Concept Mapping: Connecting Educators
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EFFICIENCY OF CONCEPT MAPPING FOR THE CONCEPTUAL UNDERSTANDING OF *BURNING AND UNDERLYING PROCESSES OF COMBUSTION* FOR ELEMENTARY SCHOOL STUDENTS

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Abstract. The study shows the triangulation of qualitative and quantitative research methods on concept mapping. The research questions focus on two aspects: 1) How must the topic *burning and combustion* be educationally structurized to promote meaningful learning and 2) do elementary school students learn science concepts more efficiently by the use of Concept Mapping than with traditional linear methods.
Concept Mapping is used in this study as a) a qualitative research method to investigate student's conceptions about the specific content and b) as the object of interest in the investigation as they were quantitatively compared to a linear method to investigate the efficiency of concept maps in their function as a learning method. The aims of the study lay in the combination of findings to create guidelines for learners and teachers for their work with Concept Mapping within this domain specific content of chemistry education.

1 Introduction

In studies about how young children learn science concepts meaningfully it is often reported that they tend to have problems integrating new scientific concepts in established knowledge structures (Rahayu et al. 1999, Seré 2000). Thereby scientific knowledge stands isolated in opposition to "every-day" assumptions. Everyday concepts can have a great impact on observations and interpretation of scientific phenomena (Prieto 1992, Anderson 1990, Meheut 1982).

Additionally, Concept Maps are often described as "metacognitive tools" that support children's reflective thinking by using visual and conceptual representations (Mintzes et al. 1997). By creating and modifying a concept map the creator needs to make comprehensible decisions about which concepts are related or subordinated and in which context they are used. As processes of individual self-reflection, self-control and evaluation are necessary for creating a concept map, these processes will concurrently be positively influenced. Concept Mapping has been proved to be efficient for short-time memory of concepts (Bernd et al. 2000). Concept Mapping also exert an influence on long-time memory of knowledge concerning an overview of a domain area (Juengst 1995). A positive effect of the use of Concept Mapping could be reported for student's attitude in relation to science as they gain a transparent overview of domain specific knowledge fields (Jegede et al. 1990). So far it is not yet investigated how and in which extend the method of Concept Mapping has a positive influence on elementary school students learning alleged abstract concepts such as *burning and combustion*. According to these research interests, this study uses Concept Mapping as a) a research method and b) as the object of interest of the inquiry.

2 Design of the study

The study combines the interests of two different fields: the interest of pedagogical psychology in the efficiency of a certain learning method such as Concept Mapping and the reveal of underlying cognitive processes and the interests of science education in elementary students (pre-) conceptions about a special chemical phenomenon. The aim is, to combine the results of these two research fields in the background of a practical orientated research model to give advices for school learning.

Therefore the investigation focuses on two research questions:
1. How can the topic *burning and combustion* be structured for elementary school students?
2. Do children learn science concepts more efficiently by using networking learning methods such as Concept Mapping?

To answer these questions three parts of investigation were made:
a. By using interviews, experts identified the scientific (chemical) matter of the topic *burning and combustion* for elementary school students from their own experiences.
b. Qualitative analyses revealed the students' conceptions about the topic *burning and combustion* and have been related to other research results.

c. By using a special quantitative scoring the efficiency of Concept Mapping for learning the matter *burning and combustion* has been evaluated.

Two of the three parts of the study and their specific influence on the educational structuring process are described below.

The research is methodologically settled in the research frame of the underlying model of *Educational Reconstruction* (Kattmann et al. 1997). This model aims at the iterative connection of

- the clarification and simplification of the specific subject matter,
- the analyses of students' (pre-)conception about the specific topic and
- an educational structuration of the specific subject matter which constitutes the research target.

