often overloaded with facts and a rather historical view on chemistry and relevant research topics, so called context-based curricula such as *Salters* (Salters, 1994) or *Chemistry in the Community* (ACS, 1993) offer a more authentic insight into the relevance of chemistry in everybody's daily-life and in our research community. Experiences with the Salters curriculum developers and the teachers using it as well as a literature research on theories about learning and motivation finally became the background for the first developments of the CHiK-project in 1997, which were followed by a national approach of implementation in 2002[2]. In 2004, National Standards were additionally implemented into the German school system. This article describes the background, the framework with regards to the National Standards, some exemplary units and some research results of the CHiK-project, looking back at ten years of experience.

National Standards for science education in Germany

In 2004, an important development took part in Germany: National Standards for the science subjects biology, chemistry and physics had been developed and implemented into the school system (Schecker & Parchmann, 2006). This was a huge step for the education system because of two reasons: a) For the first time, unique standards for all 16 German states and all types of secondary schools were mandatory, and b) those standards describe learning outcomes instead of teaching inputs. The background philosophy of such standards derives from the definition of "scientific literacy" (see figure 1), leading to four described areas of competence:
(1) development and application of basic concepts as a structure for subject matter knowledge (with four basic concepts in chemistry: matter and particles, structures and properties, chemical reaction and energy),
(2) methods of investigation (experiments and models, "Nature of Science", NoS),
(3) communication in science (daily-life and subject specific languages, symbolic language, graphical representations, research and presentation of information) and
(4) reflection and judgment (application of knowledge and competencies for authentic questions, e.g. for society issues, personal issues or career issues related to chemistry).

"Scientific literacy is the capacity

- **to use scientific knowledge**,
- **to identify questions** and
- **to draw evidence-based conclusions**
- in order **to understand and help make decisions**

about the natural world and the changes made to it through human activity."

(OECD-PISA, 1998)

Figure 1: The educational goal of scientific literacy

As these goals are very similar to the goals of so called context-based approaches, they offered a suitable foundation also for the *Chemie im Kontext*-programme. Therefore, the (mandatory) implementation of the National Standards supported the (voluntary) implementation of the CHiK-approach on the one hand side. On the other hand side, the CHiK project offered exemplary units and material to deal with the demands of the National Standards in school practice. The following paragraphs will therefore describe the framework of CHiK and some teaching and learning units as examples for standard-based teaching and learning.

Chemie im Kontext (CHiK) as one approach of standard-based teaching and learning

Even though CHiK began as an idea for a different way of teaching and learning chemistry, it soon became a huge project with different aspects and goals (see figure).

1 The CHiK-project was carried out as cooperation between the IPN in Kiel, the universities of Oldenburg, Dortmund and Wuppertal and 14 participating states with 10-30 teachers and their classes in each state.

2 The CHiK-project was funded by the German Federal Ministry of Education (BMBF), the participating states and the foundation of the German chemical industries (Fonds / VCI). The exchange with the Salters group was supported by the DAAD.

