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SUPPORTING COMPREHENSION IN CHEMISTRY EDUCATION – THE EFFECT OF COMPUTER GENERATED AND PROGRESSIVE CONCEPT MAPPING

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Abstract. Teaching and learning chemistry in a context based curriculum requires the process of decontextualization to make chemistry concepts transferable to other contexts. The method of progressive concept mapping is promising to support this process. Research results report difficulties in teaching chemical concepts like the solution concept because students often have resistant alternative conceptions of the processes, formed in everyday life experiences. It is assumed that the process of externalizing concept with the method of concept mapping and also communicating the maps in a group can support the awareness of misconceptions and also to overcome them. In a study 13 to 15 year old students learning chemistry through the German curriculum Chemistry in Context (ChiK) use the computer based concept mapping program CmapTools as a progressive reflecting tool. The experimental design compared this method to the conventional ChiK portfolio method "Lernbegleitbogen" (LBB). Additional the condition reflecting in pairs or alone is altered. The presentation will report theory, design and instruments of the study as well as the results of the pre-study in two classes with 60 students.

1 Introduction

Computer based concept mapping is a promising method for reflecting activities in classroom learning. It allows the learner to (re-)arrange complex knowledge structures easily and in a flexible manner. Therefore it is of interest to use it as a supporting tool in science education. Concepts in biology, chemistry or physics like the energy concept are often complex and will be developed over a longer period up to several school years. The students need methods or instruments to build up a coherent knowledge structure. In recent years, it has been emphasized that teaching science need to account for pupils' daily experiences. Considering and connecting application areas of science and elements of students' everyday life in school seems to be an appropriate method to enhance motivation and interest in scientific concepts on the one hand and to foster students' understanding of these concepts on the other hand (Bennett, Gräsel et al. 2005; Parchmann, Gräsel et al. 2006).

Context Based Curricula like "The Salters Advanced Chemistry Project" (Bennett, Gräsel et al. 2005) and the German approach "**Ch**emie **i**m **K**ontext" (ChiK, Chemistry in Context) (Parchmann, Gräsel et al. 2006) comply with these requirements. According to these approaches chemistry education is characterised by context-oriented aspects in connection with a cumulative development of fundamental concepts (so called basic concepts, e. g. the particle concept, the concept of chemical reaction or the concept of the chemical equilibrium). Following the theory of ChiK, the term "context" refers to a complex, multidisciplinary, and ongoing problem, which addresses pupils' everyday experiences and which is supposed to clarify the essential structures of the discipline (Parchmann, Gräsel et al. 2006). Tuition deals with chemical phenomena and problems, which are embedded in different contexts and which can normally be referred to one fundamental chemistry concept. This curriculum also takes into account the formation of a coherent knowledge structure referring to the fundamental concepts of chemistry. In order to build up an understanding gradually, students get repeatedly the opportunity of transferring the particular concept to further examples: the concept is taken out of its familiar context, it will be "decontextualized" (Parchmann, Demuth et al. 2001).

Until now there is a surprising lack of appropriate instruments for this procedure. ChiK uses a portfolio method called "Lernbegleitbogen (LBB)"; a proper translation might be the term "monitoring worksheet". Students answer questions to explain phenomena using a part of concept. The students then get the opportunity to modify their answers after completing a new learning period. We assume the computer based concept mapping method as an alternative method with benefits in correcting alternative conceptions. This paper reports an experimental study comparing both reflection methods (concept mapping and LBB). The study is based upon the theory of conceptual change that also reports benefits when learning takes place in a collaborative setting. So as a second variable we compare reflecting alone or in pairs. In the following we first provide an insight into the important theoretical aspects of conceptual change, collaborative learning and using concept mapping as a reflective tool. We then describe our research questions and the design of the study. Currently the study is carried out with two classes as a pre-study testing the design and the instruments. This part will be finished at the end of June 08. The presentation will consider the results of the pre-study also to illustrate the aims and possible results of the study itself[1].