Epistemologically the model bases on constructivist ideas that assume the (re-)construction of a certain subject matter by the individual itself. As science education acts as a meta-science against domain specific science, it requires the inclusion of students' (pre-)conceptions as part and parcel in the process of (re-)construction. The following graphic shows the interaction of all research paradigm related to the specific parts of this study:

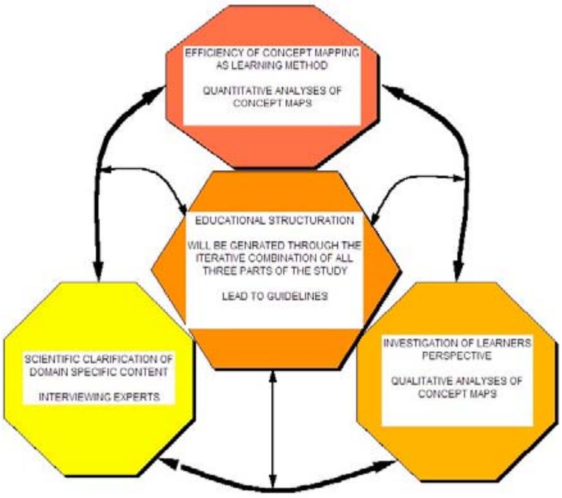

Figure 1: Design of research included in the research framework of the Model of Educational Reconstruction

The scientific clarification and the investigation of the student's (pre-)conceptions mark these parts of the study that are focused on the answering of the first research question, because they refer to the content *burning and combustion*. Here, two investigations were made which are presented under 2.1 and 2.2. Part 2.3 shows the results of the study about Concept Mapping as the focus of the investigation; this part is described more in detail as it is of greater importance for the aims of the study.

2.1 Clarification of specific subject matter by interviewing experts

The simplification of scientific matter, which is in this case the topic *burning and combustion*, marks one of the central aspects within the model of Educational Reconstruction (Kattmann et al. 1997). To identify concepts that are relevant for elementary school students, four experts have been interviewed. These experts all have a scientific background and have developed different educational submissions for elementary school students for the topic *burning and combustion*. The method of interviewing experts has often been used in qualitative research (Meuser 1994) and proofed its value. As it is not the focus of this overview the findings on that are omitted.

2.2 Concept Mapping as research method – the investigation of student's preconceptions of the topic burning and combustion

The Concept Maps of 92 elementary school students at the age of 10 have been evaluated qualitatively. As *burning and combustion* has not been discussed in school lessons these mapped concepts base on preconceptions.

This part of the study represents methodologically an empirical-qualitative exploration. First the data has been deductively related to results of studies in the field of science. In the qualitative analysis, theory-based aspects of the evaluation were related to the data, then deduced and in a formal-contextual way structurized sensu Mayring (2000). Second, the data has been searched for everyday concepts, which were collected indicatively. Through processes of generalization categories were identified and communicatively validated.

In the process of collecting the data, the propositions (a proposition consists of two concepts linked by a labelled relation) within the Concept Maps were analysed under the named procedures. Over all 118 concepts were counted and 9 different categories could be identified which should be mentioned here in detail:
Scientific concepts: The most prominent concepts were *wood as an example for a combustible material*, which forms 24% of all scientific concepts and therefore is one of the most prominent concepts and *water as a solution for extinguishing a fire* which was named 25 times and makes 21% of all scientific concepts. A lot of other examples for a burning material were also named (paper, coal and hay), but surprisingly the candle or the burnt wax was only named three times. Even two children noticed that a fire needs a *temperature for burning* and 12 named a *source of ignition* like lighters or matches.
Sensitive perception: The most frequently named sensitive perception was *fire is hot* (named 55 times). 9 times the *generated heat* was mentioned.
Destruction and dangerousness: The most important thing the students named under this aspect was that *fire is dangerous* and not that it can be dangerous if handled wrongly. They also mentioned fire to be *deathly*.
Description of the phenomena: Often the students knew that a fire *has a flame* (named 21 times) and *smoke occurs* (named 23 times).
Own experiences: What is outstanding within this class is the experience of *getting burnt*.
Aesthetic dimensions: Students often described the fire with certain qualities of *colour and smell*.
Institution fire station: Almost all students named the *fire station* and their responsibility for extinguishing fires.
Word associations: Special German words are mentioned like the fire station, but rarely.
Historic dimension: Twice the invention of fire by *prehistoric men* was mapped.

It is not surprising that elementary school students have more everyday concepts than scientific concepts. Remarkable, but well in line with other research findings is the fact that there is a dominance of concepts that describe *fire* as being dangerous and destructive (Prieto et al. 1992; Rahayu et al. 1999). These concepts even outweigh concepts that are based on own experiences. Working with scientific experiments can help to fill the gap of own experiences and can also influence the strong believe that *fire* is dangerous. Maybe making experiments can even help regarding *fire* as less dangerous if handled well and that it requires certain care.