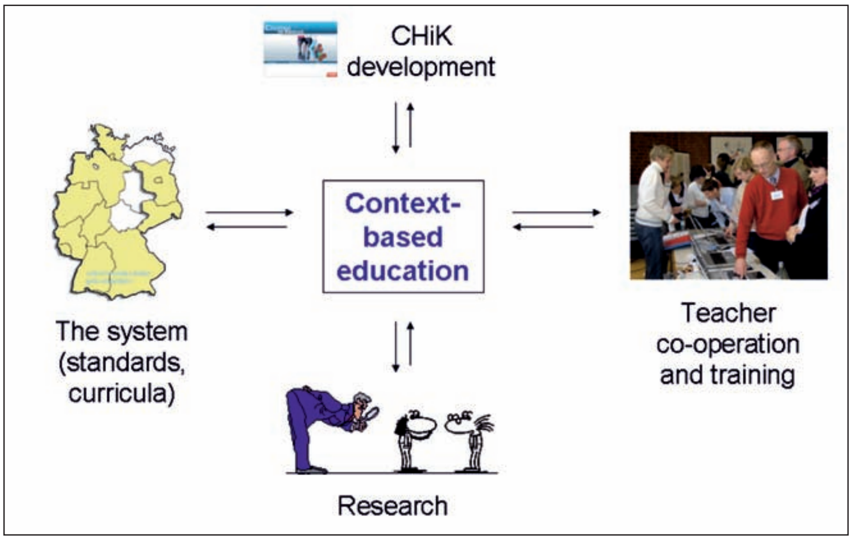

Figure 2: The different goals and aspects of the project Chemie im Kontext

By the end of 2008, more than 200 teachers and more than 4000 students participated in the project, many more probably used the CHiK material, e.g. through the text-books (Demuth et al., 2006 and 2008). As the implementation was also followed by a research program (Parchmann et al., 2006), an additional international co-operation began (see the special issue on context-based learning in the International Journal of Science Education IJSE, Gilbert et al., 2006).

The framework of the teaching and learning approach of Chemie im Kontext

The CHiK-framework consists of three columns:

1. Context-based learning: Learning environments are considered **"**in context**"**, when learners acquire knowledge and competence on a need-to-know-basis in dealing with a relevant issue, starting with their questions and ideas. Examples are: "Food design - why, how and where?"; "Carbon dioxide and climate change?"; "Materials by design"; "A mouth full of chemistry".

2. Development of basic concepts: To develop a basic knowledge foundation that can be applied to new contexts and situations, the main principles of chemistry must be derived and abstracted from the contexts. These principles are described as "basic concepts", they structure and summarize the factual knowledge (see the basic concepts of the National Standards).

3. Variety of teaching and learning methods: A variety of teaching and learning methods is one of the key elements for a successful chemistry education, a) because it considers the diversity of interests, pre-knowledge, capabilities and learning styles and b) because it offers the students situations in which they can develop and apply competencies in all areas as demanded by the National Standards.

All teaching and learning units are structured by four phases:

1) phase of contact (aiming at the students´ motivation and an activation of their pre-knowledge),

2) phase of curiosity and planning (aiming at the development of the students´ questions and structuring the following learning process),

3) phase of development and presentation and **4) phase of summary, deepening, exercise and abstraction and transfer**.

A typical unit of CHiK applies the following steps (see figure 3), of course in different length and depth for different units