[1] The reader of this paper will also get this further information on www.chemiedidaktik.uni-hannover.de/projekte_procmap.html

2 Theoretical Framework

2.1 Conceptual Change

Since the procedure of "decontextualization" is an instrument for discovering students' misconceptions, this study is primarily based upon conceptual change theory. In general there are two cases conceptual change theories are considered in: first, if students' preconceptions do not go along with functional concepts and second, if a new concept causes (typical) misconceptions in many cases. There are a lot of theoretical approaches, which describe conceptual change using different terminologies (e. g. Chi, Slotta et al. 1994; Vosniadou 1994; Tyson et al. 1997) whereby Tyson et al. (1997) developed a multidimensional framework most theories can be located in. In our project, we will adopt this common framework. Tyson et al. describe conceptual change from three perspectives the ontological, the epistemological, and the social and affective perspective. From the epistemological perspective conceptual change requires an adequate understanding of knowledge. Knowledge is not absolute and certain and ever has to be viewed in relation to a specific context or situation. Otherwise it might be difficult for a student to give up or modify a concept of a phenomenon even if he or she recognizes that it is inapplicable to a new situation. From the ontological perspective conceptual change can be described as a shift of the concept from one ontological category into another. The social and affective perspective considers non-cognitive aspects like motivation and design aspects of the learning environment. All perspectives can hardly be regarded independently. A conscious conceptual change in terms of a shift from one ontological category into another will be most likely when the learner is motivated to deal with the subject and also when he or she has a relativistic position of knowledge. How concept mapping can support conceptual change will be discussed below.

2.2 The method of Lernbegleitbogen - LBB (proper translation: monitoring worksheet)

The method of LBB is a ChiK internal development and can be described as a kind of open-ended questionnaire: students have to give answers to questions about a part of a basic chemical concept, which was not considered during the lessons before, in form of short texts. Furthermore the pupils are invited to prepare a drawing in order to illustrate their understanding and application of the respective concept. The students' LBB will not be commented or corrected by the teacher and is disseminated progressively to the students in certain intervals. After the students have answered the questions for the first time, they consistently get their answers back in order to refine or revise them (progressive reflection). This method can be regarded as a kind of portfolio. In ideal cases the students could see their progress every time they get back their LBB for revision.

2.3 Concept Mapping as a Reflective Tool

Concept mapping bases upon Ausubel's cognitive learning theory (Ausubel 1968). Ausubel assumes, that in human's mind knowledge is presented in form of a network. Concept mapping is a process of organizing this knowledge in an external visual form. Following Ausubel, Novak and Gowin (1984) suggested that creating a concept map is a means for identifying scopes of a concept which are understood and which are not. The more a domain is understood the more complex the accordant concept map will be. In comparison to a (normally linearly) written text, constructing a concept map does not impose limitations with regard to the structure. Because of its absent linear structure a concept map can easily be augmented or refined; creating new or deleting incorrect propositions does not entail as many problems as correcting a text. The method of concept mapping is said to be supportive for the process of conceptual change (e. g. Martin et al. 2000; Pearsall 1997). A first map of a concept can be seen as a pre-conception. Being engaged with the learning object might cause new knowledge that can be integrated into the map. Additions and extensions are smaller changes of the existing knowledge structures. The reconstruction of larger parts of the map can indicate the process of conceptual change. Studies that use the concept mapping method in this context could not provide evidence sufficiently. Van Zele et al. (2004) noted that a problem might occur in the uncertainty of analyzing the maps when the method will be used as an assessment tool: "there should be a fair chance that the instructor intuitively adds and assumes links that are not mentioned or inadequately described in the student's response and that may not exist in the student's mind" (van Zele et al. 2004, 1045). We will use the concept mapping method progressively as a learning tool and not as an assessment tool. The term "progressively" goes back to a definition of Liu: "students create progressive concept maps through ongoing revision" (Liu 2002, 377) meaning that revision takes place in an isochronous way.

Computer Generated Concept Mapping: In this research project the concept maps will be computer generated using CmapTools, although the application of a computer is not essential for concept mapping. However, computer generated concept maps can more easily be revised than paper and pencil concept maps. As

Royer and Royer showed (2004), students who used a computer to create a concept map (a) made more complex maps and (b) preferred using this tool instead of using paper and pencil. Following the theory of Novak and Gowin (1984), computer generated concept mapping supports more meaningful learning by facilitating the construction of complex concept maps.

