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# EFFICACY OF COMPUTATIONAL MAPPING TOOLS FOR IMPLEMENTING NEW STANDARDS AND INNOVATIONS IN TEACHING CHEMISTRY AT SCHOOL

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**Abstract**. German students showed only a mediocre performance in national and international scholastic tests. As a consequence of the subsequent discussion the school administration initiated educational standards which were supposed to cause an educational change in German classroom teaching and school staff collaboration. Knowledge management research proposes to use 'synergy maps' as a focusing tool in the communication of innovation. The goal of this study is to develop and optimize a set of computational maps, produced with CmapTools, which can facilitate and support these change processes.

## 1 Introduction

The mediocre results of German students in national and international scholastic tests, like PISA or TIMSS, were succeeded by a wide and open discussion in the German society and educational research. The political consequences of this discussion led to fundamentally different requests from German teachers. The 'Munich Knowledge Management Model' (MKMM) (Reinmann-Rothmeier, 2000) and the 'Concerns Based Adoption Model' (CBAM) (Hord, 2006) sketch an approach how this educational change in classroom teaching can be managed. Eppler (Eppler, 2004) proposes to use structured visualizations as 'synergy maps' in knowledge management and change processes. This study is to investigate in how far structured visualization and networking can facilitate and support the process of implementing curricular changes.

## 2 Political background: Recent developments in secondary education

With chemistry teaching in Lower Saxon[1] grammar schools being in the focus of this research project, the new Lower Saxon chemistry core curriculum (CCC) (Kultusministerium Niedersachsen (KM), 2007) is quite different to all the directives, chemistry teachers had to fulfill before. Former curricula were input-detailed by drawing a timescale of themes, whereas the new core curriculum only presents a rather abstract schedule of goals to be reached in two year terms, that is after $6^{th}$, $8^{th}$, $10^{th}$ and $12^{th}$ grade (with the last being in development). The way to reach the goals of the CCC is left to the chemistry staff of each school. Furthermore the Lower Saxon school administration developed a quality management including an 'orientation schedule' giving advice to schools which aspects are important for quality management and controlling (KM, 2006). It consists of several aspects of school with one being important within the scope of this study: 'professionalization of teachers'. The core of the teacher's professionalization is to facilitate collaboration within a school's staff, being unfortunately quite uncommon among German grammar school teachers (Graesel, 2007). Thus, requests and prerequisites on the chemistry teachers have changed very much within a short period of time.

Statewide teacher training courses for the CCC were initiated by the Lower Saxon school administration. The author is one of the trainers, and his subjective qualitative impressions of the training program can be summarized as follows:

- Motivation and attitudes towards this 'top down'-innovation varies from 'negative' to 'curious'.
- Many teachers are frustrated because of the lack of material and because of the demand to complete what they call 'the job of the administration'.
- The CCC is quite abstract and in its text structure rather unclear and hard to be transferred to a practical use.

These impressions clarified the need of "*bridges*" between the abstract goals of the CCC and the daily practice of classroom teaching. Visualization and mapping tools like CmapTools (Novak & Cañas, 2008) may serve promisingly to be such kind of support. However, open questionnaires with chemical education students and beginning teachers have indicated that there is little to no experience with mapping and computational mapping tools yet. Both the students and the beginning teachers commented a disadvantage of mapping lying in the reduced and abstract content of information. On the other hand both groups mentioned text-based chunking by writing summaries as an important aspect of successful preparation of major exams. This indicates the lack of

1 Lower Saxony is a federal state of Germany, and school administration is a state matter.

knowledge, routine and appropriate use of general as well as computational mapping methodologies. Therefore, there is an essential need for teacher training programs in visualization tools, like CmapTools.

## 3 Theoretical background

The main focus of this research project is the educational change process of a chemistry staff of a school. Therefore, the theoretical models were chosen in order to be able to describe, structure and analyze this kind of developmental processes.