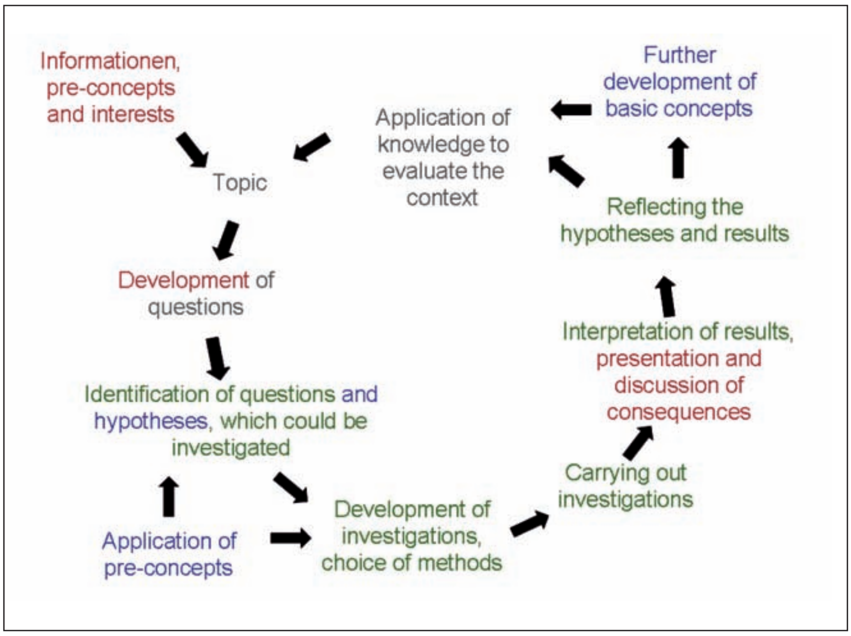

Figure 3: Steps of development in a context-based units of CHiK

The implementation of Chemie im Kontext

CHiK was not developed as a complete curriculum, it was developed as a framework with exemplary units to enable teachers in different states and schools to adopt it to their syllabi and conditions (see also Parchmann et al., 2006 and Nentwig et al., 2007). Hence, the implementation of CHiK was also part of the further development of teaching and learning units and material, based on the idea of "learning communities" (see figure 4). Such communities enable a close co-operation between teachers in practise and university educators and researches, which assured the CHiK approach to consider the demands of research findings and school practise at the same time.

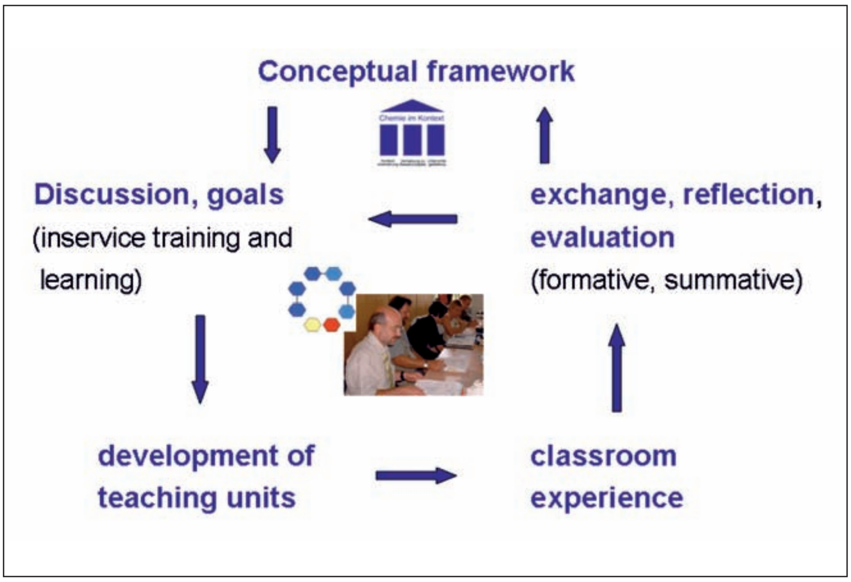

Figure 4: The implementation of Chemie im Kontext through learning communities: steps of discussion, development, evaluation and optimization

Exemplary units

1. The Taster – an introduction into chemistry *(see also Nentwig et al., 2007)*

In many states, the introductory unit (age group 11-13) was "The taster in danger – chemistry replaced the taster" (Nentwig et al., 2007). The main goals of this unit are the introduction of typical chemical questions and experimental methods, such as the analysis of mixtures or the properties of substances as well as the introduction of the idea of using models to explain phenomena and ideas.

In the phase of contact, the students were told the story of the former tasters and asked if that was still relevant to them. The unit trials showed that students always found examples in which they could not taste or smell the ingredients of food, or in which they were even cheated, for example about the amount of sugar in Coca Cola.®

In the phase of curiosity and planning, the students were asked to develop questions and ideas of their own interest. Here, they often asked about poisoning substances or ingredients (again, for example, of Coca Cola) and they told stories about own experiences with food and drinks

The phase of development was divided into two mayor parts: a) the introduction of experimental methods and b) the introduction of the use of models. Not all teachers decided to do both parts in this unit, some introduced models in following unit. The first part was sometimes starting with the demonstration of a swimming and a sinking can of Coke (figure 5), several questions and hypotheses were collected to explain this phenomenon and leading to the investigation of the ingredients of coke.