2.4 Collaborative Learning

A Concept map can be regarded as an externalization of parts of the individual's knowledge structure and gives the opportunity to communicate this structure. Discussing and comparing these externalizations can be seen as a collaborative learning phase (Hathorn & Ingram 2002). Students work together in searching for understanding and a shared knowledge. If students get the opportunity to discuss about their ideas of a concept there will be a right chance to detect existing alternative conceptions. By verbalizing their thoughts the students themselves might perceive deficits sooner. The students begin to "reflect on their limitations, contradictions, presuppositions and the implications of their conceptions" (Havu-Nuutinen 2005, 262) so that conceptual change may be stimulated.

3 The study proCMap – progressive computer based concept mapping in chemistry education

3.1 Research Questions

With our study, we refer to research conducted by Schmidt et al. (2003). In their project pupils of a 7th grade ChiK course in Varel (Lower Saxony) had the opportunity of reflecting progressively on the solution concept by using a LBB dealing with the dissolution concept (brewing and sweetening tea). In their report, Schmidt et al. predominantly gave an overview about the misconceptions pupils mostly have with regard to the dissolution concept. Without having analysed the reflection method systematically, experiences showed that students, who used the LBB, had a deeper understanding of the respective concept. In our empirical investigation we will address the possible connection between kind and process of reflection on a basic concept on the one hand and its impact on students' understanding on the other hand. Beyond this (possible) interconnection, the study seeks to gain information about students' attitude towards the reflection method they used.
In summary, the following research questions will be considered:

- Does students' understanding of a basic concept depend on the reflection method they used? If yes, to what extend?
- What do students think about reflection itself and especially about the method they used?
- What kind of misconceptions about the respective concept can be determined? Are there any differences between German and English speaking students?

3.2 Design of the Study

3.2.1 Participants:

The target group of this study is pupils of 7th grade chemistry courses (13 to 15 years old students) from different schools in Lower Saxony (Germany). The selection is dependent on teachers who are experienced in teaching ChiK and volunteering to teach one default teaching unit. The unit is a consensus of all participating teachers, reached in a workshop before the project will start (in-service training).

3.2.2 Procedure

In this study two reflection methods will be compared: Constructing a concept map and answering the LBB. The concept maps will be computer generated using the software CmapTools. These methods will be combined with a second variable: pair working students and single working students. Pupils discuss their results or they have to check it on their own. Figure 1 gives an overview:

		reflection method	
		concept mapping	Lernbegleitbogen
social arrangement	single working	I	II
	pair working	III	IV

Figure 1: 2x2 design; combinations of reflection method and social arrangement

Since two methods for the procedure of decontextualization are supposed to be compared, instruction of these courses has to be context-oriented, according to the German approach ChiK (Chemistry in Context). Following the theory of ChiK, the term ‘context’ refers to a complex, multidisciplinary, and ongoing problem, which addresses pupils’ everyday experiences and which is supposed to clarify the essential structures of the discipline. Tuition deals with chemical phenomena and problems that are embedded in different contexts and can normally be referred to one fundamental chemistry concept. According to the theory of ChiK, tuition can be divided into four characteristic phases (Parchmann, Demuth et al. 2001):

- 1st phase: The phase of contact with a new context: At this point, students are encountered with the context getting the opportunity to orientate themselves within this context.
- 2nd phase: The phase of curiosity and planning: At this stage, students are invited to ask questions with simultaneous regard to the context on the one hand and their personal interests on the other hand. Important questions are identified and a schedule (e. g. planning different experiments) for the next lessons is formulated.
- 3rd phase: The phase of elaboration: Now, the formulated questions will be considered in depth. Different social arrangements and methods are used (working in groups, aggregation and presentation of results, carrying out experiments in order to answer the formulated questions).
- 4th phase: The phase of deepening and connecting: At this stage, the considered and compiled concept is decontextualized meaning, that it is transferred to further examples and other contexts.

In this study, a defined and standardised unit dealing with the dissolution concept will be taught. In order to achieve this standardization of the respective unit, two aspects will be considered: Firstly, only ChiK experienced teacher will take part in the study. Secondly, an in-service training for the participating teachers will take place in the forefront of the study. Furthermore, the teachers are supposed to keep a standardised tuition-diary meaning that they have to describe several aspects of each lesson, which are considered as important with regard to the development of the comprehension of the dissolution concept (e. g. description of the blackboard drawing, materials used in the lesson, etc.). We are aware of that a complete standardization of instruction is nearly impossible, but we assume that little variance in the work plan of the course has no relevant influence on the results of the study.

