Concept Mapping: Connecting Educators
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COLLABORTIVE CONCEPT MAPPING IN CONTEXT-ORIENTED CHEMISTRY LEARNING

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Abstract. Teaching chemistry in everyday life contexts has been seen as one way to raise students' interest in science and to educate scientific literate citizens. Teachers, however, often doubt that the actual content knowledge of the field is adequately acquired if it is taught in contexts that might distract the learner. In order to guarantee enough emphasis to be given to the underlying concepts and their relation, this study investigates whether concept mapping as a learning strategy helps students acquire the content knowledge of a chemical topic better than by means of writing a summary. In a one-factorial control-group design, students revise and link the learnt concepts in a collaborative paper-and-pencil concept mapping task. The prior learning environment is highly collaborative in that a problem-solving task relating to a problem taken from the students' everyday experience is presented. Guidance is given by appropriate information material. The two groups are constant concerning their problem-solving task but only differ in the way the content knowledge is revised. According to recent meta-analyses, effects of concept mapping in chemistry are generally small. This has also been confirmed by this study. Positive achievement effects are found in the achievement tests administered directly after the session. However, students in the concept map group do not outperform the control group if achievement is measured in a pre-post comparison. The quality of concept maps and summaries is still to be scored and compared as to the level of performance in relation to achievement test results.

1 Introduction

Since the 1980s, an increasingly significant interest in the instructional effectiveness of concept maps (Novak & Gowin, 1984) can be observed. An expanding interest in how to implement the principles of constructivist learning into classroom practice made it necessary to investigate new teaching and learning methods. This need resulted in research conducted on the various ways of implementing concept maps into classroom practice. As the varieties to use the method as a teaching and learning tool are quite diverse, this is reflected in the research approaches. While cognitive psychologist like Dansereau and colleagues (McCagg & Dansereau, 1991; Hall, Dansereau, & Skaggs, 1992) concentrate on preconstructed maps with a predetermined set of links, other research branches, pioneered by Novak, focus on the cognitive effects of self-generated maps. Other differences in approaching the tool can be found distinguishing computer-based vs. paper-pencil, individual vs. collaborative maps, or maps used as advance organizer as compared to maps recollecting, structuring and expanding knowledge that has previously been acquired. This diversity in approaches shows the need to clarify the implementation method and the research objectives of the concept mapping method as explicitly as possible. The project presented in this paper therefore focuses on self-generated concept maps in the field of chemistry education in early secondary education. The instructional tool is implemented as a collaborative paper-and-pencil task in which students are supposed to recollect and expand the knowledge they have acquired during a preceding small group discussion phase. The method is compared to a control group writing a traditional summary so that time on task is kept constant.

2 Concept mapping as a learning strategy

2.1 Concept mapping in chemistry education

In the field of science education, concept mapping has been introduced to face the problem of linking the often multidimensional nature of the subject. Especially in chemistry students are faced with what has been termed three levels of representation: 1) the macroscopic, 2) the microscopic and 3) the symbolic level (Johnstone, 1993). The underlying chemical concepts can be represented on each level which generally results in students having difficulty transferring the concept from one level to the other (Gabel, 1998). In early chemistry education it is essential to guarantee students' ability to transfer knowledge from the macroscopic level, including concepts from the students' everyday life experiences, to the microscopic level, relating to the underlying concepts of matter like atoms, molecules etc. Students have to acquire the knowledge on the microscopic level in order to explain phenomena on the macroscopic level.

As recent context-based approaches to teaching chemistry like Salters Advanced Chemistry (Burton, Holman, Pilling, & Waddington, 1994) emphasize the necessity to take students' everyday life as a starting point in order to teach chemical concepts, the students' ability of transferring knowledge becomes more and more important. Concept maps can be seen as one means to facilitate this transfer by either linking concepts on the macroscopic level with those on the microscopic level or help students link the underlying concepts on the microscopic level only. This process is always regarded as constructivist in that the learner constructs knowledge by linking the relevant concepts.

With regard to learning in the field of science education, results of two key meta-analyses (Horton et al., 1993; Nesbit & Adesope, 2006) generally show positive effects of concept mapping on students' achievement levels. These effects are, however, highly dependent on the subject domain as well as on other factors such as the degree of involvement and collaboration. Effect sizes vary enormously if domain-specific achievement levels are compared between different fields. While general science education studies have medium effect sizes (d = .52), effects diverge enormously if studies in chemistry education (d = .20) are contrasted to studies in e.g. biology education (d = .67). Other studies conclude that effects also vary depending on further variables such as verbal ability (Stensvold & Wilson, 1990). Furthermore, effects are far too often subject to the applied test instruments and highly dependent on the design. Many studies which did not show any effects stress the fact that an adequate training to accustom the students to the method is inevitable (Markow & Lonning, 1998).