Figure 5: Swimming and sinking cans of (diet) coke

Separation and identification methods for substances were now introduced, for example for sugar, for acids in general and phosphoric acid in particular, for carbon dioxide or for water. Several methods of separation (e.g. filtration, absorption or distillation) were also applied for other mixtures. In summary, the students learned the same methods and terms as in traditional introductory units, but additionally, they saw a good reason and a personal relevance for what they did.

The second part – introduction of models – started with students´ drawings (see figure 6) and their own ideas about processes. Such ideas were reflected and the necessity of using models for processes that cannot be observed directly was introduced.

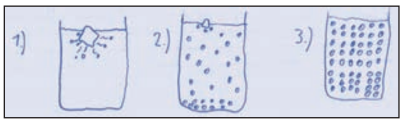

Figure 6: Students drawings as starting points for the reflection of preconcepts (here about the idea of sugar particles dissolving in tea)

The phase of abstraction and transfer summarized and pointed out the methods that the student had learned and the idea of a very first particle model, if introduced. Possibilities for application and exercise were different foods (e.g. chocolate) and drinks (e.g. milk) or other mixtures the students know, such as cosmetics or water treatment.

2. The discussion about fuels, climate change and alternatives for the future: CHiK-units for lower and upper secondary education

Processes that enable human beings and societies to consume energy are crucial for our daily-life and business. However, they also cause questions and problems, such as the amount of fossil fuels that is left, problems caused by unwanted products or possible alternatives. The unit "Wanted burnings, unwanted products" confronts the students with the often described pre-concepts that burning processes destroy matter and reports about products, such as carbon dioxide. The leading question is why chemists, however good, can never avoid the development of products by burning processes?

In this unit, the students work in groups and investigate the origins of different fossil fuels, such as coal, oil or gas. As a result in the discussion, they come up with a cycle (see figure 7). This cycle leads to the following question: What does actually cycle in cycles?

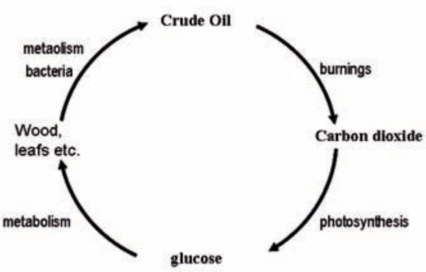

Figure 7: The development of reaction cycles to introduce the idea of the conservation of atoms

To answer this question, the students were now given several ideas of well-known chemists, such as John Dalton, and they were asked to discuss and to apply their ideas to explain the cycling processes.

"We can try to bring a new planet into the solar system or to destroy one, but we cannot produce or destroy an atom. **Changes that we can produce are caused by the separation of atoms that had been connected or by the connection of atoms that had been separate before."**
John Dalton (Jansen, 1984)

By this, the idea of atoms and the conservation of atoms was introduced in a context-based way that again makes it relevant to the students.

The students then got experiments and phenomena in which they had to apply the idea of atoms, such as the conservation of mass. They finally had to discuss alternative fuels and to predict possible products (e.g.: burning hydrogen can never develop CO_2 as there are no carbon atoms in hydrogen).

The unit "The hydrogen car – the car of the future?" picks up this discussion in upper secondary classes and introduces the idea of electric energy and its production by fuel cells. After some advertisements, the students first developed their own ideas of fuel cells, based on their pre-knowledge about batteries (see figure 8). Afterwards, they learned about fuel cells which are used nowadays and about possibilities of the production of hydrogen (see figure 9). In summary, the unit enables them to apply and deepen their understanding of donor-acceptor reactions, about methods of investi-