The collection of "scientific" and "everyday" concepts through the research method of Concept Mapping and their utilization for Educational Structuration in the sense of the model of Educational Reconstruction has been innovative. Through the results, the effect of emotional affected concepts in this specific content and their great influence on learning processes could be demonstrated.

2.3 Concept Mapping as the subject matter of the inquiry – efficiency of Concept Maps for elementary school students

In the past, the method of Concept Mapping has been proven to be very effective for adult learners (Juengst 1995; Bernd et al. 2000) as well as for the use of learning strategies (Fischer et al. 2000) and diagnostical knowledge research (Stracke 2003; Weber et al. 2000). Contrary to some assumptions, even young children are able to produce meaningful concept maps (Novak et al.1983; Novak et al. 1984).

According to this, the third research question focuses on whether elementary school children learn more efficient by using networking learning methods such as Concept Mapping.

Students' cognitive abilities were investigated with the CPM-Test (Coloured Progressive Matrices by Raven). In form of guided inquiry learning, the students acquired the underlying chemical concepts of the topic *burning and combustion* which was embedded in an excursion to the students' chemical laboratory („CHEMOL“[1]) at the University of Oldenburg.

Subsequent to this, two cognitively homogeneous groups recorded their knowledge by either taking traditional keyword-list[2] (group A) or building up a Concept Map (group B)[3]. A follow-up multiple-choice knowledge test two weeks later was handed out to show the students overall conceptual understanding.

A quantitative evaluation analyses which of the two groups, the keywords-list-group or the Concept Map group, has learned more effectively than the other group. Therefore all data have been investigated with a specific score-code: In the key-word group all concepts have been counted, then the occurring misconceptions have been pointed out and finally the scientific concepts, which were taught in the intervention, have been counted. The same has been done for the Concept Mapping group, but additionally the frequency of cross links has been scored. These results have been compared with the data collected from the knowledge test by correlation testing. The following charts show an example of a before- and after-intervention Concept Map with the detected scoring:

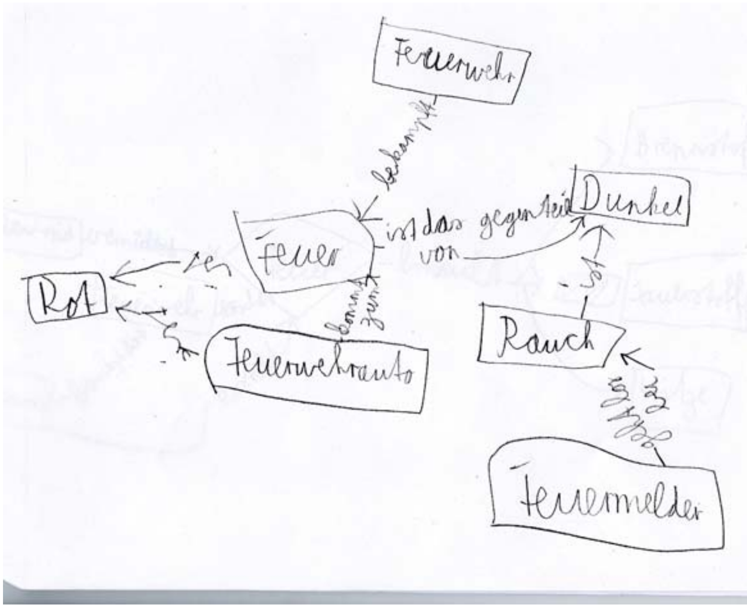

Figure 2: Max Concept Map before intervention

<u>Translation</u>:
Rot – red
ist - is
Feuer – fire
Feuerwehrauto – fire engine
kommt zum – comes to
Feuerwehr – fire brigade
bekämpft – fights against
ist das Gegenteil von – is the opposite of
dunkel – Darkness
Rauch – smoke
Feuermelder – fire detector
geht an bei – sounds the alarm when

<u>Scoring</u>:
All: 7
Scientific Concepts: 0
Misconceptions: 0
Crosslink: (7+1) 8

The most interesting results were the fact that the amount of used scientific concepts within the Concept Maps correlate positively on the score of the knowledge-test (r=.30*,N=48). And the level of networking within the Concept Maps also correlate positively on the score of the knowledge test (r=.80**,N=17). While the results show that the level of cognitive ability of the students had no influence on the possibility to learn effectively with the method of Concept Mapping it can be used in educational surroundings to emphasize the scientific concepts and their function for burning processes. The degree of deeper understanding can be promoted through a directed use of certain concepts and the intention of maximum linking. How to force those processes without disturbing the process of construct knowledge is not yet defined.