2.2 Individual vs. collaborative concept mapping

Investigating the learning outcome of students in a collaborative setting as compared to individual learning has shown that students benefit from a collaborative learning environment in which they are able to exchange ideas and communicate their knowledge if sufficient guidance is offered (Hogarth, Bennett, Campbell, Lubben, & Robinson, 2005). These findings are reflected in the results of studies which compare individual vs. collaborative concept mapping and its effect on students' achievement. Most studies found higher achievement levels of learners in a collaborative setting if compared to other individual tasks (Okebukola & Jegede, 1988; Czerniak & Haney, 1998). These two studies also show that collaborative CMs score higher than individual CMs. However, research in the field also resulted in studies disconfirming the advantage of collaborative CMs (Van Boxtel, Van der Linden, & Kanselaar, 2000).

3 Method

3.1 Design

The presented study was conducted in an experimental setting. Two groups are compared by means of a one-factorial control-group design. Students worked together on a chemical problem-solving task. This problem-solving task always involved small experiments and was highly context-based in that it related to students' everyday experience. After this phase, students were supposed to revise the learnt concepts either using the concept mapping strategy or writing a traditional summary in order to guarantee time on task.

Treatment group	experimental group (EG)	control group (CG)
Phase 1 (25 minutes)	context-oriented problem-solving task	
Phase 2 (15 minutes)	concept mapping	summary

Fig. 1: Design of the study

The overall unit contained five small group sessions over a week which were carried out after the students' regular school day. The contents of the small group discussions comprised different aspects of acids and bases embedded in different real life applications. The learnt concepts were acquired in a cumulative way as the contents of the previous sessions could always be linked to the actual task. Achievement levels were assessed after each session by a short MC test.

3.2 Sample

Students were recruited from seven secondary schools in North Rhine-Westphalia, Germany. The average age was almost 13 years (M=12.88; SD= .572). Both groups consisted of about 60% girls and 40% boys. In each school, an approximate number of 12 students could be recruited per treatment group so that an overall sample size of N = 147 distributed evenly among the groups and schools could eventually be included in the analyses.

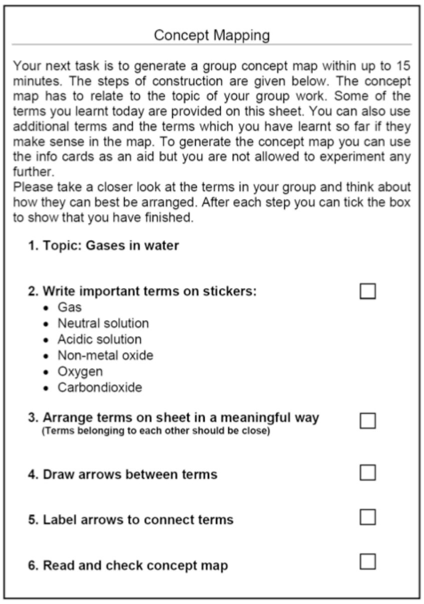
3.3 Instructional Tool

3.3.1 Concept Map Training

As concept mapping is usually not applied in German schools and therefore unknown to students, it had to be introduced and trained. Students in the experimental group were instructed before the first small group session to ensure that they can apply the method and avoid effects because of deficient training. The instruction is based on a student folder containing three different phases of instruction: 1) theoretical introduction of how to construct a CM, 2) a self-generated example CM explicitly following these steps (whole class), 3) self-generated example CM (student task). The example CMs of this training are based on content knowledge which is not part of the study but well-known to the students to avoid cognitive load due to difficult concepts.

The concept mapping method is applied as a paper-and-pencil tool. Concepts are predetermined based on the preceding problem-solving task to facilitate concept map generation as students are neither used to the method nor advanced chemistry learners. The steps of construction are provided on a laminated sheet of paper as an aid (see figure 2).

In order to offer students the possibility to move concepts around, stickers are distributed for concepts. Relations and thus propositions have to be generated by the students themselves and are the focal point of discussion in the small groups during CM generation.



Concept Mapping

Your next task is to generate a group concept map within up to 15 minutes. The steps of construction are given below. The concept map has to relate to the topic of your group work. Some of the terms you learnt today are provided on this sheet. You can also use additional terms and the terms which you have learnt so far if they make sense in the map. To generate the concept map you can use the info cards as an aid but you are not allowed to experiment any further.
Please take a closer look at the terms in your group and think about how they can best be arranged. After each step you can tick the box to show that you have finished.