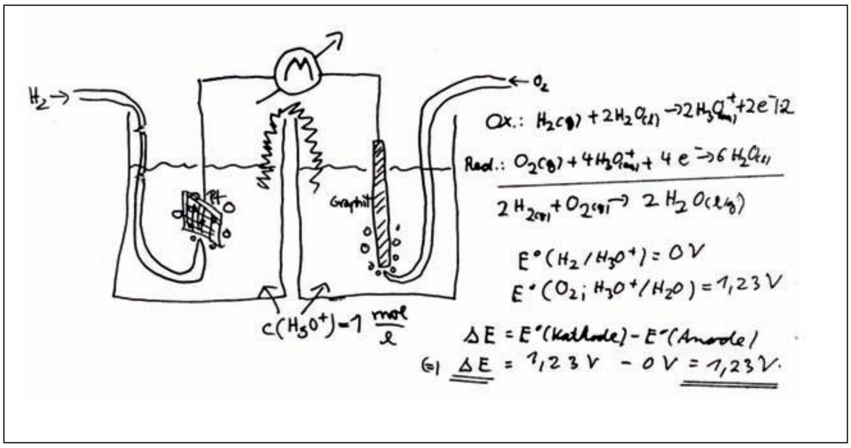

Figure 8: Result of the students´ group work on the design of possible fuel cells

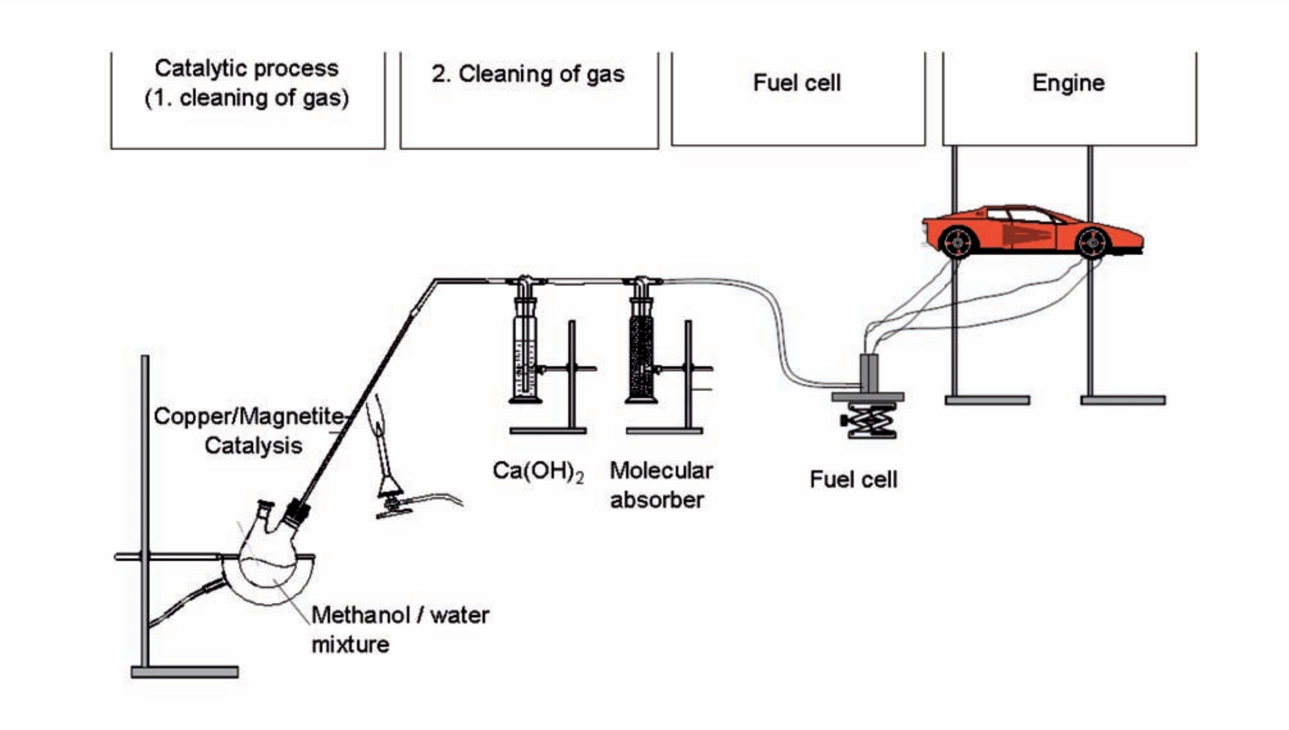

Figure 9: A model experiment to demonstrate the fuel cell car run by methanol

gating and the functioning of different authentic cells, as well as on reasons and discussions necessary for the evaluation of possible techniques for the future (e.g. considering the production of hydrogen, costs etc. next to their chemistry knowledge).