[1] CHEMOL is a interdisciplinary project where elementary school students learn science concepts by doing experiments in a chemical laboratory.

[2] Key-word list means a linear list with related words and associations. They are not connected with each other in any traceable way.

[3] The methods have been introduced and used for several other topics with the test persons. One can say that all probands could handle the method of writing a key-word list and creating a Concept Map very well.

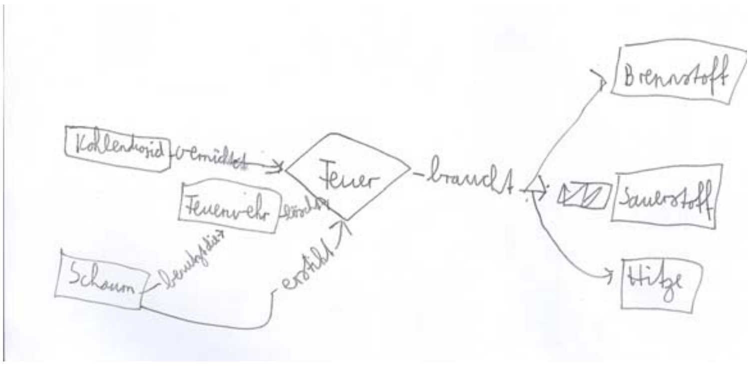

Figure 3: Max Concept Map after intervention

<u>Translation</u>:
Kohlendioxid – Carbondioxide
Vernichtet - extinguishes
Schaum – foam
benutzt – used by
erstickt – chokes
braucht – needs
Brennstoff – burnable material
Sauerstoff – oxigene
Hitze - heat

<u>Scoring</u>:
All: 7
Scientific Concepts: 5
Misconceptions: 0
Crosslink: (7+1) 8

3 Summary and Outlook

Based on the model of Educational Reconstruction an Educational Structuration forms the aim of this research work. Therefore the research object had to be examined from different perspectives. Different perspectives required different evaluation methods which evoked successively from the object itself. Alongside hermeneutic text analysis and inductive content analysis the study required quantitative analyses. To meet the requirements of the research interests a triangulated design (Flick 2004) was necessary and has proofed its value.

The investigation of the students' preconceptions brought up several hints to tie up to. Together with the predictions of the experts the aim is to find guidelines for the work with elementary school students where their special pre-knowledge is to be considered and included into the didactic requirements given by the experts.

The investigation showed that using Concept Mapping as a learning method can have a positive effect on learning science in this specific content, because of the advantages in "usage" of learned concepts as well as the level of networking concepts which showed a positive effect on keeping in mind and understanding of new learned concepts. In this sense, Concept Mapping can be proposed to be an effective learning tool to

- support processes of accumulation of (scientific) concepts. Rote learning can be counteracted through Concept Mapping as concepts must be included meaningfully,
- visualize learning processes in a traceable and transparent way. In the function of being a diagnosis instrument for teachers and researchers, Concept Mapping can be used to show changes or variances at different times of the learning process as well as misconception and the level of severity can be revealed.

The topic *burning and combustion* implies several difficulties for young children. In terms of science content for elementary school students scientific knowledge can not in any case easily been achieved through experiments only but requires the use of abstract model concepts[4] (Harrison et al. 1996) as the experts also advice. The analyses of the students' conceptions showed a big variety of scientific as well as everyday concepts. These concepts are often presented parallel to each other and seem to have no further connection which can be impressively demonstrated through the concept maps of the students. For educational purposes the idea of practical examination through experiments leads to:

a. Give students the possibility to get to know and to use scientific thinking and abstract models of explication,
b. Learn scientific concepts meaningfully and integrate them into existing knowledge structures,
c. Extend the students' experiences with *fire*, which might positively influence their conceptual understanding and emotional access towards *fire*.

The method of Concept Mapping will form the promoter for learning concepts more efficient and therefore more lasting.

[4] These models can be described as rather simple and mainly initiate the micro-macro way of thinking in science.

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