### *3.1 The Munich Knowledge Management Model*

The MKMM is an educational-psychologically grounded theory of knowledge management usually used to administer knowledge in corporations. The theoretical and the practical approach of the model is held general enough to be promising for the demands of the school system as well. The model intends to lead a system into a vivid and lifelong 'learning organization' with a dynamical culture of knowledge and learning. It defines a constructivistic understanding of knowledge based on the widely accepted 'knowledge of information' (KoI) and 'the knowledge of action' (KoA). These are represented in four different aspects of knowledge management, each of which is accompanied by corresponding psychological aspects to be kept in mind (Reinmann-Rothmeier, 2000).

The *communication of knowledge* is necessary to interchange, share and network the concepts and the knowledge of individuals. Communication processes can be disturbed heavily by antipathies and a lack of trust between individuals. The communication can induce a *representation of* knowledge being a materialized, transparent and technically applicable knowledge which is desirably achieved in a consensual process. The psychological problem of representation of knowledge is that the individual has to express his (lack of) knowledge. This can cause distress of incompetence and loss of power. Synergetical effects can cause a *generation of knowledge* with new, innovative ideas. Curiosity, creativity and the ability to question routine are supportive conditions of a successful generation process. At last, the *use of knowledge* has to transfer the KoI to an applicable KoA that supports daily problem solution processes. An individual meta-knowledge is essential in all of the four aspects of knowledge management to overcome most of the psychological problems.

The MKMM has both an organizational and an individual component. The organization is the place, where the change has to be managed, and has to set up the general framework for the change process. The management aspect, 'top-down' vs. 'bottom up', is also very critical with 'bottom up'-management being more promising. The individual within the organizational system has to organize and accomplish his or her individual change. The MKMM lists three cumulative 'stations of an individual learning cycle' which are referred to the school system:

- *New skills* expand the patterns of thinking and handling daily classroom teaching
- The new scope of patterns leads to a *new sensibility* and a new *awareness* of teaching and useful changes
- This new sensibility causes *new attitudes and perspectives* and thus implements the change

'Communities' (Wenger, 2000) play an important role during this process. They are informal, desirably hierarchy-free and self-organized networks of individuals of the system driven by a convention of interests and/or problems. Central processes in the communities are communication, cooperation, exchange of experience, generation of knowledge and mutual learning (Parchmann, 2006).

### *3.2 The Concerns Based Adoption Model*

The CBAM can be characterized as an innovation-focused framework for educational change describing and predicting teachers attitudes and behaviors (Anderson, 1997; Hord 2006). It is applicable to the understanding of both 'bottom up-' as well as 'top down'-change initiatives, and consists of the following components:

- *Stages of Concern (SoC):* The model describes seven possible stages of concern of teachers. Stage 0 'Awareness' means that teachers have little to no interest or information about the change whereas Stage-6-teachers ('Refocusing') reflect the entire innovation process. The model offers diagnostic tools.
- *Levels of Use (LoU):* While the SoC represent the attitudes of the teachers the LoU describe general patterns of teacher behavior as they prepare to use, begin to use, and gain experience implementing classroom changes. Level-0-teachers ('Nonuse') have no knowledge of changes and no plans for an implementation. Level-6-teachers ('Renewal') may modify the innovation or explore an alternative practice.

- *Innovation configurations (IC):* The key assumption is that teachers rarely implement an innovation in the same way and in the manner intended. The CBAM therefore offers an *Innovation Configuration Component Checklist*.

Further focuses of the model are put on the role of the change facilitator, on the intervention itself (*Intervention Taxonomy*) and on aspects concerning the innovational context.

## 4 Goals and design of the developmental research project

The goal of this research project is to provide CmapTools change facilitators for the implementation of the CCC. The role of these change facilitators, proposed by the CBAM, will be investigated qualitatively as part of a knowledge management process of a school's chemistry staff.

To prepare these change facilitators two groups of potential users will interviewed. University students participating in last semester's 'chemical school experiments'-course used CmapTools to develop teaching units where the experiments of the course were part of. Their practical experience will be explored through interviews. Furthermore, exemplary mapping results of the university students will be shown to teacher trainers. These practitioners used text based documentation proposed by the CCC to document their teaching units and are not qualified in using CmapTools yet. The contents of this interview will be possible benefits and problems along with further aspects to be kept in mind when developing change facilitators with CmapTools. Both interviews will be analyzed using the qualitative content analysis (QCA) according to Mayring (Mayring, 2003). The categories for the QCA will be drawn from the MKMM and the CBAM.