Hence, all areas of science knowledge and competencies were included in this unit and can lead to an understanding of basic concepts when combined with other units (see figure 10).

The unit "Wanted burnings, unwanted products" confronts the students with the often described pre-concepts that burning processes destroy matter and reports about products, such as carbon dioxide

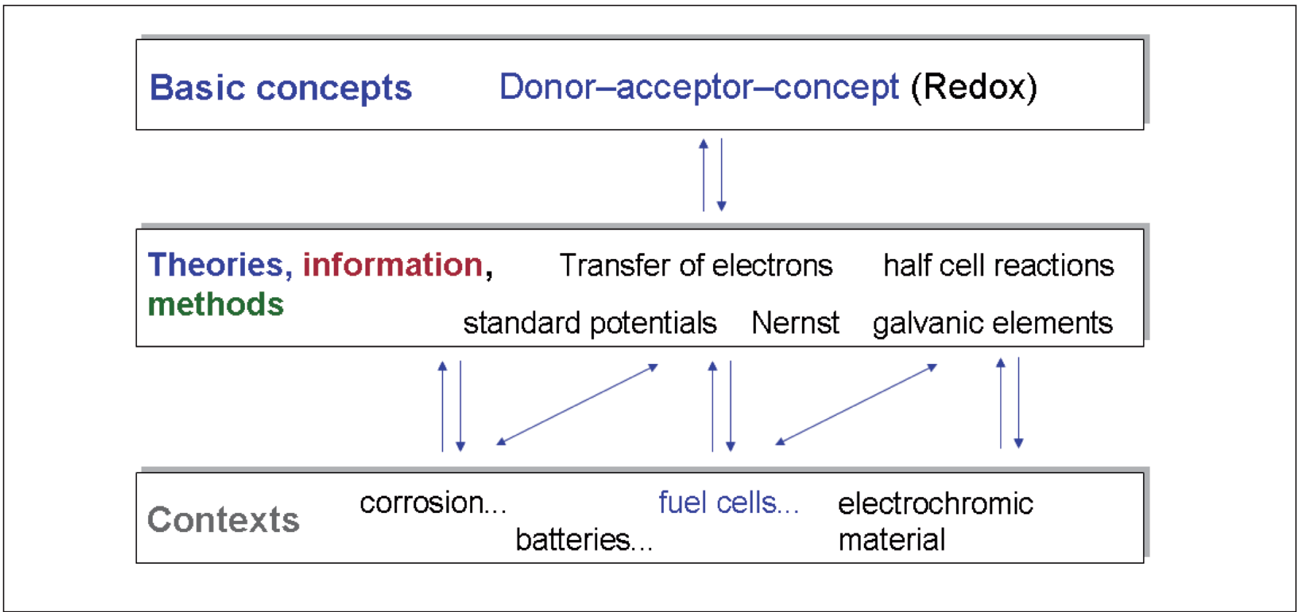

Figure 10: The three levels of Chemie im Kontext to develop context-based questions and understandings, factual knowledge and competencies as well as a general understanding of basic concepts

Exemplary research findings

Before and accompanying the CHiK-project, research studies on other context-based approaches had been studied (e.g. Pilling et al., 2001, Bennett et al., 2005, Pilot & Bulte, 2006). For the CHiK-project itself, a variety of research findings were gained, looking at the implementation process and its conditions (Parchmann et al., 2006), the perception of changes by teachers and students or exemplary assessment of learning outcomes (e.g. Eilks et al., 2004, Menthe, 2005, Fach & Parchmann, 2007). This paragraph will point out some of the research results.