In the run-up to the start of the teaching unit the students are introduced to the method of concept mapping by members of the research team. During this introductive session, the students get the opportunity of constructing a concept map using the software CmapTools for a topic of their choice. Furthermore, two questionnaires are administered to the students in the forefront of the unit: the first questionnaire is a cognitive ability test (Heller 2000), whose results are used for assigning the students to the four experimental groups. By doing so, homogeneity of the groups will be controlled. Secondly, the students answer a questionnaire, which is based on the solution concept test developed by Uzuntiryaki and Geban (2005). The test used in the current study consists of 15 multiple-choice questions, which refer to the dissolution concept. Since the test will be used for two more times (as a regular post-test and as follow-up-test, eight weeks after the unit is finished), data about students’ learning progress respectively conceptual change and comprehension of the dissolution concept will be collected.

During the course, reflection takes place for three times: after finishing the ChiK phases 2, 3, and 4. Thus the students have the opportunity to revise or refine their “reflection results” for two times. Since intensity and length of reflecting maybe differ between pair and single working students, the latter will get some additional questions following Duschl and Gitomer (1997) (e. g. Which concepts belong together? Does your statement tell what you want it to tell? Is your statement clear to someone else?). Thereby the single working students are supposed to reflect as intense as the pair working students. All students will get comparable instructions.

After the unit is finished, some students will be interviewed. According to a study of Ebenezer and Gaskell (1995) an informal conversational interview will be conducted with approximately 24 students (six from each experimental group). The data collected by interview are supposed to validate the questionnaire. In addition these data allow a deeper insight into students’ understanding of the respective concept. Figure 2 gives an overview about the schedule of the study:

IT	RU	Q1 Q2	RI-1	T1	RI-2	T2	RI-3	T3	P	I	RI	F
			teaching unit									

IT: in-service training
RU: run-up
Q1: cognitive ability test
Q2: solution concept test

RI-1 phase of curiosity and planning
T1: 1st reflection activity
RI-2 phase of elaboration
T2: 2nd reflection activity
RI-3 phase of deepening and connecting
T3: 3rd reflection activity

P: post-test
I: interview
RI: regular instruction
F: follow-up-test

Figure 2: Schedule

3.3 Analysis

The solution concept test will be analysed by the number of correct answers. Since the items also contain common alternative conceptions concerning the dissolution concept, students' response patterns can be used for assessing the development and the stability of the comprehension of the dissolution concept. With regard to conceptual change theory, the expected developmental character of students' responses will be classified according to the ontological categories following Tyson et al. (1997) and Chi et al. (1994).

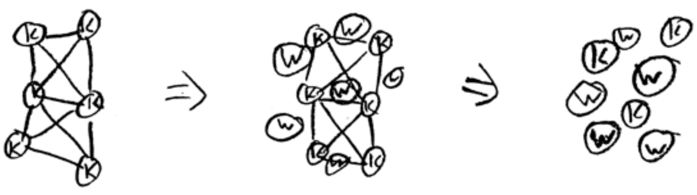
According to the description and classification given in Uzuntiryaki and Geban (2005), the data collected by interview will also be assigned to the respective ontological categories on the one hand and to the common students' conceptions of the dissolution concept on the other hand. By doing so, the validity of the solution concept test can be controlled as well.

Teachers' notes and description given in the tuition-diary will be compared and checked with regard to the default teaching unit. In case of discrepancies its impact on the reflection activities and on the results of the solution concept test will be investigated in more detail.

4 Piloting and Preliminary Results

In February 2008 we started the study with two classes (60 students) using the complete design and methods described above. Because we are testing all instruments and are willing to refine the design in case we will detect some difficulties or inaccuracies, this phase could be regarded as a pilot of the study. Until now (June 08) three reflection activities took place. The whole teaching unit will be finished at the end of June 08 and the data sampled and analyzed to be reported at the conference. Up to now, following rudimental findings could be detected:

In the case of answering the LBB students often revised their initial texts by crossing out single words or little parts of the old one and only a few students formulated complete new answers. Generally, correctness and complexity of the texts increased during the three reflection activities. After ChiK phases 2 and 3 a lot of answers contained alternative conceptions concerning the particle concept (e. g. sugar confers its sweetness upon water particles) or only phenomenological descriptions of the process of brewing tea ignoring the chemical aspects (application of the particle model). However, after ChiK phase 4 a lot of students used the particle model at least for describing the structure of sugar. Figure 3 shows a drawing which was added during the third reflection activity whereas this student did not use the particle concept in his / her former answers.