To show an example, the structured visualization of a chemistry teaching unit (fig. 1 (Parchmann, 2008)) was developed after the introductory CCC teacher training.

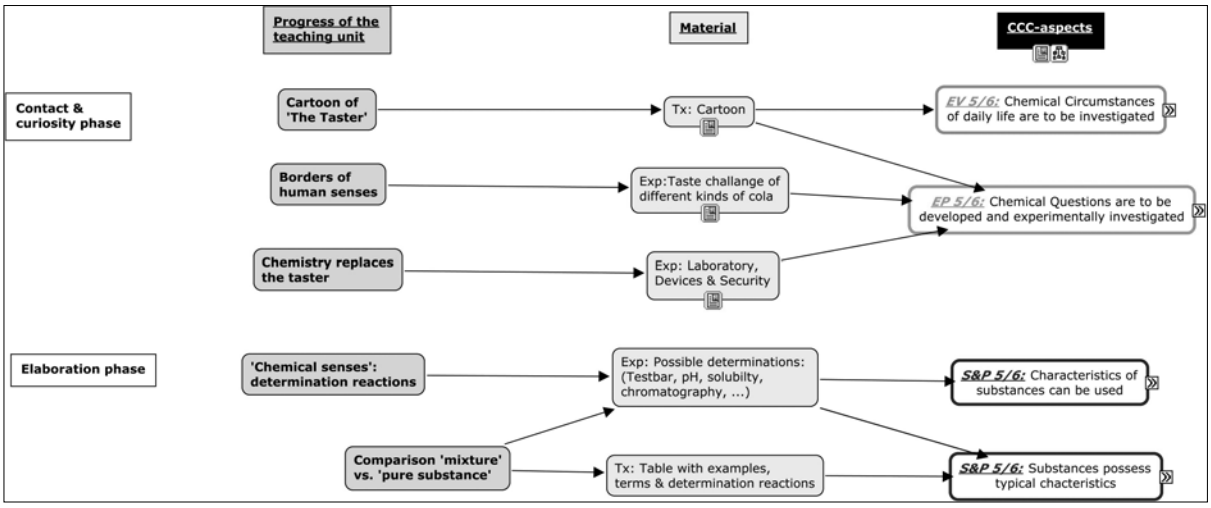


**Figure 1**. Flow diagram of the 'chemistry-in-context'-unit 'The Taster'.

Figure 1 contains a part of a flow diagram of the 'chemistry-in-context'-unit 'The Taster' (Nentwig, 2007) also by using CmapTools. The black-rimmed white icons on the left are the overall phases, and the dark-grey icons indicate the progress within the teaching unit. The arrows to the light-grey icon connect teaching material on the computer's hard disk or internet-URLs to the corresponding step of the unit. At last, this is connected to one or more related competencies of the CCC shown on the right side of the flow diagram.

Keeping in mind the teacher's IT-competencies, the computational mapping tool 'CmapTools' is a complex matter to many teachers. The use of this complex tool must be justified by the complex task the teachers have to succeed in as well as an effective and practical use of the results for the development of teaching units and in classroom teaching. Therefore, a CmapTools- teacher training will be developed to scope the demands described before. The teachers will be especially encouraged to use their CmapTools skills to document their teaching units. This training program will contain strategies and material, like exemplary 'synergy maps', according to the results of the QCA of the interviews.

Finally, the success of the training program along with the mapping results of the teaching units will be evaluated again by interviews with an adjacent QCA. The mapping results will be compared with text-based CCC documentation equivalently using hyperlinks to crosslink the documentation with material. The results of this QCA will finally lead to an optimization of the strategies and the material.

The presentation will contain first results of the QCA of the university students' and the teacher trainers' interviews and a sketch of the teacher training program.

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