The perception of the teachers showed that they had realized two of the three CHiK columns: they enhanced the use of contexts as "backbones" for their teaching units and they also enhanced the variety of teaching methods, without feeling a loss of control (see figure 11). However, they did not put the same emphasis on the development of basic concepts, which may have lead to rather poor learning results and motivation in some classes (which said they had lost their "guideline" during the unit), while motivation and learning outcomes were very good in other classes.

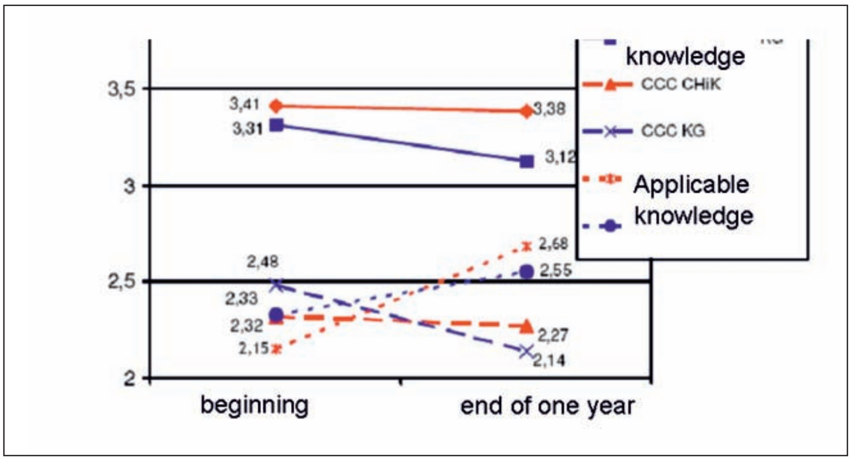

Figure 12: Exemplary findings of the students´ perception at the beginning of the project and at the end of one school year, in comparison between CHiK- and non-CHiK-classes (source of results: CHiK-research report, Fussangel et al., 2007)

A comparison study showed significantly better results for CHiK classes compared to others, regarding the students´ perception (see figure 12)

On the whole, the implementation process can be regarded as highly successful, while context-based teaching and learning can only be successful when the same emphasis is given to the identification of successful contexts and the structuring of units and learning outcomes, e.g. by basic concepts for the area of subject matter knowledge. The transfer of concepts is one of the most difficult abilities for students and can only be built up by many applications and exercise tasks.

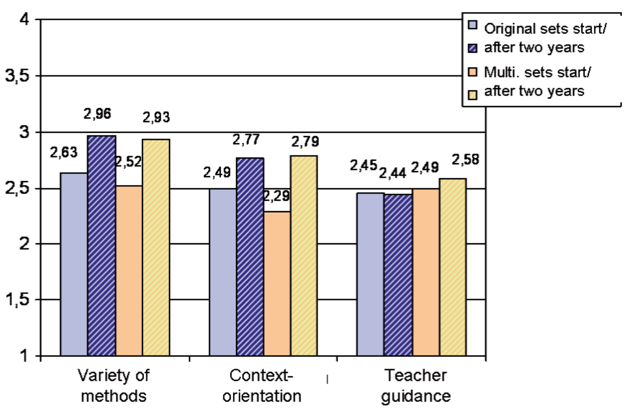

Figure 11: Exemplary findings of the teachers´ perception at the beginning of the project and after two years for the implementation groups and the multiplication groups

Summary and outlook

As a summary, the CHiK project delivered the following outcomes and findings:

- A pool of **tested modules and material, including a textbook with CD and teachers guide;**
- **positive results showing that learning communities** support changes and development;
- a positive development of **relevance and motivation in class**, but **depending on the context and the teaching,**
- **diverse learning outcomes**, but as good or better than traditional classes and
- a signal that teachers **focused very much on contexts, students´ activities and a rise of the variety of methods**, but **less emphasis was given to the development of basic concepts which might lead to learning problems in class.**

Further activities and studies shall set a special focus on the necessity of basic concepts and the transfer of knowledge, others on the development of tasks for learning and assessment.

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