Caption: K = Kandis (rock sugar) W = Wasser (water)

Figure 3: Drawing describing the process of sweetening tea after ChiK phase 4

In the case of constructing a concept map, hints are found that the method (a) supports the addition of concepts and relation in a further reflection phase (see figure 4, 5 and 6) and (b) allows students to externalize alternative concepts as well. Within one concept map a student argues “hot water abstracts substances from tea” because “substances will dissolute automatically” while “changing their state of aggregation from solid to liquid”. Latter proposition is a misconception that can often be found in the description of the solution process. It can be traced back to the observation that a rock sugar will disappear forming flowmarks. Another student describes the solution of sugar in tea in two ways as “a mixture of sugar and tea” and that “sugar will partly dissolute in tea”.

So the revision of the answers given in the LBB and the revision of the concept maps both can be characterized as enhancement of the previous one rather than as restatement. We want to emphasize that the concept maps and the answers given in the LBB both will not be part of the analyzing procedure for answering the question of the use of the learning methods as tools to foster conceptual change. But a first look at the concept maps as well as at the LBBs provides an indication that the methods are used as intended and that they both functions as learning tools (independent of the social arrangement). That is why currently no statement can be made with regard to the question whether one reflection method outclasses the other.

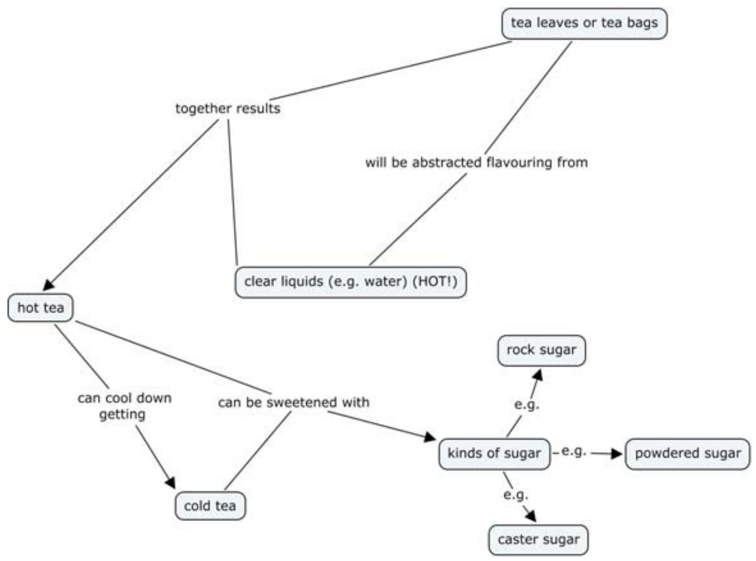


Figure 4: Concept map describing the process of making and sweetening tea after ChiK phase 2