1. **Topic: Gases in water**
2. **Write important terms on stickers:** ☐
   - Gas
   - Neutral solution
   - Acidic solution
   - Non-metal oxide
   - Oxygen
   - Carbondioxide
3. **Arrange terms on sheet in a meaningful way** ☐
   (Terms belonging to each other should be close)
4. **Draw arrows between terms** ☐
5. **Label arrows to connect terms** ☐
6. **Read and check concept map** ☐

Fig. 2 Construction aid for students

3.3.2 Contents

The content knowledge of one small group discussion phase is limited to five to eight major conceptual terms. The propositions which are to be generated should have been acquired during the preceding small group session. Concepts can, however, also be linked as a result of knowledge acquired in previous sessions so that the concept map may relate to those sessions as well. In this paper, one session is evaluated as an example dealing with the properties of gases dissolved in water (session 4).

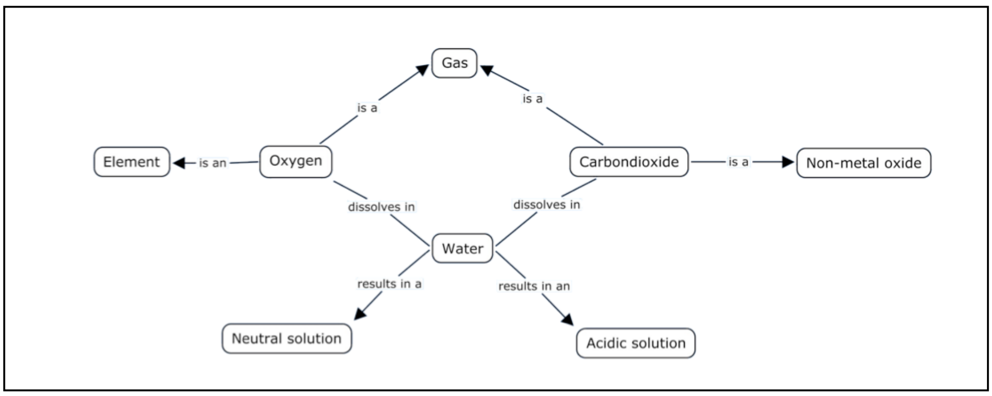


Fig. 3 Example CM of session 4

4 Results and Discussion

4.1.1 Concept Map Evaluation

Concept maps have been scored according to a coding scheme developed by Glemnitz (2007). The quality of propositions and the level of linkage are determined. If the scores are correlated to the achievement test, significant correlations can be found as shown in Table 1 for session 4:

		Achievement test score
CM score	Pearson Correlation	,363(**)
	Sig. (1-tailed)	,010
	N	41
Level of linkage	Correlation Coefficient (Spearman)	,369(**)
	Sig. (1-tailed)	,009
	N	41

Tab. 1 Correlation coefficients of session 4

The correlations are, however, not very high either due to the fact that group CM are correlated with individual test scores or because MC achievement data is not sufficient to reflect the conceptually interrelated knowledge represented by a CM.

4.1.2 Group differences

Students in the experimental group outperformed students in the control condition in the tests after each session ($F(1;147)=4.3$, $p<.05$, $\eta^2=.03$). The effect of the concept mapping task is, however, highly dependent on the particular topic in the session which should be object of further consideration. Generally speaking, the overall effect in the tests administered after sessions is very small. Considering a pre-post-comparison, the achievement effect cannot be found at all.

These results pose questions as which contents can be learnt more efficiently with a concept map than with a traditional summary as well as why achievement effects appear to be very short lasting. In order to determine whether the effects are due to the quality of propositions generated in the respective method, the traditional summaries are scored according to the CMs.

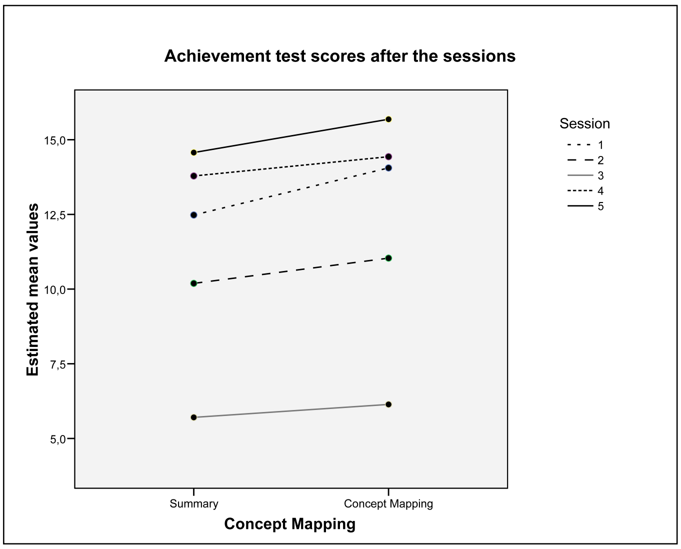


Fig. 4 Group differences in achievement tests after each small group

Analysis of this evaluation is still in progress and cannot be included in this proposal. It can, however, be made available at the CMC2008 meeting as analysis will be finished by this time. The results promise further in-depth results of which factors influence the efficiency of concept mapping as a learning strategy in specific learning contexts.

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