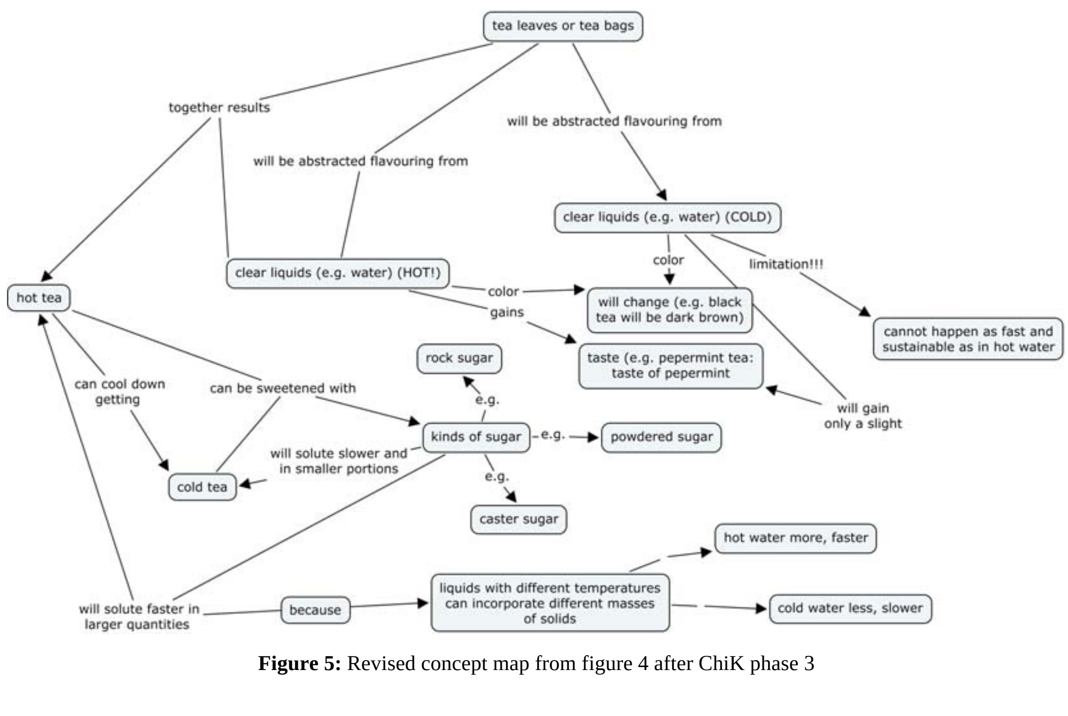


Figure 5: Revised concept map from figure 4 after ChiK phase 3

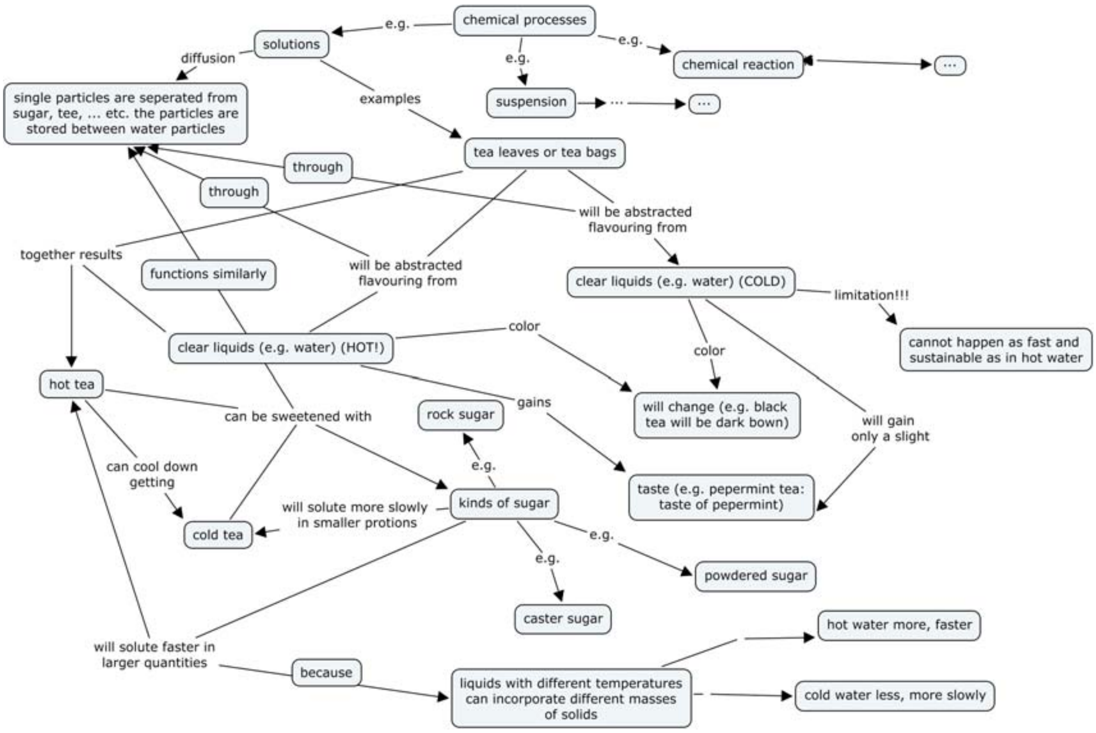


Figure 6: Revised concept map from figure 5 after ChiK phase 4

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